What *is* information after all? How the founder of modern dialectical logic could help the founder of cybernetics answer this question

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Abstract

N. Wiener's negative definition of information is well known: it states what information *is not*. According to this definition, it is neither matter nor energy. But what *is* it? It is shown how one can follow the lead of dialectical logic as expounded by G.W.F. Hegel in his main work [1] – "The Science of Logic" – to answer this and some related questions.

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1 Introduction

It can be considered by now indisputable that the general notion of information is central to pretty much all of modern science and engineering. Somewhat surprisingly however, the proper concept of information is not available yet. In other words, information still remains somewhat of a mystery as far as its true nature is concerned. Most people – professional scientists and philosophers included – can recognize information when they see it, but would in general find themselves at a loss if asked to explain what it really is. Academic philosophy recognized this situation by spawning from within itself a growing sub-area known as the philosophy of information (PI) – see, for example, [2] for an introduction. One of the main founders of the new field, L. Floridi, enumerated eighteen problems, so that making progress in solving any of these would advance the field. The first of these problems, quite naturally, is simply: *What is information?* L. Floridi characterizes this particular problem in the following words [3]:

> This is the hardest and most central question in PI. Information is still an elusive concept. This is a scandal not in itself but because so much basic theoretical work relies on a clear analysis and explanation of information and of its cognate concepts. We know that information ought to be quantifiable, additive, storable and transmittable. But apart form this, we still do not seem to have a much clearer idea about its specific nature.

This is indeed a very fair assessment of the current state of affairs which – as noted in the quotation just given – has somewhat of a scandalous air about it. One would definitely be justified in stating that making some amends in this regard would be rather desirable. Respectively, the main goal of this article is to use the logical machinery developed by G.W.F. Hegel (as expounded primarily in his main work [1]) to make progress in this particular direction. During Hegel's times, the term "information" was not yet in wide use (for example, it is not used a single time in "The Science of Logic"), and Hegel himself had little to say about the corresponding concept. Our intention is to employ "The Science of Logic" methodology to process the knowledge available now to arrive at a rational understanding of its true nature.

If one goes back to the more recent history of science in search of fundamental progress in understanding of various aspects of information, the names of C. Shannon and N. Wiener, the founding fathers of the modern Information Theory and Cybernetics, respectively, immediately come to mind. C. Shannon, apparently, held a rather pessimistic view on the existence of a general concept of information [4], p.180:

> The word 'information' has been given different meanings by different writers in the general field of information theory. It is likely that at least a number of these will prove sufficiently useful in certain applications to deserve further study and permanent recognition. It is hardly to be expected that a single concept of information would satisfactorily account for the numerous possible applications of this general field.

It is interesting to note that apparently C. Shannon himself was somewhat dissatisfied with the name (Information Theory) that his theory became known under. The reason was that both him and his prominent collaborator W. Weaver believed that what had been developed could better be described as the *Mathematical Theory of Communication* [5], and that the term "Information Theory" was unjustifiably too broad.

N. Wiener is credited with the following rather famous sentence [6]:

> Information is information, not matter or energy.

This sentence can be considered a negative definition of information. In our view, it is fully correct, and thus will be made the starting point of our discussion. In this quotation, N. Wiener acknowledges that he does not know what information is, but states what information is not (it is neither matter nor energy). Moreover, the real beauty of Wiener's negative definition lies just a bit below its surface. Specifically, it implies that the concept of information is likely as fundamental as those of matter and energy and thus provides a hint for those looking for clarity in these fundamental matters: to understand the true nature of information – taken in its most general sense – one would be well served by starting from those of matter and energy. Our task here will be relatively straightforward precisely due to the previous contributions of the two great thinkers: G.W.H. Hegel and N. Wiener. We will simply take the direction provided by the latter and move along using the tools developed by the former, the level of our own efforts being rather modest as a result.

1.1 Why Hegel and is the author an amateur Hegelian?

It is going to become clear very soon that, methodologically speaking, a very extensive use of Hegel's logical system expounded in his most important work, "The Science of Logic" [1], is made. An obvious question any inquisitive reader is likely to ask is what makes Hegel's philosophy (since it is well known that he is exclusively a philosopher) in general, and "The Science of Logic" in particular, so special as to be chosen the main methodological foundation for solving puzzles of information, especially since that book was written about two centuries ago. To explain such a seemingly exotic methodological choice, a small digression into the micro-history (not in the sense of being extremely detailed but in that of being very insignificant) of the present article is in order.

The author has to confess right away to not being a professional philosopher, but rather an industrial engineer with a specific interest in information/probability aspect of the field, and some prior experience of a physicist. The original motivation that eventually gave rise to the present article was that of wishing to develop a general method – a "mathematical framework" in the language preferred at the time of the original motivation occurrence – for optimal extraction of additional information in optimization and decision making under uncertainty. With respect to the existing Shannon's Information Theory, the method to be developed was being envisioned as its complement and extension: while Information Theory provides a general method for information optimal transmission, the method to be developed would address the "end links" of the "information chain" – the chain that begins with obtaining of information and ends with its usage for solving a problem. The "middle link" – that of transmission – might not even be present in any given instance of the "information chain," and was seen as being largely independent of the two "end links," which had to be considered together since, in particular, the details of information to be obtained were determined by the demands of the problem to be solved.

While the first version of the envisioned method was being developed, it was gradually becoming clearer and clearer to the author of the present article that the research itself, the results it produced and, most importantly, the methodology that was used in developing the new method were unsatisfactory in some fundamental – but not yet sufficiently understood at the time – way. More specifically, we were finding ourselves constantly making assumptions without justification (for example, that of incomplete information being described by a probability distribution) and trying to generalize from examples of the existing practice of various "agents" dealing with information, with the resulting generalizations formulated as postulates. The idea was to obtain a suitable "quantification" of information characteristics pertaining to the process of information extraction from sources and its consequent usage to solve optimization problems under uncertainty. Even though quantification of various things and their properties that are understood vaguely at best is a standard practice in modern science, our own quantifications of questions and answers did not sound sufficiently convincing. We started realizing that our object of interest that was resisting our attempts at its quantification – information itself – is one of those entities that everyone uses but nobody really understands. We looked outside of engineering and found out that this problem was at least explicitly acknowledged by philosophers, and a branch of philosophy dedicated to such issues – Philosophy of Information – had been recently established.

This turn of events brought our attention to philosophy. Fortunately, we weren't quite at ground zero with regards to the knowledge of philosophy, the latter having been a kind of hobby of ours for several years at the time of the realization that some philosophical tools might have been needed for making progress in understanding information. Remembering N. Wiener's hint that information is likely to be of the utmost fundamentality, on par with matter and energy, we began looking specifically for logic suited for a rational comprehension of the fundamental *unity of the world.* We were already aware that, in the modern era, I. Kant was the first to attempt a study of reason's ability to comprehend the world as a whole, in his main philosophical work "Critique of Pure Reason." His idea was to perform a careful study of the tools of reason before one could trust the latter's results and conclusions. But, as Hegel noted later, if one intends to study the tools of reason prior to using it as such, one ends up exploring the reason by means of something else than reason, which could easily end up being a slightly disguised ordinary common sense. But what Kant had discovered was that reason – if "pushed" far enough – invariably produced *antinomies*, i.e. contradictions. The conclusion that Kant made from this discovery though was of a sceptical[1] variety: reason is fundamentally limited and therefore has to be supplemented by some human faculty of a different nature (like religious faith and various purely empirical considerations). Hegel held Kant's discovery of reason antinomies in very high regard but was very critical of Kant's conclusions [1], p.741:

> It must be regarded as an infinitely important step that dialectic is once more being recognized as necessary to reason, although the result that must be drawn from it is the opposite than Kant drew.

Between Kant and Hegel, it were J.G. Fichte and F.W.J. Schelling who tried to develop Kant's ideas further. The former took a somewhat one-sided subjective way out of Kant's antinomies, and the latter had to – similarly to Kant – "demote" the rational aspect of reason and appeal to intuition, sudden revelation etc. in order to overcome contradictions that fully rational reason was bound to produce. Hegel was the first to realize that Kant's antinomies were not a deficiency of reason but rather its great strength – the main mode of creation of the new from the old – both in subjective thought and objective reality. While for Kant, antinomies signified some fundamental boundaries to the reason's ability to rationally comprehend the world, for Hegel, they were just an expression of the world itself which is inherently antinomic. Indeed, the *unity in multitude* – the most accurate concise

[1]Perhaps, that was due to the fact that Kant's work grew to a significant extent out of polemics with D. Hume, with his scepticism and radical empiricism/subjective idealism. Apparently, Kant had thought about Hume's philosophy so much that in the end could hot overcome his own "internal" Hume.

description of the world as a whole and the only *principle*[2] worth adhering to – is explicitly a contradiction. This implies – even without further discussion – that any system of logic useful for fully adequate rational comprehension of the world as it stands and becomes the object (and the subject) of human practice has to be able to rationally deal with contradictions. And this is exactly what Hegel's dialectical logic most comprehensively presented in "The Science of Logic" is all about. Once a reader begins understanding what exactly the author meant (and this is far from an easy task that requires a good deal of concentrated and prolonged effort which we will say a bit more about below), it becomes clear that the latter went to great pains, to the detriment of exposition clarity and to the considerable increase of the risk of not being understood (which is, generally speaking, exactly what happened), in order to maintain an unyielding commitment to the cause of unity of the world – in both its objective and subjective aspects. In this regard, Hegel did all he could at his time, and quite possibly some more.

The second part of the first possible question we are trying to preventively answer here is the following. Even if Hegel made a major breakthrough in logic, it took place two centuries ago, and, therefore, how can it be that his original breakthrough hasn't been greatly extended by the later researchers? Indeed, if one takes any topic, for example, in mathematics or physics, it is almost always learned not from the original works of, say, Gauss or Maxwell, but from any of the numerous modern textbooks which contain the results of interest presented in a more convenient and complete fashion, including later developments. Why would it be different for philosophy and dialectical logic? To try to answer this question, let us consult Stanford Encyclopedia of Philosophy, the article on G.W.F. Hegel. There, we can find the following passage:

> In Britain, where philosophers such as T.H. Green and F.H. Bradley had developed metaphysical ideas which they related back to Hegel's thought, Hegel came to be one of the main targets of attack by the founders of the emerging "analytic" movement, Bertrand Russell and G.E. Moore. For Russell, the revolutionary innovations in logic starting in the last decades of the nineteenth century with the work of Frege and Peano had destroyed Hegel's metaphysics by overturning the Aristotelian logic on which, so Russell claimed, it was based, and in line with this dismissal, Hegel came to be seen within the analytic movement as a historical figure of little genuine philosophical interest.

[2] As opposed to many empirically derived "positive" non-dialectical principles that become their opposites if allowed to be sufficiently generalized, i.e. if used as principles. The most well-known examples are probably the principle of relativity and the principle of complementarity devised by physicists only superficially familiar with philosophy.

The reading of this passage was accompanied with the joint feeling of amazement and amusement, on the part of the present article's author. It was followed by the proverbial silent "Really?" making an immediate uncontrollable appearance. A work in mathematics somehow negating Hegel's objective dialectical logic? This sounded a bit like some improvements in the design of electric guitars or electronic synthesizers making Beethoven's symphonies obsolete. Upon a bit of additional inquiry, it turned out that this – somewhat surprisingly – was indeed a rather widespread view. Due to this fact, we decided – instead of the originally planned a couple of pages worth of its refutation – to provide a more detailed account. It is the subject of Appendix A, and focuses on the philosophical content of B. Russell's "logical atomism" and its relation to logic in general and Hegel's system in particular. Speaking specifically of the logico-philosophical views of B. Russell himself, it turned out – in a nutshell – that he studied Hegel's logic, but at a very young age and without sufficient dedication. As a result, failing to understand it, he acted like a school kid who, after his first (and only) unsuccessful attempt to get on terms with differential calculus, started claiming that they should have just canceled the d's in their expressions of the type $\frac{dy}{dx}$ and be done with it.

B. Russell's philosophical views are now widely known in connection with his (joint with G.E. Moore) "revolt against idealism" undertaken in the very beginning of 20th century and directed at the philosophical idealism of Kant in Hegel, mostly known to B. Russell (as far as we can tell) in the rendition of F.H. Bradley (that left little of the authentic Hegel's logic). As a result of the young Bertrand's (likely and expected due to his age and general "young genius" hasty attitude unsuitable to the study of dialectical logic) failure at a proper comprehension of the content of Hegel's main work, his revolt was not actually a rebelion against Hegel. Using a sports related metaphor, one could say that B. Russell as a philosopher was not playing in the league of Hegel, but rather in that of Berkeley and Hume. More details are given in Appendix A. Speaking of G. Frege whose work, according to B. Russell, made Hegel's logic obsolete, one can read in Wikipedia:

> It should be kept in mind that Frege was a mathematician, not a philosopher, and he published his philosophical papers in scholarly journals that often were hard to access outside of the German-speaking world. He never published a philosophical monograph other than "The Foundations of Arithmetic," much of which was mathematical in content, and the first collections of his writings appeared only after World War II.

Thus G. Frege himself would have likely been surprised had he been told about the deep philosophical implications of his work. For what it was, on the other hand, – a development in the realm of *mathematical* logic – it had all the groundbreaking qualities for which it received the well deserved – if somewhat belated – recognition.

In a wider context, the philosophical movement, of which B. Russell happened to be one of main initiators and which included, in particular, the activities of the members of Vienna Circle, can be roughly characterized as a movement of further *reduction* of the logical aspect of philosophy. As is well known, the last third of 19th century was distinguished by the "back to Kant" (from Hegel) drift that found its outward expression in the rise of the neo-Kantian school. The objective content of this direction, logically speaking, mostly consisted of going back from Hegel's dialectics, that unfortunately had not been properly assimilated by the philosophical and scientific "mainstream" tradition, to the original "negative dialectics" of Kant. That negative dialectics in its original version was given the following reference by Hegel in [1] (p.25):

> But the *reflection* of the understanding seized hold of philosophy. We must know exactly what is meant by this saying which is otherwise often used as a slogan. It refers in general to an understanding that abstracts and therefore separates, that remains fixed in its separations. Turned against reason, this understanding behaves in the manner of *ordinary common sense*, giving credence to the latter's view that truth rests on sensuous reality, that thoughts are *only thoughts*, that is, that only sense perception gives filling and reality to them; that reason, in so far as it abides in and for itself, generates only mental figments. In this self-renunciation of reason, the concept of truth is lost, is restricted to the knowledge of mere subjective truth, of mere appearances, of only something to which the nature of the fact does not correspond; knowledge has lapsed into *opinion*.

As have already mentioned a bit earlier, Kant's negative *dialectics* was still a major step forward since it rediscovered dialectics for the modern times. At the same time, Kant stopped short of *rational dialectics* leaving – as it happened – it to Hegel to take the next step. But Kant's gnoseological position was, from the point of view of particular (especially natural) sciences, that of an "unstable equilibrium," so to speak: the inherent antinomial property of reason requires either going forward to rational dialectics or backward to empiricism and ordinary common sense with its belief that "truth rests on sensuous reality." Such a position of pure empiricism (which is essentially an implicit form of subjective idealism) was elaborated in its radical form by D. Hume. Thus the movement of "back to Hume" was very likely to follow that of "back to Kant." It indeed took place early in 20th century, with B. Russell being one of its pioneers. In the course of this movement, happening mostly under the banner of logical positivism, the objective logic of Hegel received the label of metaphysics and was thereby discarded. What was left of logic was its formal component, but in a much more developed mathematical logic form thanks to the works of Frege and Peano. Still, regardless of the degree of its development, formal logic, *due to its different subject matter*, can never take place of the objective (dialectical) logic. Neither B. Russell, nor other participants of the "back to Hume" movement, obviously ever realized that.

Since any science, according to Hegel, is applied logic, such regressive development in the realm of logic might have had some negative effect on particular sciences progress. This was indeed the case, as we show, using physics as an example, in Appendix B. In short, for the first couple of centuries (counting from Newton) of its history, theoretical physics had the mechanical form (or, rather, metaform) of the universal motion of matter as its primary subject matter. Due to its particular simplicity and the related existence of simple and accurate phenomenological laws (Newton's laws including the gravitational one), it was possible for physicists to rely on mathematics and common sense for further development of mechanics and its various applications. In addition, the physics common sense itself developed and acquired many elements of spontaneous dialectics (like the general idea of essence behind the surface of things, transmutations of forms[3] of the same essence etc.). But due to its spontaneous character, the dialectics of the classical tradition in (theoretical) physics was somewhat limited. In particular, the classical tradition (due largely to its success with the mechanical form) held the general belief of the physical (meta)-form of the universal motion being just a more complicated version of the mechanical one, i.e that it could be *directly reduced* to the mechanical form.

When the attention of physics shifted to electromagnetism and optics, and it was found that the direct reduction to mechanics approach ran into difficulties, physics found itself at a crossroads where rational dialectics was objectively needed for further progress of the fundamental theory. Due to the disconnect between physics and philosophy and the current (at the time) trends in philosophy itself, such junction did not take place. As a result, theoretical physics took the phenomenological descriptive route in the guise of a fundamental theory. Since elecromagnetism/optics was the historically first class of phenomena that defied the *reduction to a mechanism* approach, certain features of electromagnetic/optical phenomenology were chosen for the "promotion" to the fundamental status. One can say, somewhat metaphorically, that theoretical physics had chosen – without realizing that – the time honored in human history way of constructing a cult of sorts of natural phenomena defying rational understanding at the time. The result of such construction was the univer-

[3]As we will see in Appendix A, B. Russell in the course of his "back to Hume" philosophical journey, went as far as challenging – from typically Humean sceptical standpoint – the notion of water and ice being just different forms of the same substance.

salisation and absolutisation of such electromagnetism specific parameters as the speed of light and Planck's constant.

Further strengthening the resemblance was the "tampering" with the fundamental notions of space and time undertaken in the process of such absolutisation. The classical tradition's space and time concepts had a metaphysical moment (along the dialectical one) in them, primarily in the form of Newton's notion of absolute space (and thus the absolute reference frame). The philosophically incompetent revision undertaken (by a very young person who did not have a chance to acquire competence in philosophy) in early 20th century in theoretical physics made matters worse. It divested the notions of space and time of their proper absolute moment (which they rightfully possessed by virtue of being abstractions) thereby transferring it to a particular characteristic of a *finite* form of matter motion – the speed of light.[4] Even though the conclusions made in that instance were unusually bold due to the fundamental nature of the very subject of the revision, the (objective) logical mistake that led to them was typical for any subjective thought process not guided by proper logic. As Hegel put it in [1], (p.472):

> It (cognition) behaves like an external understanding, taking up the determinations as *given* and *reducing* them to the absolute but not taking their beginning from it.

Taking some experimental results – not in their entirety and not very carefully[5] – and some existing phenomenological descriptions ("determinations") *as given* and *deducing* some ("freely invented" as we will see in Appendix B) fundamental principles ("the absolute") from them had become the *modus operandi* of the fundamental theoretical physics for the following century. More details of this story are given in Appendix B.

Finally, we have come to the second possible question: as to whether the author of the present article is an amateur Hegelian. To answer this question, let us first find out what it means to be a Hegelian these days. In Stanford Encyclopedia of Philosophy, we can read:

[4]In spite of constituting a basic logical error, such revision was a bit later given a philosophical blessing and got touted as a major advance thereof. Originally, this was done primarily by the members of Vienna Circle who, to put it somewhat bluntly, had no business speaking on behalf of philosophy by virtue of the lack of the specifically philosophical – as opposed to mathematical – qualifications.

[5]Everyone familiar with basic statistic knows that it is never easy to confirm a null result. It is especially difficult to do so in an experiment running at the very edge of available equipment resolution. If such an allegedly null result (that is never literally null due to noise and measurement errors) were even contemplated as a potential basis for a radical revision of any kind, extreme care would have to be taken and all available experimental evidence would have to be studied. None of that happened with the results of the famous Michelson-Morley experiment.

> Certainly since the revolutions in logical thought from the turn of the twentieth century, the logical side of Hegel's thought has been largely forgotten, although his political and social philosophy and theological views have continued to find interest and support.

It follows from this passage reflecting the current general attitude towards Hegel's legacy that the qualification "Hegelian" nowadays implies primarily (if not exclusively) a follower of his political, social and theological views – as opposed to the logical aspect of his work. Put slightly differently, the modern day Hegelians study and further develop the applied branch of Hegel's philosophy as opposed to its fundamental part (according to his own classification).

This article, as far as Hegel's overall legacy goes, relies almost exclusively on the content of "The Science of Logic," which – without any exaggeration – can be equated with the fundamental core of what Hegel as philosopher is known for. Thus, according to the currently predominant views, the author thereof should not be labeled an (amateur) Hegelian, but, rather, – if some kind of a label has to be attached – a "The Science of Logic" (or Hegel's dialectical logic) aficionado. At this point, it becomes somewhat clear that either the author is simply not aware of the obsolete status of the logical side of Hegel's thought, as hinted at rather transparently in the quotation just given, or there is more to that "largely forgotten" side than it is typically admitted. The earlier part of the present section has already given some indication that the latter option is indeed the correct one. More about the relevance of the logical side of Hegel's thought is said in Appendix A (and Appendix B). Here, we would only like to point out one more time that no amount of advances in formal and mathematical logic could – or can in the future – somehow negate the content of dialectical objective (along with subjective) logic as expounded as a system for the first time in Hegel's main work. The complete lack of understanding of this important point on behalf of most scientists, mathematicians and philosophers at the "turn of twentieth century," when the "logical revolutions" *in mathematical logic* referred to in the quotation from Stanford Encyclopedia took place, resulted in the still widespread misconception expressed in the quotation.

Speaking of the philosophical legacy of Hegel overall, it can be summarized relatively well (for a two-sentence summary) in the following way. Had Hegel written "The Science of Logic" and nothing else, objectively he would have been the same Hegel with the same fundamental contribution to philosophy. Had he written everything else except "The Science of Logic," his lasting objective contribution would have been limited to the bits of dialectics present in his "applied" works on aesthetics, history, religion etc. Whereas his "applied" work, in spite of its undeniable merits at the time, had been mostly superseded by the more advanced investigations on the same topics (especially by those based on his own logic), his fundamental contribution to logic is still – surprising as it may sound two centuries later –

every bit as modern and relevant as it was at the time of writing. The present article can be thought of as an illustration of the potential power of dialectical logic in sciences. That potential power should not come as any surprise since rational dialectics is identical with the proper theory of thought and knowledge.

What are the possible objective reasons for such disproportion of the lasting relevance of Hegel's "fundamental" (i.e. logic) and "applied" (history, religion etc.) philosophy, in the first place, and the almost exactly opposite disproportion in its (the lasting relevance) current perception? Put slightly differently: why was Hegel able to come up with a correct general theory of thought, but was less successful (in the sense of lasting contribution) with applications of his logic? This is an interesting topic deserving special attention and careful inquiry. In a few words though, first of all, rational comprehension of general questions – once a sufficient overall level of human practice has been achieved – is objectively logically and especially technically simpler than that of particulars. For example, as this article illustrates, rational concepts of matter and energy (and even information) are relatively easy to develop, due to their extreme generality. On the other hand, a rational concept (i.e. a proper theory uncovering the essence and developing appearance and actuality on its basis) of, for instance, gravitation will undoubtedly require a lot more effort.

As we have already indicated, Hegel was able to understand the true meaning of Kant's "negative dialectics" of reason realizing that it had provided the key to the rational understanding of the unity in the multitude of the real world, including humans and the "spirit." Then he went above and beyond developing this observation into rational dialectics which resulted in "The Science of Logic" – the first and still the only compendium of dialectical (objective and subjective at the same time) logic. His later philosophical work amounted to applying the newly discovered logic to various fields: both natural of social. There, the complexity of the corresponding subjects, the lack of empirical data (for example, the energy conservation law had not even been formulated yet) and – quite possibly – the overconfidence he felt upon completion of his foundational work caused Hegel to cut the proverbial corners and thus let his well known idealism come to the fore. Speaking of idealism as it is usually understood, "The Science of Logic" itself has very little of it or, at least, it does not get in the way of rationality.

Why was not Hegel's logical contribution understood and appreciated enough to at least realize the simple truth that the dialectical logic could not possibly be superseded and made obsolete by *any* advances in *any* branch of mathematics even if it had the word "logic" in its name? A related question: if that logic was so potentially useful for science, how was it possible that it failed being adapted as one of its main tools, along with mathematics, in such a long time? We say more about these questions in Section 4 of this article and in Appendix A.

Very briefly though: subjectively speaking, "The Science of Logic" is *a lot more difficult* to read and understand compared to almost anything else. Compared to most philosophical works of similar size and subject matter, we are talking orders of magnitude more time required.[6] Due to this characteristic feature, it was not well understood even by 19th century philosophers which considered themselves Hegel's followers such as F.H. Bradley. When "industrialization" of philosophy (among other academic disciplines) gained momentum in early 20th century, and the requirement of productivity became commonplace even for very young people (such as graduate students on an academic career path), such disproportionate time and effort requirements made a potential decision to study, apply and further develop the dialectical logic a clear career threat. Thus when the likes of B. Russell pronounced Hegel's logical system made obsolete by new developments in mathematical logic, few professional philosophers were inclined to inquire further. (There was simply no time for that, as many colleagues were getting ahead in the game of academic life by publishing at a steady rate in prestigious journals).

On the objective side, it might appear that scientists would find a way to learn about any methodology if it really held a promise for faster progress. First of all, contemporary scientists were professionals, just like philosophers, and same considerations were just as important for them as well. Secondly (and more objectively), science as a whole is one (very important) aspect of the ideal moment of the (totality of) human practice (as we discuss in more detail in Section 4). The human practice takes place in a particular social form. Thus any science has both a future oriented "eternal" moment (by virtue of being an aspect of *human practice*) and a situational "pragmatic" moment (by virtue of being an aspect of human practice *in a particular form*). When the given historic form passes its zenith, it loses much of its progressive potential and starts showing more of its conservative side, with corresponding changes in sciences as well – as their "pragmatic" moment comes more to the fore. The current predominant social form, in particular, by its very nature, does not have very high ambitions with regards to scientific progress. Interstellar travel and even full material production automatization, for example, are not part of these ambitions. So the demands it objectively places on sciences reflect this nature, meaning that the sciences, objectively, could be less eager to strive for their own progress than one might think. As a result, potentially promising methodologies could easily be passed over for long time periods due to objective deficit of such eagerness.

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[6] In Section 4, we consider a comparison with K. Popper's "The Logic of Scientific Discovery" and note the at least *two* orders of magnitude difference in time requirements.

1.2 Conventions and organization

Both in the main body of the article and the appendices, we make use of extensive quotations: mostly from the "The Science of Logic," but also from the works of B. Russell, L. Wittgenstein, and some other philosophers and scientists. For convenience, we use the following highlighting convention. In any verbatim quotation, *italics* are always due to its author. **Boldface**, on the other hand, is always ours.

The next section is a brief review of Section I of Book Two of "The Science of Logic." Book Two is devoted to the Doctrine of Essence which is arguably the key – and the most difficult to comprehend – ingredient of Hegel's dialectical logical system. Section I of Book Two studies essence in its own right. This is the key section of the key part of the whole Hegel's system. Reviewing some of this material prepares us for the main task of the article and – hopefully – can help anyone interested in learning Hegel's logic get over the psychological barrier created by its reputation of near impenetrability.[7] Section 3 is devoted to the development of rational concepts of matter and energy using the material reviewed in Section 2. It is a necessary preparatory step for tackling the problem of information, as N. Wiener's negative definition indicates. Section 4 contains the main part of this article: the study of a rational concept of information, i.e. an extended answer to the *ti esti* question. We follow the same general logic used in Section 3 for matter and energy. As a byproduct of this development, the rational meaning of several well-known information related mathematical constructs such as probability distribution, Kolmogorov complexity, Kullback-Liebler divergence and Shannon entropy is clarified. It turns out that all of them – not entirely unexpectedly – are different measures (in proper Hegel's sense) of information. Towards the end of Section 4, the notion of knowledge and its relation to information, along with several well-known information paradoxes and the current status of the foundational questions of Philosophy of Information, are considered. Section 5 contains a summary intended as a quick resume of the rational concepts of matter, energy, information – along with those of space and time – that were developed in this article. One of the purposes of Section 5 is to describe the main content of the article to anyone not in possession of sufficient amount of free time to read all of it.

The goal of Appendix A is to substantiate the claim of the fallacy of the currently seemingly predominant view of Hegel's dialectical logic having been made obsolete by the early 20th century advances (or any later or even future advances, for that matter) in mathe-

[7] This reputation of being excessively difficult is nowadays combined with the general (plain wrong) notion of its having been made obsolete by the mathematical logic advances, mentioned earlier in this section. It is this combination that makes many potentially interested people decide the learning not being worth the required considerable effort.

matical logic. Since this opinion is largely attributed to B. Russell, who apparently studied Hegel's logic in his younger years (with very limited success, to put it mildly) only to find it to be a weaker version of the newly developed mathematical logic of Frege and Peano, the logico-philosophical views of B. Russell himself take the center stage in Appendix A. Using extensive quotation from the works of B. Russell and his pupil and follower L. Wittgenstein, it is shown what their views on the subject of logic were, how these views compared with those of Hegel, and what they really replaced Hegel's dialectical logic with. Getting a bit ahead of ourselves, we can give a hint: they replaced it with nothing, as B. Russell himself explicitly admitted.

Appendix B can be thought of a supplement to Appendix A in the following sense. While Appendix A shows that, contrary to the B. Russell's claims and the current popular belief, mathematical logic cannot possibly displace the dialectical one for the simple reason of their different subject matter, Appendix B illustrates this point by means of taking a closer look at the development – primarily from the logical point of view – of one of particular sciences from the time of the revision of the logical aspect of philosophy in early 20th century. Physics specifically provides a good illustration because this was the time when it started facing problems that objectively put higher than before requirements on rational thought (which, accidentally, happens to be the main subject matter of dialectical logic). It is shown in Appendix B what logic physicists were able to come up with for tackling these problems, given that the contemporary philosophy was in the process of being cleansed, as shown in Appendix A, from... the proper philosophical content.

2 A brief overview of (Section I of) Hegel's Doctrine of Essence

As all familiar with that Hegel's seminal work know, "The Science of Logic" is comprised of two volumes, the first of which is devoted to (in Hegel's words) "the Objective Logic" and the second to "the Subjective Logic." The latter one is synonymous with "the Doctrine of the Concept." The former volume is divided into two books: the Book One is The Doctrine of Being and the Book Two is the Doctrine of Essence.

Very briefly, Hegel's Doctrine of Being deals with what can be called the surface of things, the multitude that has unity still behind it, waiting to be uncovered. The main categories belonging the the sphere of being are the quality, the quantity, and the measure (understood by Hegel as the unity of quality and quantity) which we will have to turn to later in our discussion. Here our most immediate needs lie in the realm of the Doctrine of Essence.

The notion of essence is central to the whole of philosophy starting from the days of Aristotle. It literally plays "the central" role in the logical system of Hegel constituting the middle link between the immediate experience, the *being*, and the *concept* that embodies the mature knowledge of what that experience means. Hegel in "The Science of Logic" introduces the essence in the following way [1], p.337:

> The *truth of being is essence.*
>
> Being is the immediate. Since the goal of knowledge is the truth, what being is *in and for itself*, knowledge does not stop at the immediate and its determinations, but penetrates beyond it on the presupposition that *behind* this being there still is something other than being itself, and that this background constitutes the truth of being.

The Doctrine of Essence, the second book of the first volume, is divided into three Sections: Essence as Reflection Within (Section I), Appearance (Section II), and Actuality (Section III). Correspondingly, Hegel first studies Essence in its own right, and then does what is often referred to as "an ascent from the abstract to the concrete": having understood the essence – the background of being – he goes back to the surface of things but now at the new level – equipped with the understanding of essence. The essence in this motion becomes appearance and then actuality.

In the "Science of Logic" Hegel concisely expresses this idea as follows [1], p.418:

> The essentiality that has advanced to immediacy is, *first, concrete existence*, and a concrete existent or *thing* an undifferentiated unity of essence and its immediacy. The thing indeed contains reflection, but its negativity is at first dissolved in its immediacy; but, because its ground is essentially reflection, its immediacy is sublated and the thing makes itself into a positedness.
>
> *Second*, then, it is *appearance.* Appearance is what the thing is in itself, or the truth of it. But this concrete existence, only posited and reflected into otherness, is equally the surpassing of itself into its infinity; opposed to the world of appearance there stands the *world that exists in itself* reflected into itself.
>
> But the being that appears and essential being stand referred to each other absolutely. Thus concrete existence is, *third*, essential *relation*; what appears shows the essential, and the essential is in its appearance. – Relation is the still incomplete union of reflection into otherness and reflection into itself; the complete interpenetrating of the two is *actuality.*

Again, as far as our immediate goal is concerned, it's the essence in its own right (the subject of Section I of the Doctrine of Essence) that we need. Section I, in its turn, consists of three chapters: Shine (Chapter 1), The essentialities or the determinations of reflection (Chapter 2), and Ground (Chapter 3).

2.1 Shine and reflection

Chapter 1 is an introductory one where Hegel approaches the essence from the surface of things – the being. In a nutshell, he describes this path as follows [1], p.341:

> As it issues from being, essence seems to stand over against it; this immediate being is, first, the *unessential.*
>
> But, *second*, it is more than just the unessential; it is being void of essence; it is *shine.*
>
> *Third*, this shine is not something external, something other than essence, but is essence's own shining. This shining of essence within it is *reflection.*

Paragraph A of Chapter 1 is titled "The essential and the unessential" and is very short. Its main purpose is to simply point out, at a very superficial level at this stage, that essence is distinct from the immediate being. In Hegel's own words [1], p.339:

> Consequently, inasmuch as *essential* and *unessential* aspects are distinguished in an existence from each other, this distinguishing is an external positing, a taking apart that leaves the existence itself untouched; it is a separation which falls on the side of a *third* and leaves undetermined what belongs to the essential and what belongs to the unessential.

Paragraph B of Chapter 1 is titled "Shine." While in Paragraph A one simply notes a difference between essential and unessential, in Paragraph B the thought takes one step further and looks back at the immediate being while having the presence of essence underlying this immediate in mind. In slightly different words, shine is the immediate inasmuch essence is given in it (i.e. essence "shines" through it). So shine is what being used to be, but looked upon from the angle of essence. In shine, the unessential is no longer simply different from the essential, but rather determined by essence. At this point of the analysis, however, the determination is negative (the positive determination of being by essence is studied within the realm of the category of appearance that comes logically later). Hegel puts it this way [1], p.344:

> The immediacy that the determinateness has in shine against essence is thus none other than essence's own immediacy, though not the immediacy of an existent but rather the absolutely mediated or reflective immediacy which is shine – being, not as being, but only as the determinateness of being as against mediation; being as moment.

Now that one has realized that the immediate being is just shine of its essence (and not something self-subsistent), one needs to get hold of the essence itself. This is the more difficult part. Hegel has the following to say about it [1], p.345:

> This first immediacy is thus only the *determinateness* of immediacy. The sublating of this determinateness of essence consists, therefore, in nothing further than showing that the unessential is only shine, and that essence rather contains this shine within itself. For **essence is an infinite self-contained movement** which determines its immediacy as negativity and its negativity as immediacy, and is thus the shining of itself within itself. In this, in its self-movement, essence is *reflection*.

We see that essence is an essentially "dynamic" entity and the key to it is held by **reflection** which is understood as the movement of the being (i.e. the various transmutations of matter forms if using the more contemporary language) itself via which the unity shows itself in the multitude. The determinations of essence are therefore, as we would say nowadays, dynamic, or relational, in character. Hegel, respectively, calls them "reflexive."

Reflection, correspondingly is the main subject (and the title) of Paragraph C of Chapter 1. Hegel says further on p.345 of [1]:

> Essence is *reflection*, the movement of becoming and transition that remains within itself, wherein that which is distinguished is determined simply and solely as the negative in itself, as shine.
>
> In the becoming of *being*, it is being which lies at the foundation of determinateness, and determinateness is reference to *an other*. Reflective movement is by contrast the other as *negation in itself*, a negation which has being only as self-referring.

The notion of reflection had been traditionally associated with the activity of a thinking mind. Hegel, however, emphasizes that the reflection he has in mind in the Doctrine of essence has a decidedly objective character as well as subjective, the subjective reflection being just a more or less correct description of the objective one. In the Remark about reflection, he writes [1], p.350:

> Reflection is usually taken in a subjective sense as the movement of judgment which transcends an immediately given representation and seeks more universal determinations for it or compares it with such determinations. Kant opposes *reflective* and *determining judgment* (Critique of Judgment, Introduction, pp. xxiiiff.). He defines judgment in general as the faculty of *thinking the particular as contained under the universal*. If *the universal* (the rule, the principle, the law) is given, then the judgment which subsumes the particular under it is *determining*. But if what is given is only a particular, for which it is up to the *judgment to find the universal*, then the judgment is *reflecting*...
>
> **But at issue here is neither the reflection of consciousness, nor the more specific reflection of the understanding that has the particular and the universal for its determinations, but reflection in general.**

Hegel specifically emphasizes the objective nature of essence and the movement of being that leads to it (and thus its necessarily dynamic character) in the very beginning of Book Two. He writes on p.337 of [1]:

> Only inasmuch as knowledge recollects itself into itself out of immediate being, does it find essence through this mediation...
>
> When this movement is represented as a pathway of knowledge, this beginning with being and the subsequent advance which sublates being and arrives at essence as a mediated term appears to be an activity of cognition external to being and indifferent to its nature.
>
> **But this course is the movement of being itself.** That it is being's nature to recollect itself, and that it becomes essence by virtue of this interiorizing, this has been displayed in being itself.

In Paragraph C of Chapter 1, Hegel describes the details of that universal motion of being. In particular, he begins with the *positing reflection* which negates itself into becoming the *external reflection*. The unity of both yield the *determining reflection* which is the true reflection of essence. The positing reflection is defined as the *purely negating motion* that takes place in being (in the whole of matter, in more modern language). Hegel puts it in the following terms [1], p.346:

> Reflection is at first the movement of the nothing to the nothing, and thus negation coinciding with itself. This self-coinciding is in general simple equality with itself, immediacy. But this falling together is not the transition of negation into equality as into a *being other than it*; reflection is transition rather as the sublating of transition, for it is the immediate falling together of the *negative with itself*. And so this coinciding is, first, self-equality or immediacy; but, second, this immediacy is the self-equality *of the negative*, and hence self-negating equality, immediacy which is in itself the negative, the negative of itself: its being is to be what it is not.

The positing reflection is thus a contradiction: it has to start from the immediate, but, on the other hand, it cannot start with the immediate because it has to posit the immediate as a negation. The positing reflection, by its definition is more fundamental than the immediate fleeting being; thus it can't take the latter as its basis, its starting point. Thus the positing reflection can't be just that and has to have an *external* side to it. Hegel expresses this conclusion in the following way [1], p.348:

> The immediacy which reflection, as a process of sublating, presupposes for itself is simply and solely a *positedness*, something *in itself* sublated which is not diverse from reflections turning back into itself but is itself only this turning back. But it is at the same time determined as a *negative*, as immediately in opposition to something, and hence to an other. And so is reflection *determined.* According to this determinateness, because reflection *has* a presupposition and takes its start from the immediate as its other, it is *external reflection.*

He then goes on to consider the external reflection (that explicitly begins with the immediate) and concludes that it, in its turn, necessarily has a side ("moment" as Hegel liked to say) of the positing reflection in it. He summarizes these findings as follows [1], p.349:

> It thus transpires that external reflection is not external but is just as much the immanent reflection of immediacy itself; or that the result of positing reflection is essence existing in and for itself. External reflection is thus *determining reflection.*

The resulting determining reflection is then, in Hegel's words, "the unity of positing and external reflection." The determining reflection is the true motion of essence, or, put slightly differently, the motion of the being that produces the essence. The determining reflection can be thought of as a resolved contradiction between the positing and the external reflection. Hegel writes [1], p.351:

> External reflection begins from immediate being, *positing* reflection from nothing. In its determining, external reflection posits another in the place of the sublated being, but this other is essence; the positing does not posit its determination in the place of an other; it has no presupposition. But, precisely for this reason, it is not complete as determining reflection; the determination which it posits is consequently *only* a posited; this is an immediate, not however as equal to itself but as self-negating; its connection with the turning back into itself is absolute; it is only in the reflection-into-itself but is not this reflection itself. The *posited* is therefore an *other*, but in such a manner that the self-equality of reflection is retained; for the posited is only as sublated, as reference to the turning back into itself.

In the more contemporary language, one could say that even though the external reflection begins with the immediate (since, logically, it has to begin with something we already have at our disposal) and proceeds to the essence, the immediate is still secondary and not the fundamental one, as opposed to the essence that is the constant motion from one immediate to the other which are all sublated by this motion. Hegel explains this point as follows [1], p.352:

> Positedness gets fixed in determination precisely because reflection is self-equality in its negatedness; the latter is therefore itself reflection into itself. Determination persists here, not by virtue of being but because of its self-equality. Since the being which sustains quality is unequal to the negation, **quality is consequently unequal within itself, and hence a transient moment which disappears in the other**. The determination of reflection is on the contrary positedness *as negation* – negation which has negatedness for its ground, is therefore not unequal to itself within itself, and hence *essential* rather than transient determinateness. What gives subsistence to it is the *self-equality of reflection* which has the negative only as negative, as something sublated or posited.

2.2 Essentialities

Chapter 2 of Section I is titled "The essentialities or the determinations of reflection" and is devoted to the study of what Hegel refers to as "Wesenheit" ("essentiality" in the English translation). This means the specific determination in the sphere of essence, or, roughly speaking, the counterpart of quality in that sphere.

First, Hegel remarks that such essentialities had been traditionally taken in the form of (logical) propositions that were considered fundamental laws of logic. He states the following [1], p.354:

> The *determinations of reflection* have customarily been singled out in the *form of propositions* which were said to *apply to everything*. They were said to have the status of *universal laws of thought* that lie at the base of all thinking; to be inherently absolute and indemonstrable but immediately and indisputably recognized and accepted as true by all thought upon grasping their meaning.
>
> Thus identity, as an essential determination, is enunciated in the proposition, "*Everything is equal to itself*; $A = A$," or, negatively, "*A cannot be A and not-A at the same time*."

Hegel's intention here is to argue that these essentialities' nature is objective and that they are not just the subjective rules of logic. Moreover, he makes an important for his whole system remark that, contrary to a rather general belief, each one of them (if taken in the form of a proposition) cannot be looked upon as an undisputable truth. He states this point as follows [1], p.355:

> Now this propositional form is, for one thing, something superfluous; the determinations of reflection are to be regarded in and for themselves. Moreover, the propositions suffer from the drawback that they have "being," "everything," for subject. They thus bring being into play again, and enunciate the determinations of reflection (the identity, etc., of anything) as a quality which a something would have within – not in any speculative sense, but in the sense that the something, as subject, persists in such a quality as an existent, not that it has passed over into identity (etc.) as into its truth and essence.
>
> Finally, although the determinations of reflection have the form of self-equality, and are therefore unconnected to an other and without opposition, they are in fact *determinate against* one another, as it will result on closer examination – or is immediately evident in them in the case of identity, diversity, and opposition – and are not therefore exempt from transition and contradiction because of their reflective form. Therefore, on closer examination, the *several propositions* that are set up as *absolute laws of thought* are *opposed to each other*: they contradict each other and mutually sublate each other.

A few lines later, he adds:

> The thoughtless examination of them enumerates them *one after the other*, so that they appear unconnected; it merely adverts to their reflectedness without paying attention to their other moment, to the *positedness*, or the *determinateness* as such which propels them on to transition or to their negation.

This quotation is very important for all of Hegel's logic as it concisely states just where is differs from the formal logic of propositions.[8]

The following three paragraphs of Chapter 2 discuss the three main essentialities in turn. They are Identity, Difference and Contradiction (the unity of the former two). Let us first take a look at Paragraph A: "Identity." Hegel describes this essentiality in the following terms [1], p.356:

> Essence is simple immediacy as sublated immediacy. Its negativity is its being; it is equal to itself in its absolute negativity by virtue of which otherness and reference to other have as such simply disappeared into pure self-equality. Essence is therefore simple *self-identity*.
>
> This self-identity is the *immediacy of reflection*. It is not that self-equality which *being* is, or also *nothing*, but a self-equality which, in producing itself as unity, does not produce itself over again, as from another, but is a pure production, from itself and in itself, *essential* identity. It is not, therefore, *abstract* identity or an identity which is the result of a relative negation preceding it, one that separates indeed what it distinguishes from it but, for the rest, leaves it *existing* outside it, the same after as before. Being, and every determinateness of being, has rather sublated itself not relatively, but in itself, and this simple negativity, the negativity of being in itself, is the identity itself.
>
> In general, therefore, it is still the same as essence.

The simple notion of *essential identity* introduced in this quotation is central to Hegel's logical system. It will play an important role in our developments concerning the true nature of energy and information. As Hegel notes in the above excerpt, this essential identity that is produced by the negating motion of being (i.e. the objective reality) is essence itself which, at this point, appears simple and featureless.

Hegel then adds in Remark 1 [1], p.356:

> Thought that keeps to external reflection and knows of no other thought except that of external reflection does not attain to identity as we have just grasped it,

[8] We will say more about the relation between these in Appendix A.

> nor does it recognize essence, which is the same. Such a thought will always have only abstract identity in mind, and, outside and alongside it, difference.

This last remark hasn't lost its actuality to this day, and the intellectual attitude that Hegel criticizes here has considerably slowed down the progress of science and related areas. *To recognize essence*, in general, still presents often unsurmountable difficulties in much of the modern day scientific theory.

Hegel then argues, further in Paragraph A, that identity is inseparable from difference. He concludes the Paragraph with the following words [1], p.357:

> *Internally*, therefore, identity is absolute non-identity. But it is also the *determination* of identity over against non-identity. For, as immanent reflection, it posits itself as its own non-being; it is the whole, but as reflection it posits itself as its own moment, as the positedness from which it is the turning back into itself. **Thus identity is such only as a moment of itself**, as *determination* of simple self-equality over against absolute difference.

The sentence highlighted in the above quotation is a key point. The familiar to everyone identity of the formal logic is really just a moment (i.e. a side) of the whole identity that always has difference as its second moment.

Paragraph B of Chapter 2 is titled "Difference." Hegel begins with the simple, or absolute, difference that, as we know now, is inseparable from identity. Hegel states [1], p.361:

> This difference is difference *in and for itself, absolute* difference, *the difference of essence.* – It is difference in and for itself, not difference through something external but *self-referring*, hence *simple*, difference.

He then argues that, just like identity, difference can be considered as both the whole (reflection) and only its moment [1], p.361:

> Difference in itself is the difference that refers itself to itself; thus it is the negativity of itself, the difference not from another but *of itself from itself*; it is not itself but its other. What is different from difference, however, is identity. Difference is, therefore, itself and identity. The two together constitute difference; difference is the whole and its moment. One can also say that difference, as simple difference, is no difference; it is such only with reference to identity; even better, that as difference it entails itself and this reference equally. – **Difference**

> **is the whole and its own moment, just as identity equally is its whole and its moment**. – This is to be regarded as the essential nature of reflection and as *the determined primordial origin of all activity and self-movement.* – Both difference and identity make themselves into *moment* or *positedness* because, as reflection, they are negative self-reference.

Hegel then takes a closer look at the difference that is inseparable from identity so that they are both at the same time are the whole and its moment (one side). He first states on p.362 of [1]:

> Difference, inasmuch as it has two such moments which are themselves reflections into themselves, is *diversity.*

After that, he notes that, since difference and identity are just moments of the same whole (that is the reflection) but, at this point, indifferent to each other, we have also an external reflection in the picture. He formulates this result as follows [1], p.363:

> Reflection in itself and external reflection are thus the two determinations in which the moments of difference, identity and difference, are posited. They are these moments themselves as they have determined themselves at this point. – *Immanent reflection* is identity, but determined to be indifferent to difference, not to have difference at all but to conduct itself towards difference as identical with itself; it is *diversity.* It is identity that has so reflected itself into itself that it truly is the one reflection of the two moments into themselves; both are immanent reflections. Identity is this one reflection of the two, the identity which has difference within it only as an indifferent difference and is diversity in general. – *External reflection*, on the contrary, is their *determinate* difference, not as absolute immanent reflection, but as a determination towards which the implicitly present reflection is indifferent; its two moments, identity and difference themselves, are thus externally posited, are not determinations that exist in and for themselves.
>
> Now this external identity is *likeness*, and external difference is *unlikeness.* – *Likeness* is indeed identity, but only as a positedness, an identity which is not in and for itself. – *Unlikeness* is equally difference, but an external difference which is not, in and for itself, the difference of the unlike itself.

This diversity, or external difference, that is split into two separate and indifferent to each other moments – likeness and unlikeness – can be thought of as a negation of the absolute, or simple, difference. Upon closer examination though it transpires that the separation of these two moments is just an abstraction and they are really two moments of the same reflection, the *implicitly existent reflection* that has no external moment to it. This transition can be considered as negation of a negation. Hegel states this point as follows [1], p.364:

> Because of this separation from each other, they sublate themselves. Precisely that which should save them from contradiction and dissolution, namely that something is *like* another in *one respect* but *unlike in another* – precisely this keeping of likeness and unlikeness apart, is their destruction.

and a little later (p.365):

> Likeness and unlikeness themselves, the positedness, thus return through indifference or through implicitly existing reflection back into negative unity with themselves, into the reflection which is the implicit difference of likeness and unlikeness. Diversity, the *indifferent* sides of which are just as much simply and solely *moments* of a negative unity, is *opposition*.

The opposition is thus the most developed form of the difference. Hegel says it as follows [1], p.367:

> In opposition, the *determinate reflection*, difference, is brought to completion. Opposition is the unity of identity and diversity; its moments are diverse in one identity, and so they are *opposites*.

Then he shows that, in opposition, what used to be likeness and unlikeness in diversity becomes the two sides of the opposition: the positive and the negative [1], p.368:

> Opposition is, on the one hand, *positedness* reflected into its *likeness with itself*; and, on the other hand, it is the same positedness reflected into its inequality with itself: the *positive* and the *negative*.

The positive and the negative are, first opposite to each other and, in this sense, inseparable and do not exist without the other one [1], p.369:

> The determinations which constitute the positive and the negative consist, therefore, in that the positive and the negative are, *first*, absolute *moments* of opposition; their subsistence is indivisibly *one* reflection; it is one mediation in which

> each is by virtue of the non-being of its other, hence by virtue of its other or its own non-being. Thus they are simply *opposites*; or *each* is only the opposite of the other; the one is not yet the positive and the other not yet the negative, but both are negative with respect to each other.

But, on the other hand, as it transpires upon closer examination, they are also the positive and negative in their own right. In particular, one can't simply rename them freely without changing their meaning [1], p.369:

> But, *in third place*, the positive and the negative are not only a posited being, nor are they something merely indifferent, but their *positedness*, or the *reference to the other in the one unity which they themselves are not*, is rather *taken back* into each.

The positive in its own right becomes a sort of condensed identity, or likeness, as such, and the negative, on the opposite end, is just something like a concentrated opposition to that, all unlikeness collected into a single point [1], p.370:

> Each is thus self-subsistent unity existing for itself. The positive is indeed a positedness, but in such a way that the positedness for it is only positedness as sublated. It is the *non-opposed*, the sublated opposition, but as the side of the opposition itself. – As positive, it is indeed a something which is determined with reference to an otherness, but in such a way that its nature is not to be something posited; it is the immanent reflection that negates otherness.

and a few lines later:

> The negative is the independently existing opposite, over against the positive which is the determination of the sublated opposition – the *whole opposition* resting upon itself, opposed to the self-identical positedness.

Paragraph C of Chapter 2 is titled "Contradiction." The difference reached its most developed form – the opposition – and presented itself in the form of two moments – the positive and the negative – that are, at the same time, indifferent to each other and mutually excluding. They are indifferent by virtue of each one containing the relation to the other one inside of itself. Hegel puts it the following way [1], p.374:

> Difference as such is already *implicitly* contradiction; for it is the *unity* of beings which are, only in so far as they are *not one* and it is the *separation* of beings

> which are, only in so far as they are separated *in the same reference connecting them.* The positive and the negative, however, are the *posited* contradiction, for, as negative unities, they are precisely their self-positing and therein each the sublating of itself and the positing of its opposite.

The resulting contradiction then resolves itself [1], p.376:

> In the self-excluding reflection we have just considered, the positive and the negative, each in its self-subsistence, sublates itself; each is simply the passing over, or rather the self-translating of itself into its opposite. This internal ceaseless vanishing of the opposites is the *first* unity that arises by virtue of contradiction; it is the *null.*
>
> But contradiction does not contain merely the *negative*; it also contains the *positive*; or the self-excluding reflection is at the same time *positing* reflection; the result of contradiction is not only the null. – The positive and the negative constitute the *positedness* of the self-subsistence; their own self-negation sublates it. It is this *positedness* which in truth **founders to the ground** in contradiction.

The word combination highlighted in the above quotation has a double meaning in German language: it means to go to the ground understood as a basis, or foundation, of something but also to literally go down to the bottom of some water body (like a lake or an ocean). Hegel apparently finds it to be a useful metaphor and uses this word combination throughout his work. So, to summarize the main idea, of this quotation and the whole Paragraph C (if not the whole Hegel's logical system), contradiction which is a unity of opposites gets resolved whereby the opposites founder to the ground. What's important to understand here is that the said resolution of a contradiction happens not just in somebody's mind, but objectively as well. But, as stated in the previous quotation, a resolution of a contradiction can proceed along two different paths: a resolution into the null and a "constructive" resolution that leads to something new. It is the latter contradiction resolution mode that constitutes the main logical "mechanism" of what is nowadays called the "innovation." Hegel writes further in Paragraph C (p.377):

> According to this positive side, since self-subsistence in opposition, as excluding reflection, makes itself into a positedness and equally sublates this positedness, not only has opposition *foundered to the ground* but has gone back *to its foundation, to its ground.* – The excluding reflection of the self-subsisting opposition turns it into a negative, something only posited; it thereby reduces its formerly self-subsisting *determinations*, the positive and the negative, to determinations

> which are *only determinations*; and the positedness, since it is now made into positedness, has simply gone back to its unity with itself; it is *simple essence*, but essence as *ground*.

We see that, in this quotation, Hegel distinguishes between the opposition foundering to the ground and going back to its ground, the latter foundering being just the mode of resolution of the contradiction to the null. Granted, Hegel is being rather vague here concerning the said distinction. A few pages later, in Remark 3 devoted to a discussion of a contradiction in general, Hegel states the following [1], p.384:

> On the contrary, every determination, anything concrete, every concept, is essentially a unity of distinguished and distinguishable elements which, by virtue of the *determinate, essential difference*, pass over into elements which are contradictory. This contradictoriness of course resolves itself into nothing: it goes back into its negative unity. A thing, a subject, a concept, is then precisely this negative unity; it is something inherently self-contradictory, but it is no less the *resolved contradiction*; it is the *ground* which contains the determinations it bears. The thing, the subject or the concept, each as reflected into itself within its sphere, is their contradiction as resolved; but the whole sphere of each is in turn *determinate, diverse*, and therefore finite, and this means *contradictory*. This sphere is **not itself the resolution of its higher contradiction but has yet a higher sphere for its negative unity, for its ground**.

We see, in the above quotation, a direct mention (highlighted in boldface) of the two modes of resolving a contradiction, the second being the one referring to a higher sphere where the contradiction is resolved in a "nontrivial" fashion leading to innovation.

2.3 Essence as ground

Chapter 3 of Section I is titled "Ground." The notion of ground has been already encountered in Chapter 2 where the latter was defined as follows [1], p.378:

> Ground is essence as positive self-identity which, however, at the same time refers itself to itself as negativity and therefore determines itself, making itself into an excluded positedness; but this positedness is the whole self-subsisting essence, and essence is ground, self-identical in its negation and positive.

In the beginning of Chapter 3, on p.387, Hegel explains it further:

Reflection is *pure mediation in general*; ground, the *real mediation* of essence with itself. The former, the movement of nothing through nothing back to itself, is the reflective shining of *one* in an *other*; but, because in this reflection opposition does not yet have any self-subsistence, neither is the one, that which shines, something positive, nor is the *other* in which it reflectively shines something negative. Both are substrates, actually of the imagination; they are still not self-referring. Pure mediation is only *pure reference*, without anything being referred to. Determining reflection, for its part, does posit such terms as are identical with themselves; but these are at the same time only *determined references*. Ground, on the contrary, is mediation that is real, since it contains reflection as sublated reflection; it is essence that *turns back into itself through its non-being and posits itself*. According to this moment of sublated reflection, what is posited receives the determination of *immediacy*, of an immediate which is self-identical outside its reference or its reflective shining. This immediacy is *being* as restored by essence, the non-being of reflection through which essence mediates itself. Essence returns into itself as it negates; therefore, in its turning back into itself, it gives itself the determinateness that precisely for this reason is the self-identical negative, is sublated positedness, and consequently, as the self-identity of essence as ground, equally an *existent*.

In the more modern language, one could say that essence has dynamic nature meaning that, behind being, the ever-changing immediate multitude, there is no other separate entity on which that multitude existed and played the role of its surface. The unity lurking behind the immediate multitude can be only comprehended by virtue of transmutations that the multitude constantly undergoes. That motion of the multitude itself is the essence. The motion constantly negates the immediate, changing it into something else. One can say therefore that the positivity of essence, its very existence, is found only in its negativity. Essence thus is necessarily a contradiction. This contradiction gets resolved (in objectivity itself, not just subjectively), and its resolution produces ground. Ground therefore can be thought of as essence in its self-subsistent, solidly established form in which the dynamics of essence is sublated. It is the unity behind the multitude that unquestionably establishes itself as a base and a reason for all that multitude. Hegel calls that last act of essence "ground as the last reflexive determination of essence."

In the end of Chapter 2, on p.385, Hegel says the following words that are very important for his whole system:

In customary inference, the *being* of the finite appears to be the ground of the

> absolute; because the finite *is*, the absolute *is*. But the truth is that the absolute is because the finite is the immanently self-contradictory opposition, because it is *not*. In the former meaning, the conclusion is that "the *being* of the finite is the *being* of the absolute"; but in the latter, that "the *non-being* of the finite is the *being* of the absolute."

So, the absolute, or, in slightly different words, unity behind multitude, is not a figment of imagination, or some kind of explanatory trick or convention. It is just as real as the immediate multitude itself, but exists in the multitude's own negation, in the constant change and transmutation.

Ground is then considered in several logical steps. In the first step, it is taken as an "absolute ground" (i.e. simple ground) which is the subject of Paragraph A of Chapter 3. At this level, the relation of ground is considered in the most general terms. Later, we will see that, due to the nature of our subject, this is the level that we'll need the most. As far as absolute ground is concerned, at first, the relation constituted by the category of ground appears as that of **form and essence**. On p.389 of [1], we read:

> The ground is not an indeterminate but is rather essence determined through itself, but *determined* as *indeterminate* or as sublated positedness. *It is essence that in its negativity is identical with itself.*
>
> The *determinateness* of essence as ground is thus twofold: it is the determinateness of the *ground* and of the *grounded*. It is, *first*, essence as ground, essence *determined* to be essence as against positedness, as *non-positedness*. *Second*, it is that which is grounded, the immediate that, however, is not anything in and for itself: is positedness as positedness. Consequently, this positedness is equally identical with itself, but in an identity which is that of the negative with itself. The self-identical negative and the self-identical positive are *now one and the same identity.*

In the very end of the above quotation, roughly speaking, the former (self-identical negative) is the **form** and the latter (self-identical positive) is the **essence**. So, as we see, form and essence appear to be inseparable and (almost) same. They are same and different at the same time [1], p.391:

> Form is absolute negativity itself or the negative absolute self-identity by virtue of which essence is indeed not being but essence. This identity, taken abstractly, is essence as against form, just as negativity, taken abstractly as positedness, is

> the one determination of form. But this determination has shown itself to be in truth the whole self-referring negativity which within, as this identity, thus is simple essence. Consequently, form has essence in its own identity, just as essence has absolute form in its negative nature. One cannot therefore ask, *how form comes to essence*, for form is only the internal reflective shining of essence, its own reflection inhabiting it. Form equally is, within it, the reflection turning back into itself or the identical essence; in its determining, form makes the determination into positedness as positedness.

He adds on p.392:

> Determining form refers itself to itself as sublated positedness; it thereby refers itself to its identity as to another. It posits itself as sublated; it therefore *pre*-supposes its identity; according to this moment, essence is the indeterminate to which form is an other. It is not the essence which is absolute reflection within, but essence determined as formless identity: it is *matter*.

We thus see that the form and essence that were inseparable got split into **form and matter**, where the two are explicitly separate from each. The *form and matter* relation is the first negation of the *form and essence* one. Matter now is, as noted in the above quotation, just formless mass completely devoid of all features of form. It is this level of analysis which will be of immediate importance to us when we tackle the problem of the true nature of energy (and matter) in the next section.

The following quotation is a good explanation of what exactly matter is [1], p.392:

> If abstraction is made from every determination, from every form of a something, matter is what is left over. Matter is the absolutely *abstract*. (One cannot see, feel, etc. matter; what one sees or feels is a *determinate matter*, that is, a unity of matter and form.) This abstraction from which matter derives is not, however, an *external* removal and sublation of form; it is rather the form itself which, as we have just seen, reduces itself by virtue of itself to this simple identity.

The mutual indifference of form and matter is, as mentioned in the previous quotation, just an abstraction even though an abstraction that is grounded in objectivity. Further concretization of that abstraction shows that "*matter must be informed*, and *form* must *materialize* itself" ([1], p.393). Thus we arrive, in the end, to a unity of form and matter which is now negation of the first negation (in which the form-essence relation was negated to yield the form-matter one) [1], p.395:

> Inasmuch as form presupposes a matter as its other, it is *finite*. It is not a ground but only the active factor. Equally so, matter, inasmuch as it presupposes form as its non-being, is *finite* matter; it is not the ground of its unity with form but is for the latter only the substrate. But neither this finite matter nor the finite form have any truth; each refers to the other, or only their unity is their truth. The two determinations return to this unity and there they sublate their self-subsistence; the unity thereby proves to be their ground.

and, on p.396:

> The restored unity, in withdrawing into itself, has repelled itself from itself and has determined itself; for its unity has been established through negation and is, therefore, also negative unity. It is, therefore, the unity of form and matter, as the substrate of both, but a *substrate which is determinate*: it is formed matter, but matter at the same time indifferent to form and matter, indifferent to them because sublated and unessential. This is *content*.

We have thus arrived at the **form and content** relation, the best known of the three. Hegel further explains what content is as follows, on the same page:

> Content has, *first*, a form and a matter that belong to it essentially; it is their unity. But, because this unity is at the same time *determinate* or *posited* unity, content stands over against form; the latter constitutes the *positedness* and is the unessential over against content.

So content is a unity of form and matter, or, in other words, matter that has been formed. The essence that was originally inseparable from its form, now, upon sublation of the form-matter relation, acquires form again (as it indeed is never without form). But, at this level of analysis, one realizes that form, even though inseparable from essence, is still external to it: form is not essence but only form. So form appears in two guises – as a moment of content (along with matter) on one hand, and form proper on the other hand. Hegel explains this point on p.397 of [1]:

> On the one hand, content is the essential self-identity of the ground in its positedness; on the other hand, it is posited identity as against the ground connection; this positedness, which is in this identity as determination of form, stands over against the free positedness, that is to say, over against the form as the whole connection of ground and grounded. The latter form is the total positedness

returning into itself; the former form, therefore, is only the positedness as immediate, the *determinateness* as such.

The remaining two paragraphs of Chapter 3 – B "Determinate Ground" and C "Condition" – will not be of immediate interest to us due to the rather general nature of our subject matter of interest. Thus we will not cover their content in this brief review.

3 Matter and Energy

Let us first turn to matter – arguably, the most fundamental philosophical category. It is so broad that it is difficult to define in a usual way: by indicating the genus to which it belongs as a species. The most straightforward way to give a useful definition of matter (understood in the sense used by N. Wiener in his negative definition of information) is to – roughly speaking – observe that the very question (what matter is) arises only when human spirit, or consciousness, has developed sufficiently to start asking such questions. So matter in its most general sense can be defined *as all objective reality that exists independently of consciousness and can be reflected by it.* This is the standard (and a bit imprecise) definition of matter adapted in materialistic philosophy. The objective reality mentioned in this definition can exist in a multitude of forms and is included in the category of matter regardless of any form.[9] As Hegel liked to remark, the true meaning of a philosophical category becomes clear only in the context of a system. This is also true about the concept of matter: it will become clearer once we discuss the other two members of N. Wiener's triad: energy and information. We will revisit the notion of matter later in this section and also in Section 5 where we will summarize the content of all these basic categories (along with those of space and time) and relations between them.

We now switch our attention to energy. In the realm of modern sciences, the one dealing with energy in the most intimate fashion is undeniably physics. Other sciences – such as chemistry and biology – essentially borrow and use the results and conclusions developed by physics when having to address energy related issues. So let us first hear what physics has to say about energy in the most general sense.

One of the prominent physicists of the second half of 20th century and one of physics' most colorful personalities, R.P. Feynman, in his well-known lectures on physics [7], describes energy in the following way:

[9]Later in this section, we will revisit the category of matter to make its definition more precise and will see that it can be analyzed in a way very similar to that of energy.

> There is a certain quantity, which we call energy, that does not change in the manifold changes which nature undergoes. That is a most abstract idea, because it is a mathematical principle; it says that there is a numerical quantity which does not change when something happens. It is not a description of a mechanism, or anything concrete; it is just a strange fact that we can calculate some number and when we finish watching nature go through her tricks and calculate the number again, it is the same.

He then proceeds, for illustration purposes, to tell a story of a little kid who has 28 blocks and likes to play with them in a careless manner in his room so that his mother can't always find all 28 at the end of the day (or sometimes finds even more than that). However, if she carefully accounts for all possible ways in which the blocks could seemingly disappear (or extra blocks could appear in the room due to the kid's friend visit), the number of blocks at the end of the day is still 28. But to make sure this is the case, the mother sometimes has to exhibit significant ingenuity. Then R.P. Feynman summarizes his exposition by making the following confession:

> It is important to realize that in physics today, **we have no knowledge of what energy is**. We do not have a picture that energy comes in little blobs of a definite amount. It is not that way. However, there are formulas for calculating some numerical quantity, and when we add it all together it gives "28" – always the same number. It is an abstract thing in that it does not tell us the mechanism or the reasons for the various formulas.

Even though these words were written more than 50 years ago, the situation hasn't changed much since then. Most professional physicists – if pressed for an honest answer – would still agree that they "have no knowledge of what energy is" and can only calculate it with the help of some formulas the reasons for which are often still rather murky.

Now that we have the category of matter at our disposal, let us use the logical tools provided by Hegel to get a hold of the elusive energy (and, a bit later, information). To this effect, let us first note that one of the main conclusions of all the philosophy and sciences in the last about 2500 years is that there does not exist a modicum of matter not involved in some form of *motion* understood in the most general sense as *any change*. The motion takes place in a bewildering multitude of forms – from purely mechanical to biological and social. Such motion never ceases but always changes forms.[10] We are now going to take a

[10]For example, when one applies brakes in a car, the mechanical motion of the car as a whole turns mostly into chaotic thermal motion of the molecules constituting brake pads, discs and also tires and pavement, raising their temperature.

closer look at that universal motion with the help of "The Science of Logic."

In the whole of "The Science of Logic," our immediate needs lie in Section I of "The Doctrine of Essence" that was reviewed in the previous section. In the analysis that ensues, we will follow the logical sequence of Section I. Our subject here, as stated above, is the *universal motion* of matter in all possible forms. Immediately, it is just any change matter undergoes. Clearly, it has all kinds of qualitative and quantitative features that are studied by various sciences. These features, however, are not what we are interested in here. Our interest lies in the **universal motion as such**, taken in its totality.

1A. The essential and the unessential. At this level, we simply point out that there is essence of our subject – the universal motion of matter – that is different from its immediate being which is motion in a multitude of forms. Here we just state that the essence is not the same as that immediate being, that in this totality of motion, something is essential and something is unessential.

1B. Shine. At this level of analysis, we move a bit further and note that the immediate being of the universal motion is just the essence of it "showing through" (or "shining through") the surface (the immediate) of it. Thus, at this point, essence is not just different but negatively defined via the immediate. We say that essence is not simply and abstractly *"there"* but it is, so to speak, *"everywhere"* in the subject "peeking through" every single instance of the universal motion of matter.

1C. Reflection. Having realized that the essence of motion is everywhere, we can now say a bit more. Let us recall that reflection, in the sense Hegel uses it, is not simply some mental exercise in the mind of an observer or a researcher, but rather the objective motion of the being itself. In our case, since the subject in question is the universal motion – at this point, taken in the totality of its immediacy – the reflection has to be identified with the motion of that motion. To anyone familiar with sciences even superficially, this immediately suggests *change of motion forms* that can be easily witnessed even in everyday life. Let us now get to the specifics of reflection along the lines of "The Doctrine of Essence."

a) *Positing reflection.* This is the motion of *negation.* The subject, in its own motion, negates itself. In our case, this is fairly clear: the motion of matter constantly disappears in its immediacy (only to reappear in some different guise). The latter reappearance has to be established. It was a major advance in physics and all of science to learn that motion can't just vanish, but only changes forms. The disappearance of motion in any particular form is usually immediately obvious (just push the brake pedal in any car to see it, for example). Hegel, as reviewed in the previous section, expressed this observation by stating that "Reflection is at first the movement of **the nothing to the nothing**, and thus negation coinciding with itself."

b) *External reflection.* As we have seen in the previous section, positing reflection is a contradiction since it was defined as a purely negating movement with respect to the immediate, but, at the same time, we have nothing but the immediate to start with. So, upon closer consideration, it must have to have an external moment to it. This moment is the external reflection – motion that begins from some being. In our case, the only being the external reflection can begin with is the *universal motion in some particular form* – the only way it shows up "on the surface," i.e. as an immediate. Also note that the external moment of reflection comes from the nature of the subject under consideration. In our case, it is the motion in full generality, *motion in all possible forms.* This implies that the external reflection will begin with and negate *all determinations*, all specific features of (some arbitrary) motion taken in its immediacy. (If our subject of study were mechanical motion, for instance, the external reflection would negate speeds and directions of entities involved in the motion, but leave its mechanical character intact).

c) *Determining reflection.* Determining reflection was defined by Hegel as a unity of positing and external reflections. In our case, we obtain a reflection that begins with motion in some (actually any) particular form, negates it and then keeps going "from nothing to nothing" forever negating all the immediate. Since all these forms negated are just forms of **motion**, we see that what's left as self-equal in this process is just that: the motion as such. Actually, by saying this here, we are running ahead of ourselves a bit since reflection is just an all-negating dynamic process, with nothing "tangible" produced yet. The pure formless motion as such will "crystallize" fully a bit later in the analysis. As far as reflection goes, Hegel states the following (as we have reviewed in the previous section): "What gives subsistence to it is the *self-equality of reflection* which has the negative only as negative, as something sublated or posited."

2A. Identity. We have now come to the discussion of essentialities, i.e. specific determinations of essence. The first such is *identity.* Recall that Hegel characterizes it concisely in the following way: "Essence is simple immediacy as sublated immediacy. Its negativity is its being; it is equal to itself in its absolute negativity by virtue of which otherness and reference to other have as such simply disappeared into pure self-equality. Essence is therefore simple *self-identity.*" So, at first, essence appears as self-identity produced by the negating motion of the determining reflection. All specific forms of motion disappear and turn into other forms only to disappear again. They become identical to each other in this negative sense. So here we state that all **forms** of motion are just forms of **motion** and thus are identical. The immediacy of motion (its form) has been sublated – and not just in our thought, but, more importantly, in objectivity itself, by virtue of transmutations of motion forms.

2B. Difference. Difference, as we recall, is the second essentiality discussed by Hegel. Upon closer examination of identity, one realizes that it always has a moment of difference inherently present in it. Even the simplest $A = A$ identity, in order to have any content whatsoever, has to have a moment of difference: A on the left has to be different in some way from A on the right. In our application, all forms of motion were found to be identical by means of their constant disappearance in objectivity. Now we turn our attention to the fact that motion in some form disappears to just to reappear in a different form. So all these forms are *essentially identical* and are just forms of the **same motion**. But this essential identity necessarily has a moment of difference in it since without any difference there would be no transmutation of forms, no change whatsoever. This difference that is just an inseparable moment of the essential identity is the simple (or, as Hegel says, absolute) difference that has yet no additional features (or determinations, in Hegel's preferred language). As discussed in the previous section, Hegel states that, at this level of analysis, identity is the whole (reflection) and its moment, and so is the difference. So we can say that all motion is the same motion and not the same motion at the same time.

a) *Diversity.* Now we can take a closer look at the essential identity that was found to necessarily have a moment of difference in it. This difference is completely indeterminate at this point. The only way to determine it would be an external one. So, as Hegel says (as we have reviewed before), "Reflection in itself and external reflection are thus the two determinations in which the moments of difference, identity and difference, are posited." It is that external reflection that expresses the *determinate difference* (and determinate identity). These are, respectively, *unlikeness* and *likeness* that are typically expressed by phrases "in this regard" and "in that regard." In our application, since the subject under consideration is the motion taken in full generality (in all possible forms), the determinate difference is just that: difference in regard to the *form* of motion. On the other hand, all forms of motion are identical (they are just like each other) in that they are just forms of *motion.* Hegel says that "determinate difference is negated absolute difference."

b) *Opposition.* Diversity is an external comparison that takes place outside of the entities being compared, in something third. As discussed in the previous section, mutual indifference of diversity moments – likeness and unlikeness – is an abstraction, and upon closer examination, each of these moments has the other one in it and represents – just like identity and difference – both the whole and one of its moments. This whole is the full development of the determinate reflection – the opposition, and its moments are, respectively, the *positive* and the *negative.* As we know, the positive – in the sense used by Hegel and by us here – is the "concentrated" likeness (likeness reflected into itself), and the negative is the unlikeness that has received the same treatment – the "concentrated" opposite to the positive. In our application, the positive is just the motion taken from the side of its self-identity, motion as such, in abstraction from any further determinations. The negative is the opposite of that – just pure negation, disappearance, change.

2C. Contradiction. Contradiction is, most immediately, an inseparable unity of the opposites, the positive and the negative. As Hegel notes, each side of the opposition actually implicitly contains the opposite in it and thus can be regarded as both the whole opposition and just a moment of it – just the positive or just the negative. So even the positive and the negative taken by themselves are already contradictions that need to be resolved into something. As we have discussed, a resolution can be of one of two kinds: a resolution into the null – without anything essentially new resulting and a resolution with innovation (using a more modern language). Depending on the nature of the subject in question, the second kind (or mode) of resolution may or may not be present. In our view, that mode of resolution is not present whenever the subject is not yet sufficiently "ripe" (in that case it can be potentially there but still lacking some conditions for actualization) or – like in our case – the subject is so general that an essential innovation (creation of a new essence) is simply not possible. This is the case we have at hand – our subject is motion *taken in utmost generality*, i.e. including *all possible forms*, even forms that may not be sufficiently known (or not fully existent within our reach) at present time. There is simply no form of motion not already "accounted" for – at least in principle – by our subject and therefore no new essence[11] can be created by a resolution of this contradiction.

On the other hand, a resolution into the null is always there. As Hegel says on p.376 of [1], "This internal ceaseless vanishing of the opposites is the first unity that arises by virtue of contradiction; it is the null." That vanishing of the opposites is simply the movement of the subject of study itself. In our case, this is the universal motion in its constant change of forms that we witness every day everywhere.

3A. Absolute Ground. As we have learned in the previous section, ground is the last reflexive determination of essence. Essence was originally captured as a dynamic process, an inherent motion of the immediate itself resulting in transmutations of forms and revealing the unity behind the multitude. Taken as such, it may look secondary to the immediate, with the latter being the fundamental basis for its own essence.[12] But the correct point of view is just the opposite in which the essence (or the unity) is the basis for the immediate multitude.

[11]If our subject of study were, for instance just *mechanical form* of motion, this would not be the case, and a new essence would be created as a result of the corresponding contradiction resolution. This is an interesting topic that will be briefly discussed in Appendix B.

[12]It is interesting to note that this very point of view is pretty much the starting point and the main principle of all positivistic philosophy which, in its most radical forms, goes as far as proclaiming the essence (or unity) to be only an intellectual convention that helps in organizing our thought process and knowledge.

So essence has to "leave behind" (sublate) the reflection that originally seemingly "gave rise" to it and establish itself explicitly in that role. The result is *ground*. Hegel puts it this way: "Ground, on the contrary, is mediation that is real, since it contains reflection as sublated reflection; it is essence that *turns back into itself through its non-being and posits itself*." Thus ground is in a sense the same as essence, but essence firmly taken as a foundation for the immediate.

a) *Form and essence.* The essence has established itself as ground that acts as a foundation for the immediate, or grounded, which is now taken as purely derivative (or "posited," in Hegel's preferred language). On the other hand, as Hegel says (as we have reviewed in the previous section): "The self-identical negative and the self-identical positive are *now one and the same identity*." So ground (essence) and grounded (form) are, at this level, the same self-identity. Essence is form and form is essence. Specifically, in our application, this is rather straightforward: motion as such (the essence) exists only in some form and is never form-free; any form of motion is a form of that same motion as such. Motion and its form are inseparable. They are the whole taken from the side of, respectively, the unity and the multitude.

b) *Form and matter.* As we have seen, in the universal motion, form and essence are inseparable, and their difference appears rather formal at first. All specific features ("determinations," as Hegel would have probably said) of motion are those of its form. In this sense, one could say that "form determines essence." On the other hand, as Hegel says (as reviewed by us earlier): "Determining form refers itself to itself as sublated positedness; it thereby refers itself to its identity as to another. It posits itself as sublated; it therefore *pre*-supposes its identity; according to this moment, essence is the indeterminate to which form is an other. It is not the essence which is absolute reflection within, but essence determined as formless identity: it is *matter*." Put slightly differently, if one begins with the form and essence relation, and wishes to separate the moments as much as possible (which constitutes first negation of form and essence), all the specific features (determinations) have to go on the form side representing the immediate multitude. Unless one is willing to deny the objectivity of unity completely (which is precisely what some positivists do), then the unity is left with just self-subsistent identity that is totally devoid of form. This is matter. It is an abstraction but an abstraction grounded in reality: it is a way to rationally represent the unity behind the multitude in its "purest" form.

Form and matter is just the level of abstraction we need to get hold of energy. In application to the universal motion, all details are now part of form. So matter is just the uniform featureless "leftover" – the motion as such at its most abstract level. And this is precisely what became known as energy in the history of science. So we finally have a definition.

Definition 1 *Energy is the universal motion of matter taken in full abstraction from its form.*

Energy is another example of what Hegel referred to as "pure quantity" in "The Doctrine of Being" – Book One of "The Science of Logic." The examples that Hegel actually gives are space, time, and matter in general. We will say more about it later in this section when we discuss energy quantity.

c) *Form and content.* While in *form and essence* the moments coincide, in *form and matter* they are separated – this is first negation. It is a high abstraction – upon closer examination, it turns out that the separation of form from matter negates itself and matter acquires determinations of form. This is negation of negation that brings us to the relation of *form and content*, the latter being understood as formed matter. In our application, matter which we've just identified with energy acquires determinations of form while still keeping the unique characterization of matter understood as that universal indestructible motion that is always present regardless of any form. The result is energy endowed with some form. It is this level of abstraction that physicists have in mind when they talk about kinetic energy, potential energy, electromagnetic energy etc. We will say more about it later in this section.

3.1 Energy quantitative characterization

We now have a proper definition of energy. If one compares it with R.P. Feynman's description given earlier in this section, one difference is immediately obvious: our definition does not explicitly mention any *quantity* while Feynman says that, to the best of most physicists' knowledge, energy is just a *number* that happens to survive any changes if sufficient care is taken calculating it. While Feynman's description, according to his own admission, is logically incomplete, it is hardly incorrect in what it claims. This means that we need to introduce an appropriate *quantity* that can be assigned to energy (and happens to stay intact in all material processes).

Quantity is the subject of Section II of "The Doctrine of Being," Book One of "The Science of Logic." "The Doctrine of Being" as a whole is devoted to the logical study of the immediate. It begins with Section I titled "Quality" which is followed by Section II "Quantity" and Section III "Measure." So logically quality precedes quantity. The discussion of quality begins with the category of *pure being* that describes the most abstract indeterminate immediate. This pure being is empty and hence same as *nothing*. These two categories are abstract and vanish into each other giving rise to the first concrete category of *becoming*. Becoming gets sublated and turns into *existence*, or *determinate being*. *Quality* itself is that determinateness of determinate being taken by itself. In words of Hegel himself [1], p.83: "Through its quality, *something* is opposed to an *other*; it is *alterable* and *finite*, negatively determined not only towards an other, but absolutely within it." Thus the sphere of existence and quality is transient, ever-changing by its nature.

Before quantity can be rationally discussed, determinate being needs to become, roughly speaking, unchanged and uniform. In Hegel's system, this is accomplished by an introduction of the category of *being-for-itself*. This category, simply put, reflects existence of entities that are relatively stable in space in time, in spite of their constant change and multifaceted "composition." Hegel puts it this way [1], p.126:

> Existence is therefore the sphere of differentiation, of dualism, the domain of finitude. Determinateness is determinateness as such; being which is relatively, not absolutely, determined. In being-for-itself, the distinction between being and determinateness, or negation, is posited and equalized. Quality, otherness, limit, as well as reality, in-itselfness, ought, and so forth, are the incomplete configurations of negation in being which are still based on the differentiation of the two. But since in finitude negation has passed over into infinity, in the *posited* negation of negation, negation is simple self-reference and in it, therefore, the equalization with being – *absolutely determinate being*.

Only once being-for-itself is understood, can one go over to quantity. Quantity is defined by Hegel as sublated being-for-itself. In a nutshell, this means that, once being was made stable with respect to change and uniform, abstracting from its determinateness gives us just a uniform featureless continuous unity. This, according to Hegel, is *pure quantity* which does not have any magnitude yet. We can recall that energy identified by us with matter in the *form and matter* ground relation of the universal motion was precisely that – pure quantity.

If one draws a boundary (limit) in pure quantity, due to an absolutely uniform featureless nature of the latter, the boundary will be a purely external one, indifferent to pure quantity. Such a boundary represents *determinate quantity*, or *quantum*. It is that most people are accustomed two – the quantity that has magnitude, can be larger or smaller (depending on where the boundary is drawn). Hegel describes pure quantity and its transition to quantum in the following words [1], p.152:

> In the first place, we have to distinguish *pure quantity* from quantity as *deter-*

> *minate*, from *quantum*. First, pure quantity is real being-for-itself turned back into itself, with as yet no determinateness in it: a compact, infinite unity which continues itself into itself.
>
> Second, this quantity proceeds to determinateness, and this is posited in it as a determinateness that at the same time is none, is only external. Quantity becomes *quantum*. Quantum is indifferent determinateness, that is, one that transcends itself, negates itself; as this otherness of otherness, it lapses into infinite progress. Infinite quantum, however, is sublated indifferent determinateness: it is the restoration of quality.
>
> Third, quantum in qualitative form is quantitative *ratio*. Quantum transcends itself only in general; in the ratio, however, it transcends itself into its otherness, in such a way that this otherness in which it has its determination is at the same time posited, is another quantum. With this we have quantum as turned back into itself and referring to itself as into its otherness.

Determinate quantity, in order to be expressed as a number, needs to be compared to some other determinate quantity that plays the role of a unit. Thus quantum reaches its developed form as quantitative ratio, as stated in the quotation above.

One important point concerning determinate quantity that is still not fully understood by many scientists, in spite of their working with quantities on an everyday basis, is worth emphasizing here, especially because we will be relying on it in an explicit fashion. This point has to do with the **indifference** of the quantitative determinateness to being. Hegel emphasizes this indifference many times in his discussion of quantity. Thus he says in the Remark on p.153 of [1]:

> In something, its limit is as quality essentially its determinateness. However, if by limit we understand one which is quantitative and, for instance, a field alters its limit in this sense, then the field remains a field just as before. If, on the contrary, it is the qualitative limit of the field which is altered, what is altered is the determinateness that makes the field a field, and the field then becomes a meadow, a forest, and so on.

and a few lines later on the same page:

> The determination of *magnitude* as quantum just defined (as having for foundation a permanent being *which is* **indifferent** *to its determinateness*) is confirmed in every other example.

The following quotation (on the same page of [1]) is directly aimed at the misunderstanding of the true nature of determinate quantity that was present during Hegel's times and is still well and alive today.

> The definition of *magnitude* given in mathematics has likewise to do with quantum. A magnitude is normally defined as something that allows for *increase* or *decrease*. To increase, however, means to *magnify* the magnitude of something, to decrease, to *minimize* it. We have here a *difference* of magnitude as such from itself, as if it were magnitude that would allow its magnitude to alter. The definition thus proves itself to be awkward, for the very term is used in it that ought to be defined. To avoid using the same term in the definition, the *more* or *less*, the *magnifying* or *minimizing*, must be resolved into addition (an external affirmation, in keeping indeed with the nature of quantum) or subtraction (an equally external negation). The nature of *alteration* in quantum comes down in general to this *external* mode of both reality and negation. In that imperfect expression, therefore, one cannot fail to recognize the main point at issue, namely the **indifference** of the alteration: the concept of alteration itself implies its own "more and less," its **indifference** towards itself.

The indifference that Hegel insists upon so much is indeed the very definition of determinate quantity, or magnitude. The latter, to be truly indifferent to the being that underlies it (which has to reach the being-for-itself "stage"), has to be what we would call "linear" nowadays. Slightly more precisely, *an addition of the same quantity to the existing one has to have the same effect, regardless of the quantity that was already present.* Most quantities that are widely used and have gone through extensive practical trial satisfy this requirement. For example, distance is a correct determinate quantity of space: if we add 100m to the existent distance, it will increase by 100m, regardless of whether it was equal to 1km or 100km before that. In this case the "procedure" of adding 100m is straightforward and obvious (largely by virtue of being repeated billions of times before). In other cases, it might be less straightforward and then the misunderstanding Hegel referred to can take place. One can often see that, in those less straightforward cases, researchers use the expression "quantitative measure" which already hints at their uncertainty as to what the true relevant quantity is. Such quantitative measure is usually some quantity that is simply appropriately "transitive" and "monotone": whenever the (unknown) quantity of interest increases (or one "feels" that it should increase – since the true quantity is unknown), so does the number expressing the proposed "quantitative measure." The question of the nature of the true quantity (and thus the corresponding being-for-itself) involved remains unresolved and leaves a logical gap behind. In such less clear cases, the difficulty is often in identifying the correct "procedure" of adding a particular amount of the correct quantity.

Let us now review the main points in the development of the concept of determinate quantity (or quantum) in slightly more detail. In its immediacy, determinate quantity is simply number [1], p.168:

> Quantum, which *in the first instance* is quantity with a determinateness or limit in general, in its complete determinateness is *number*.

According to "The Science of Logic" (p.169), "*Amount* and *unit* constitute the *moments* of number." It is also important to note that, since determinate quantity (quantum) is a direct logical descendant of pure quantity which has no determinacies whatsoever and, in particular, no scale, the unit moment of number is purely abstract and carries no meaning. So numbers that are the subject matter of mathematics are just the corresponding amounts.[13] Nevertheless, number, according to Hegel, possesses an inherent contradiction by virtue of being something simple (and thus subject to only external relations) and, at the same time, containing a plurality of units inside of it [1], p.170:

> Number is thus a *numerical* one that is absolutely determined but which has at the same time the form of simple immediacy, and to which, therefore, the connecting reference to an other remains completely external. Further, as *numerical*, the one possesses the *determinateness* (such as consists in the *reference to other*) as a moment in it, in its *distinction of unit and amount*; and amount is itself the plurality *of the ones*, that is, this absolute exteriority is in the one itself. – This intrinsic contradiction of number or of quantum in general is the quality of quantum, and the contradiction will develop in the further determinations of this quality.

This intrinsic contradiction of number is further developed in the distinction between extensive and intensive magnitudes which are typically treated as different types in mathematics and its applications (so that any quantity can be either extensive or intensive). In Hegel's

[13] As Hegel pointed out on numerous occasions, mathematics as such knows only external relations between abstract amounts and, least of all, can in any circumstances be a model for philosophy to emulate. As he noted on p.181 of [1]:

> Essentially, however, the perversity of enlisting mathematical categories for injecting some determination into the method and the content of philosophical science shows in the fact that, inasmuch as mathematical formulas signify thoughts and conceptual distinctions, this meaning must rather first be indicated, determined and justified in philosophy.

view, they are *the same* determinacy of quantum, and in various particular cases, one of these two aspects is explicitly *posited* while the other is *in-itself* (implicit). Then, according to Hegel ([1], p.185), "with this identity, the qualitative something comes on the scene," and it is no longer possible to speak of just an abstract number (same page of [1]):

> One can speak of quantum, number as such, etc., without any mention of a something as their substrate. But the something, *self-mediated* by virtue of the negation of its determinations, now confronts these as *existing for itself*, and, since it has a quantum, it confronts them as something which has an extensive and intensive quantum.

In other words, the existence of extensive and intensive magnitudes is an expression of the intrinsic contradiction of a number mentioned earlier. Quantity in general is sublated quality, but the further logical development of quantity makes quality appear again. The sublated determinateness of quantity, "the indifferent limit, the determinateness which is just as much the negation of itself" ([1], p.189) sends quantum beyond itself, to *infinity*, by means of the famous *infinite progress* (sometimes referred to as potential infinity). The latter is still more developed expression of the inherent contradiction of determinate quantity, or of the *quantitative finite*. It is also just an expression of said contradiction, not its resolution [1], p.191:

> The *infinite progress* is now the *expression* of this contradiction, *not the resolution of it*; however, because of the continuity of one determinateness in the other, the progress gives rise to the semblance of a resolution in a union of the two.

Hegel refers to such infinite progress not brought to the resolution of the determinate quantity (i.e. determinacy of something that is fundamentally sublated determinacy) as *bad infinity*. The resolution of that contradiction however is very near [1], p.202:

> On the subject of the infinite progress as such, the only reflection which is usually made is that each quantum, however great or small, can disappear, that it must be possible to transcend it – not, however, that this sublating of the quantum, the beyond, the **bad infinite itself, also disappears**.

Finite determinate quantity therefore and bad infinity itself are just moments of their unity. The immediate meaning of the infinite progress is "*restoration of the concept of magnitude*, of being an indifferent or external limit" ([1], p.202). Magnitude is thus determined in a simple unity with itself, i.e. *qualitatively*. It does no longer have quantitative infinity outside itself, but rather within itself. That quantitative infinity is actually *qualitative* [1], p.203:

> The infinite, which in the infinite progress only has the empty meaning of a non-being, of an unattained but sought beyond, is in fact nothing other than *quality*.

It is interesting to note in this regard that, in particular, the infinities (including infinitesimals) of mathematics are also qualitative which has not been fully realized to this day. They are not determinate quantities, but, at the same time, possess quantitative determinacy (and thus can be, for example, added to numbers).

This development of the qualitative moment of determinate quantity can be summarized as follows [1], p.203:

> Quite generally: quantum is sublated quality; but quantum is infinite, it surpasses itself, is the negation of itself; this, its surpassing, is therefore *in itself* the negation of the negated quality, the restoration of it; and what is posited is that the externality, which seemed to be a beyond, is determined as quantum's *own moment*.
>
> Quantum is thus posited as repelled from itself, and with that there are two quanta which are however sublated, only moments of *one unity*, and this unity is the determinateness of quantum. – Quantum, *self-referred* as indifferent limit and hence qualitatively posited, is the *quantitative relation* or *ratio*.

Quantitative ratio is the full development of what number used to be. While number has two moments in unit and amount so that the unit is fully abstract with no meaning associated with it, in quantitative ratio, both determinate quantities involved are equally important [1], p.272:

> Unit and amount were at first the moments of quantum; now, in the ratio, in quantum as realized so far, each of its moments appears as a quantum *on its own* and as determinations of the existence of the quantum, as delimitations against the otherwise external, indifferent determinateness of magnitude.

This is what Hegel refers to as the *direct ratio*. The determinate quantity in question here is taken as the fixed given amount of the unit which is itself a determinate quantity in its own right. When the unit changes, the quantity of interest changes in the same proportion. Both determinate quantities of the ratio act as one, and the qualitative moment is still implicit. The first negation of the direct ratio relation is that of the *inverse ratio*. In the inverse ratio, the amount expressing determinate quantity of interest changes inversely to that of the unit.

In other words, a fixed determinate quantity is expressed in terms of a changing unit making the qualitative moment explicit but unchanged [1], p.274:

> In the ratio now before us, the exponent as the determining quantum is thus posited as negative towards itself as a quantum of the ratio, and hence as qualitative, as limit; the result is that the **qualitative moment distinctly comes to the fore** for itself as against the quantitative moment.

Finally, the second negation of the inverse relation (where the amount of the given unit is determined externally) yields the relation in which the amount and unit are explicitly separate as in the inverse relation and at the same time identical – the *ratio of powers* [1], p.278:

> The ratio of powers is the display of what the quantum is *implicitly in itself*; it expresses its determinateness of quantum or the *quality* by which it is distinguished from another. Quantum is *indifferent* determinateness *posited as sublated*, that is to say, determinateness as limit, one which is just as much no determinateness, which continues in its otherness and in it, therefore, remains identical with itself. Thus is quantum *posited* in the ratio of powers: its otherness, the surpassing of itself **in another quantum**, as determined through the quantum itself.

In the ratio of powers, the given determinate quantity gives rise to another determinate quantity thus also *changing the qualitative moment.* Generalizing, one can say that constructing a function of the given quantity (or several given quantities) creates a different quantity with some other quality associated with it. Examples are numerous in sciences, and especially in physics which deals with simpler forms of the universal motion.

What's not always realized however is that the quality associated with such new (determinate) quantity created by making a mathematical expression of some known (determinate) quantities *needs to be rationally understood in its own right.* Specifically, it should be possible to identify the corresponding *pure quantity* (and thus *being-for-itself*) bounding of which gives rise to that new determinate quantity. Otherwise, a formal quantity constructed externally (mathematically) might be just that: *formal*, with no quality (i.e. reality) associated with it.[14]

We can now get back to energy. The latter as originally defined is an example of pure quantity. To make it determinate, one just needs to draw a boundary in that formless unity that is energy and, slightly figuratively speaking, look at the energy within the boundary.

[14] As an example of such formal possibility, one could point out the extra six or seven dimensions of physical space discussed in String Theory.

Since the unity is completely formless, the boundary can only be external and indifferent to the unity itself. So we have an abstract determinate quantity. In order to express it with a number, one needs to compare it with some other determinate quantity that would play the role of a unit. For example, a unit can be taken to be the energy needed to heat up 1kg of water by 1K (assuming that all energy in question can acquire the form of heat). Indeed, any calorimeter does just that. As physicists say, energy is a *scalar* (i.e. a single number that is invariant with respect to a coordinate system shift and rotation). At this point of our analysis, however, we have just an abstract quantity that can be measured, if necessary, by comparing it to an external quantity chosen as a unit but yet explicitly unrelated to the characteristics of a specific motion form.

To relate this abstract quantity to a specific form of motion characteristics, we have to go to the *form and content* stage of analysis where energy is understood as *formed matter*, as opposed to simply *matter*. To find an appropriate expression for the quantity of energy "contained" in the given form of motion (i.e. mechanical motion of some concentrated mass), an understanding of this particular form is required which, in general, goes beyond a simple realization that all motion is the same at the abstract level and is therefore characterized by a single determinate quantity that does not change under form transmutations (since this is the quantity of abstract motion that is indifferent to them). Indeed, the *form and content* relation in Hegel's system goes after and is based upon that of *form and matter*. So finding a correct relation of energy quantity to the specific characteristics of motion in the given form is typically not a simple task. Historically, it required significant efforts accompanied by a lot of trial and error and often some extensive heated polemics[15] among physicists.

Now we can give a proper definition of *energy as determinate quantity* that would in particular correspond to what R.P. Feynman referred to as a "numerical quantity which does not change when something happens."

Definition 2 *Energy is the determinate quantity of abstract universal motion (i.e. energy as pure quantity) given either in some particular form or in abstraction thereof.*

One can note that energy as determinate quantity comes in two slightly different (but closely related) flavors: taken either in some form or abstractly. In the former case, one is dealing with the *form and content* logical level. In the latter, it is that of *form and matter* which

[15]Here it is interesting to note that a debate over the correct measure of mechanical motion (whether it should be proportional to mv or mv^2 and what precisely the true difference is between these two expressions) started with Descartes and Leibnitz and was still not fully settled by the time of Helmholtz. What the exact *meaning* of these expressions is – as opposed to just their *names* – is still not fully clear now, as becomes clear from R.P Feynman's admissions quoted earlier.

is immediately relevant. We see that there are three different notions of energy that can be distinguished: energy as pure quantity – the universal motion fully abstracted from form, energy as determinate quantity still taken in abstraction from form (of the universal motion), and energy as determinate quantity taken in a specific form. It is the latter notion that is used when mathematical expressions for energy are discussed. All three notions are routinely used in sciences, although the distinction is often not explicitly made. For example, when physicists talk about energy transformations being a necessary attribute of any physical process, the first notion of energy is implied. When it is claimed that 334kJ of energy (regardless of the form it originally comes in, as long as it can be used for melting that ice) is required for melting 1kg of ice, the second notion is implied. When one reads in an elementary physics textbook that the kinetic energy of a body of mass m moving with the speed of v is equal to $\frac{mv^2}{2}$, the third notion of energy is used.

Let us now use the latter example to illustrate how an expression for energy in terms of specific determinations of the particular form of the universal motion can be found. The knowledge about the mechanical form of motion that we are going to use here is that any influence in a direction *perpendicular* to the that of a motion of a mass cannot change the component of its velocity in the original direction, and that the three-dimensional space is isotropic[16] (does not have any special directions). First, it is straightforward to see (due to space isotropy) that the expression for energy has to have the form $E = mf(v)$[17] where v is the speed (i.e. the absolute value of the velocity). Our goal is to find the form of the function $f(v)$.

Let us now consider a ball of mass m moving inside a tube of negligible mass with a speed of v_1. The tube with the ball in it can freely move in the direction perpendicular to its length (and thus to the ball's motion). Another ball of the same mass moves in the same direction (perpendicular to the tube length) with a speed of v_2. The ball hits the tube in a perfectly elastic fashion[18] (so that all its energy of mechanical motion is transferred as such to the tube with the ball in it). Thus, upon the collision the tube is now moving in the direction perpendicular to its length with the speed of v_2 *regardless of the value of the speed of the ball inside* and *the speed of the ball inside is unchanged by the collision.* The two highlighted statements are essential here and follow from the assumed knowledge about the mechanical motion stated in the previous paragraph. So after the collision, the ball moves

[16]We will discuss the notion of space (along with time) in more detail in Appendix B.

[17]Here, we take it for granted that the energy has to be proportional to mass. We will say a bit more about mass later in this section.

[18]The knowledge of existence of such elastic collisions and their result also has to be taken from the assumed study of the mechanical form of motion.

with the total speed of $\sqrt{v_1^2 + v_2^2}$. Thus we obtain the following functional equation for $f(v)$:

$$f(v_1) + f(v_2) = f\left(\sqrt{v_1^2 + v_2^2}\right),$$

which holds for arbitrary values of v_1 and v_2. The only solution is $f(v) = cv^2$ where c is an arbitrary positive number. The choice of $c = 1/2$ is convenient because it makes one unit of energy ($1J$) equal to 1 $N \cdot m$ (or 1 $kg \cdot m^2/s^2$) in the SI system of units.

3.2 Matter revisited

Now that we have gone through the logical steps leading us to the rational understanding of the nature of energy, let us briefly revisit the category of matter taken in the sense used in N. Wiener's definition. It is fairly clear that, if one took all objective reality as a subject of study instead of the universal motion (of that objective reality), and went through the same steps – from the essential and the unessential through reflection and to the essentialities and the ground – one would obtain matter in place of energy – identified with *matter* at the level of *form and matter* relation of the ground. This is matter in its "pure" most abstract form. That matter is logically pure quantity. Bounding it externally and still abstractly (with no reference to the form it comes in) gives rise to matter as determinate quantity. In that case, it acquires the historic name of *mass*. Mass, still considered at the logical level of *form and matter*, has the meaning of abstract mass of everything happening to be within the chosen boundary. If one goes one logical step further – to *form and content* – matter in Wiener's definition sense would presents itself in a particular form, i.e. in a way matter always shows up in reality. One can then speak of *formed matter* which is the subject of the universal motion (as we are going to point out specifically a bit later). Mass as determinate quantity of matter then becomes just the mass of the specific object or collection of objects. One can observe that, in the case of matter as opposed to energy, there is hardly any noticeable difference between the notion of mass of the proper abstract matter (the pure quantity one) and mass of formed matter. The reason is that matter gnoseologically precedes energy (even though there have never been (formed) matter not subject to the universal motion), and therefore mass is treated – quite correctly – as a "primitive" in physics theories.[19]

Summarizing, we can now give a slightly more accurate definition of matter compared to the preliminary one presented at the beginning of this section.

[19] This obviously does not mean that mass is always measured directly in all experiments. On the contrary, it is often deduced indirectly based on measurement of other quantities. If the phenomenon under study is poorly understood (a typical situation in modern physics, for example), confusions can easily ensue. A well-known example is the notion of "relativistic mass" of the same object (i.e. fixed determinate quantity of matter) that increases only due to its speed.

Definition 3 *Matter is all objective reality taken in full abstraction from any form.*

Matter thus defined, just like energy, as we have already pointed out, is another instance of *pure quantity* – a continuous unity with no determinations. Just like the case is with energy, if pure quantity is externally bounded, a *determinate quantity* results. In case of matter, such determinate quantity has been in wide use in sciences for some time already and was given its own name: it is called **mass**. We thus have the following definition of matter taken as determinate quantity.

Definition 4 *Mass is the determinate quantity of matter if the latter is taken as pure quantity.*

As we have already noted, in contrast to matter, energy as pure quantity and energy as determinate quantity still bear the same name even though, when the term "energy" is used in sciences, it is possible to tell which energy is implied. The main reason for such terminological difference between matter and energy is, in all likelihood, the much older age of the notion of matter and the related better development of the corresponding terminology.

Now that we have a more accurate concept of matter, we can make a small but logically important correction to the whole notion of the universal motion and thus the concept of energy developed earlier in this section. When we said "the universal motion of matter," what we really meant is the universal motion of *formed matter*, i.e. the matter which is obtained at the *form and content* stage of the relation of ground. It was not the maximally abstract formless matter from the Definition 3 above. The reason is that the latter matter is simply not subject to any change – being absolute and timeless by virtue of the highest level of abstraction used in its definition. In particular, the standard fundamental notion of matter typically used in both philosophy and sciences also corresponds to that *formed matter* obtained at the level of *form and content*.

Here it is also worth mentioning that, in our experience, logical steps that lead to an identification of essence of a subject become the more straightforward the more general the subject is. This effect appears to us to be of general significance. Indeed, for a very general "all-inclusive" subject, one doesn't have to – figurately speaking – "extract" it from the rest of the universe thus cutting its ties to it and, consequently, creating the need to figure out what "boundary conditions" to put in place of the severed ties. In particular, the correct beginning of a logical analysis of a less general subject becomes less obvious, possibly causing mistakes in that regard which can easily lead the whole analysis along a wrong path.

4 Information

Now that we have clarified the question of the nature of energy, let us – recalling N. Wiener's negative but very insightful definition – go back to (formed) matter and reflect on what other fundamental attributes it has, besides the universal motion. It does not take long to realize that it is the **universal bond** that is commonly expressed by stating that everything is related to everything else in the universe. The universal bond and universal motion attributes of matter are clearly not independent but rather both expressions of the **unity in multitude** which our universe is. Figuratively speaking, one could say that the universal motion is an "immediate" and the universal bond is a "mediated" expression of the unity in multitude.

Let us take a closer look at the universal bond. At the level of individual relatively self-subsistent stable entities, a collection of which the world appears to be on its surface (that is the multitude which is immediate), the universal bond shows itself as a multitude of "imprints" that various material (and possibly ideal[20]) entities (i.e. various instances of formed matter) leave on each other as a result of their interaction. So each material entity represents itself *materially* and other entities *ideally*. That representation comes in many different material forms: from molecules and photons in the air to letters on paper and bits in computer memory. All these material objects are carriers of such "imprints" of other material objects or processes. For example, a group of photons represents itself materially but also represents the Sun where it originated and the tree from which it reflected ideally. Somebody who receives this group of photons can see the tree from which they reflected by the naked eye and can also learn about nuclear reactions on the Sun by analyzing them appropriately.

We wish to consider the dynamics of such ideal representation. An "imprint" of some entity left on some other entity always comes in a particular form related to qualities of that second entity: from molecules and photons in the air to letters on paper and miniature semiconductor transistors in flash memory. Let us take this ideal representation as our subject of study and go through the logical steps described in Section I of the "Doctrine of Essence." Just like in the previous section, these logical steps are rather straightforward due to extreme generality of our subject of study.

<u>1A. The essential and the unessential</u>. Just like we did in the previous section, here we just point out that the essence of our subject does not coincide with its immediacy. In the ideal representation taken as a whole, something is essential and something is unessential.

[20]We will explain this point a bit later in this section, when the general definition of information is presented.

1B. Shine. Here we note that essence is not simply different from the immediate being of our subject but is negatively defined by it. The essence shines through the surface everywhere such ideal representation of one entity by another takes place.

1C. Reflection. Recall that reflection, in the sense used by Hegel, is not a subjective act of thinking but an objective motion of the subject itself. In our case, this is rather obvious. An ideal image of an entity A can (and does) get imprinted in another one B but then also in C, D etc. (very similar to copying some music pieces from a vinyl disc to a magnetic tape, then to a CD, flash drive etc.). As the universal motion takes place, such imprints follow in large quantities. Let us now take a look at the specific reflection forms.

a) *Positing reflection.* Just like in the previous section, positing reflection is the motion of *negation.* The subject, in its own motion, negates itself. Indeed, any "imprint" of one entity in another, taken as is, in its specific form related to qualities of the second entity, is bound to disappear as such, in the course of the universal motion of (formed) matter. On the other hand, it is bound to reappear in some other form somewhere, in the course of the same universal motion, just to disappear again. That negation is constant, particular forms of ideal representation are fleeting and constantly disappearing. We have Hegel's "movement of **the nothing to the nothing**, and thus negation coinciding with itself" clearly present here.

b) *External reflection.* Positing reflection unavoidably has an external moment to it: that constant negation has to negate something. That something is, in our case, an ideal representation *in some particular form.* It's that whole form – in all its details – that's going to be negated by the positing reflection, due to extreme generality of our subject of study.

c) *Determining reflection.* Recall that determining reflection is understood as a unity of positing and external reflections. In our case, determining reflection begins with an ideal representation in any form and keeps negating all forms, finding its subsistence in that self-equality of total form negation.

2A. Identity. The identity of essence is the same as self-identity of the determining reflection. The latter keeps negating all forms of ideal representation of (formed) matter by itself (where all material entities leave ideal "imprints" on others). But the representation itself, taken as a whole, perseveres through that constant change of forms. So all possible instances of the representation become identical to each other in this negative sense.

2B. Difference. Identity just discussed necessarily has a moment of difference in it simply since, without such moment, there would be no motion in the subject. All forms of ideal representation are *essentially identical*, but different at the same time. For example, if one copies the content of one flash drive to another one, the two copies are still different simply because the two flash drives are distinct from each other. The difference we are discussing here is just simple difference, without any further specifications.

a) *Diversity.* Difference which is at first just a simple difference, a difference with no determinations, is, most immediately, a difference "in some regard," i.e. difference determined externally. In our case, due to the utmost generality of the subject of interest, that external consideration has to do with the form of representation, taken in its totality. Thus ideal representations, while being identical as such, are different in regard to their form.

b) *Opposition.* As has been discussed before, diversity with its two moments – likeness and unlikeness – is an external comparison that takes place outside of the entities being compared, in something third. These two moments are indifferent to each other only in abstraction and, upon closer examination, each of them turns out to have the other moment inside of itself. In our present case, the *positive* (that is likeness reflected on itself) is the ideal representation as such, taken in its self-identity. The *negative*, on the other hand, is pure change of its form. The moment of negative in the positive is the change that takes place in the self-identical ideal representation – we always keep in mind that the latter is in constant motion so has to have a moment of change despite being self-identical. The moment of positive in the negative is – on the other hand – constancy in the change. We keep in mind – and it is objectively so – that the concentrated change that is the negative takes place in something constant. (Otherwise, there would be no reason to speak of change in the first place.)

2C. Contradiction. Just like in the previous section, contradiction is, most immediately, unity (or, as Hegel mentions a few times, rather "inseparability") of the opposite. Contradiction gets resolved into something. As we have discussed, that something can be the null or not. Resolution into the null is always present and represents just a motion of the subject of study. In our case, that is the ever-changing ideal representation. The other resolution "mode" – resolution into a higher sphere – may be present in some cases. Then it is a very interesting and important question as to what this higher sphere is. In our case, due to the utmost generality of the subject of study, such higher sphere, in our opinion, either does not exist or is completely unknown to us at present time. The situation is very similar to that with the universal motion of matter considered in the previous section.

3A. Absolute Ground. The absolute (simple) ground, as we know, is the same as essence, but essence taken in its self-identity and self-subsistence, looked upon as a basis for the immediate, as opposed to the other way around (i.e. how the process of arriving at the essence by considering the self-negating dynamics of the immediate looked like). Ground, as Hegel puts it, "contains reflection as sublated reflection." In our case, absolute ground as such is just the ideal representation that is identical to self and absolutely self-subsistent, giving rise to the totality of its various forms.

Form and essence. This is the first relation of simple ground. At this level, we note that the essence taken as a self-subsistent entity always comes in some form and, on the other hand, form is always "attached" to essence. So form and essence are one and the same, but distinct at the same time. We have the ideal representation as such and its particular forms as being inseparable but distinct nevertheless. In this sense, form and essence has a contradiction inherent to it, the resolution of which gives rise to *form and matter*.

Form and matter. Since form and essence are distinct, we can consider an abstraction in which essence gets separated from the totality of its form determinations. Such a formless essence is known as matter. The only determination it has left is that it's self-equal and self-subsistent. In this abstraction, form is considered to be separate from matter and to have its determinations on matter. In our case, matter is therefore simply the ideal representation devoid of any particular form. It is what has become known as *information* in its most abstract sense. We therefore arrive at the following general all-inclusive definition of information.

Definition 5 *Information is the self-representation of (formed) matter taken in full abstraction from its material form.*

It is important to note that, in the definition above, matter that is being represented in itself (so that typically any material entity is represented ideally by some other entities) is taken not as formless matter (i.e. matter as such) but matter endowed with all form determinations. One obtains information when one takes that representation and "strips" all the material form of the *representing* entity from it while form determinations of the *represented* entity are retained in the resulting ideal image.

Also, for the sake of clarity, it is worth noting that, if one takes a particular pair of entities – a representing one and the corresponding represented – it is possible for the latter one to already be of the ideal variety. Such cases are especially commonplace – and even prevalent – in the sphere of human activity. The latter form of the universal motion is a rather developed one and, by virtue of such advanced status, has a developed ideal moment that also plays an active role. We will discuss these matters in a bit more detail when we address the issue of semantic information later in this section. In the proverbial unicorn painting example, the represented entity – the unicorn itself – is a product of the painter's imagination, i.e. an ideal entity. The painter in question is a subject (and object, at the same time) of the totality of human practice which – as a (meta)-form of the universal motion – plays the role of a universal "integrator" of all other forms. So, in particular, the unicorn created by his imagination is a product of human practice (with its material and ideal moments and their rather complicated interplay), and, in this particular example, a rather transparent ideal expression of the latter's material transformative powers. As a side remark, we can also point out that this advanced status of human practice – with its developed ideal moment and multiple "back and forth" between its material and ideal sides – makes it difficult to grasp the true nature of information by means of the standard method of empiricism consisting of external ad hoc generalization of specific examples of the phenomenon of interest. For the case of information, in particular, examples that first come to mind belong to the sphere of human practice and thereby belong to the especially complicated variety. In that variety, the formed *matter self-representation* is almost always *heavily mediated* by the totality of human practice and its relatively independent ideal side which makes it especially difficult to see from the empirical standpoint.

So we see that, logically speaking, energy and information (and matter for that matter) are indeed very similar, as was already anticipated by N. Wiener. They all – including matter – appear at the *form and matter* stage of the essence analysis of the corresponding subject and are each identified with *matter* from that logical pair. All three of them are of utmost generality, as is also implied by Wiener's definition. All three are also equally and highly abstract as seen from our discussion. Among the three, matter appears to be the most fundamental one as one can't even think about energy and information without discussing matter first. On the other hand, one can be also justified in saying that, just like there can be no energy and information without matter, there can be no matter without energy and information. Indeed, as all our experience without a single exception indicates, there is no single bit of matter not subject to the universal motion and part of the universal bond. By virtue of the universality of the latter two moments of unity of matter, each of them is a unity in its own right and can be rightfully considered in abstraction from the totality of its form thus giving us the concepts of energy and information, respectively.

Once we have obtained the general definition of information, let us briefly comment on the logical path that has led us to it. One interesting moment that was mentioned a couple of times already is that, just like the case was with energy, the logical path of determining the essence of a subject and following it through up to the level of simple ground[21] turned out to be especially simple here owing to the extreme generality of each of our subjects of study. As a consequence of this, one can easily give a brief simple summary of any of these logical derivations.

Let us begin with energy as it is a bit simpler. We start with the universal motion of

[21]The full study of essence includes, in addition to this, the whole path of an ascent from the abstract to the concrete that involves considering the logical spheres of appearance and actuality, some of which we will do for information later in this article.

(formed) matter. That motion is known to change forms – to disappear in some particular form just to reappear in a different form: if it had not been so, one would not have even been able to talk sensibly about change of form. This tells us that there is something there that stays intact behind form change. This something can only be the universal motion as such, taken in abstraction from any form. Being totally formless, it can have only one characteristic – its total quantity. That formless motion or its quantity is what has been know as energy for the last couple of centuries. Due to the generality of the subject matter, many of logical steps we went through are very similar to each other.

In case of information, the logic is almost the same with one small difference. While, as we know, if some "piece" of the universal motion taking place in some form disappears as such, it is bound to reappear in some other form (or multiple forms). It will be literally the same "piece" of the universal motion in a different guise. The law of energy conservation is just a statement of this fact. On the other hand, if (some aspect of) a material (or ideal) entity A is ideally represented in a material entity B, and this representation disappears as such, we cannot, to the best of our knowledge, be sure that the same representation is going to reappear in some other material form. For example, if an ornithologist has a flash memory stick in his pocket with pictures of rare birds he saw during his latest trip to Amazonia and accidentally drops the stick into a bonfire during a university picnic, the flash memory ideal imprints of those birds are not at all guaranteed to be kept intact in some other form. As far as we know, it is entirely possible that they simply disappear as such (ideal imprints of birds regardless of their material form). Correspondingly, there has not been discovered any kind of an information conservation law, similar to energy conservation. Rather, constant disappearance and reappearance of ideal imprints of material entities takes place at the level of the ideal representation of matter in itself *taken as a whole*, with no "detailed balance" of any sort – like in the case of the universal motion or (formed) matter itself – present. This seems to be one of the fundamental attributes of *the ideal* in general, as opposed to *the material*. Later, we will see more of it when we tackle the question of information quantity.

With this difference kept in mind, the rest of the logic that leads us to the notion of information is identical to that leading to energy. Indeed, the constant disappearance and reappearance of particular forms of the ideal representation of (formed) matter by itself leads us to the realization of a presence of some essential identity behind this multitude of forms. That identity is the essence of ideal representation in various material forms and the only thing it can be is that ideal representation itself taken as a whole. First, we arrive at it by analyzing its forms that are given in the immediate. Then, remembering that there is always unity in multitude, – that is more fundamental than the immediate multitude itself – we realize that the essence is actually ground for the immediate, i.e. the multitude of specific material forms of mutual representation (perhaps mediated) of material entities. Most immediately, essence and form are inseparable, but still distinct. The abstraction in which we separate essence from all form (so that essence becomes matter) is justified by virtue of constant transmutation of forms. The following quotation from p.392 of [1] was given before but is worth presenting again due to its utmost importance:

> If abstraction is made from every determination, from every form of a something, matter is what is left over. Matter is the absolutely *abstract*. (One cannot see, feel, etc. matter; what one sees or feels is a *determinate matter*, that is, a unity of matter and form.) This abstraction from which matter derives is not, however, an *external* removal and sublation of form; it is rather the form itself which, as we have just seen, reduces itself by virtue of itself to this simple identity.

Another quotation (from p.385 of [1]) that was given before very briefly summarizes rather well how unity is discovered in any multitude and how its self-subsistence is ascertained. This, in a nutshell, is precisely the logic that has to be used to understand the true nature of both energy and information.

> In customary inference, the *being* of the finite appears to be the ground of the absolute; because the finite *is*, the absolute *is*. But the truth is that the absolute is because the finite is the immanently self-contradictory opposition, because it is *not*. In the former meaning, the conclusion is that "the *being* of the finite is the *being* of the absolute"; but in the latter, that "the *non-being* of the finite is the *being* of the absolute."

4.1 Information quality and quantity: syntactic information

We have seen that a concept of all three members of N. Wiener's triad – matter, energy and information – can be obtained by considering the essence of, respectively, all objective reality, its universal motion and its ideal self-representation. The respective concepts come into their own at the *form and matter* logical stage of the respective essence analyses.

Matter and energy, when identified with *matter* of the *form and matter* relation, lose all determinations of the corresponding subject (since these determinations all get attributed to *form*) and become featureless uniform unities (pure quantities). Thus the only characteristic that can be assigned to them is an external determinate quantity.[22] On the other hand,

[22]These external determinate quantities are, respectively, mass and the value of energy.

information, even though identified with *matter* as well, still has determinations of the "first member" of the "binary" relation that is the ideal representation, the essence of which gives rise to information. More specifically, suppose one is interested in how entity A is represented by entity B. So when we "strip" all the specific form of this representation that has to do with various determinations pertaining to entity B to "distill" it to information, the resulting information still has to carry those pertaining to entity A. It is information "about A" after all. In our view, this is one of the reasons for the concept of information being rather elusive: information – being an essence – is not given in the immediate; what one can see there is information *in some form* that sometimes (but not always) can be called "data."[23]

4.1.1 Information contradictions and their resolution: its ideal universal form, aka probability distribution

So information proper, as we see, presents us with a contradiction: it is obtained as a complete abstraction from any form determinations of the representing entity B but, at the same time, it still has to contain the form determinations of the represented entity A. But the problem is that the form determinations of entity A are represented precisely via those of entity B. This implies that *information has to have some form and not have any form at the same time.* As we will see shortly, this is not the only contradiction related to the elusive information. What is remarkable though is that these contradictions did get resolved in practice without an explicit realization of what was happening. The downside of such a trial-and-error process is that it takes significant time and still does not bring full understanding – thereby often holding back future progress.

Let us see how this contradiction of information can be resolved. Since information is, logically speaking, *matter* that is opposed to *form*, it has to be form-free, completely devoid of the representing entity's form, i.e. ***uni****form*, but, at the same time it has to contain in itself all form of the represented entity. The only way to satisfy these contradicting requirements is to endow it with a ***uni****versal form* that can accept any content and, being universal, has nothing to do with any particular entity's (entity B's in this case) specific qualities and quantities.

"The Science of Logic" does not discuss such a universal form explicitly, but we still can obtain very useful hints from it. First of all, such universal form has to be able to represent all possible characteristics (determinations) of the represented entity. This includes both qualitative and quantitative characteristics. Measure, in Hegel's system, is a unity of quality

[23]This is likely the fundamental reason for many attempts to define information by identifying it with data in some way.

and quantity; thus a universal form we are looking for has to be most closely related to a characterization of the immediate at the level of measure. Measure, as Hegel argues, is the last stage of the logical "evolution" of the immediate before it negates itself and passes over into essence.

Qualitative and quantitative determinateness of the immediate, as shown in Section III "Measure" of "The Doctrine of Being," transition into each other as the being undergoes changes [1], p.323:

> The transition of the qualitative, of one specific concrete existence into another, is such that what happens is only an alteration of magnitude determinateness; the alteration of the qualitative as such into the qualitative is thus posited as an external and indifferent alteration, as a *coming together with itself*; the quantitative, for its part, sublates itself by suddenly turning into the qualitative, that is, a being which is determined in-and-for-itself. This unity which thus continues in itself in its alternating measures is the self-subsistent *matter* that truly persists, the *fact*.

Thus, even before the immediate passes over into essence by negating is determinateness, it becomes clear, by means of the constant change of "the surface of things," that every finite entity is just a particular state of some underlying infinite substrate [1], p.324:

> In measure, the persisting matter is itself already in itself the unity of the qualitative and the quantitative – the two moments into which the general sphere of being is distinguished, each as the beyond of the other; in this way the perennial substrate begins to possess in it the determination of an existent infinity.

and, further, on p.325:

> Such relations are now determined only as nodes of one and the same substrate. The measures and the self-subsistent forms posited with them are consequently demoted to *states*. Alteration is only the mutation of a *state*, and *that which passes over* is posited as remaining *the same* in the mutation.

In the beginning of chapter 3 "The becoming of essence" of Section III of the "Doctrine of Being," Hegel summarizes the the "evolution" of being before its transition to essence in the following words [1], p.326:

> The indifference which can be called absolute, however, is one which, *through the negation* of every determinateness of being, of quality and quantity and of

> their at first immediate unity, that is, of measure, *mediates itself with itself* to form a simple unity. Determinateness is in it still only a state, that is, *something qualitative and external* which has the indifference as a *substrate*.

Thus a proper universal (same for all represented entities) form of information will involve images of all possible states with some determinatenesses pertaining to them. The number of possible states will then depend on the particular aspect of the represented entity A one is interested[24] in. For example, a digital picture of an apple in 8-bit color will in principle contain color-related information requiring 256^n states, where n is the number of pixels in the apple image. On the other hand, if what matters is whether the apple as a whole is green, yellow, or red, the respective number of states is just 3.

To see what these determinatenesses can be, let us consider the natural dynamics of this particular "piece" of information (i.e. reflecting some particular aspect of entity A). As the information changes, the determinatenesses pertaining to images of different states change as well. While changing, they remain just determinatenesses of state images. This is their *identity*. On the other hand, since they can change they have to be different. This *difference* first appears as *diversity*, and then develops into *opposition*. The former is just the difference in how the state images reflect the actual state of entity A. The latter has two moments – the *positive* and the *negative*. The positive is, as we know, self-equality reflected on itself. And the negative is the opposite of that – the "concentrated" difference. In the present case, the positive is simply the full "match" between the actual state and the corresponding image – what is known as "true" value in standard Boolean logic. The negative corresponds, respectively, to the Boolean "false" value.[25]

We see that, if one represents information in the universal form by assigning a "true" value to one of the sates and "false" to the rest of them, the information obtained in such a way is always *complete* as far as the given aspect of the represented entity is concerned (in our last example, the predominant color of the whole apple). This conclusion stands regardless of which state is assigned the "true" value. This implies that, in order to represent *incomplete* information, there has to be at least one state to which neither "true" nor "false" value can be assigned in the universal form. We therefore arrive at the *contradiction* level of analysis. It can be called the *second contradiction of information* we have encountered. This contradiction can be stated by saying that there has to be at least one state to which *a truth-*

[24]This sounds quite "subjective" and may easily conjure up a picture of some indispensable "agent" solving a practical problem. We will discuss the issues pertaining to information objectivity later in this article.

[25]Later in this article, we will discuss the issue of objectivity and subjectivity of information and its universal form determinations.

related image value has to be assigned that can be neither "true" nor "false." Not surprisingly, this second contradiction has also been resolved in the course of the corresponding practice, even though it took considerable time, and full understanding of what exactly had been done has not been achieved yet, to the best of our knowledge.

Let us see how this contradiction can be resolved in a organized fashion. Contradiction, most immediately, is an indivisible unity of the positive and the negative. In our case this amounts to a determinateness of a particular state image in the information universal form that is "true" and "false" at the same time. This means that the corresponding determinateness has to be of the same quality as "true" and "false" but not identical to either of them. Also, it has to be able to change while maintaining the same quality. The only way to achieve the latter, as we know, is to let the change be indifferent to quality, i.e. *quantitative*. We thus arrive at a (single) quantitative determinateness of each state image in the universal form. To make it more specific for the purpose of further discussion, let us denote this newfound quantitative determinateness of the state image s_i, $i = 1, \ldots, n$, by $p(s_i|I)$, where I stands for the information available prior[26] to obtaining the new one.

As we have discussed earlier, a specific quantity, or a quantity of a given quality, in order to be such, has to possess appropriate indifference to a boundary, or additivity, in a more modern language. In other words, if an appropriate procedure of adding a given amount of such quantity is applied, the result of such addition cannot depend on the amount present in the beginning. To see what such additivity implies in the present case, suppose the two states s_i and s_j were originally thought to be different but turned out to be the same state. Then this new single state can be identified, using Boolean algebra notation, with $s_i \vee s_j$ (i.e. s_i OR s_j). On the other hand, in that case, the "partial truth" quantity $p(\cdot|I)$ will clearly have to be added regardless of the particular values. Thus we have

$$p(s_i \vee s_j|I) = p(s_i|I) + p(s_j|I), \tag{1}$$

for arbitrary values of $p(s_i|I)$ and $p(s_j|I)$. In equation (1), one readily recognizes the sum rule for probabilities of mutually exclusive "events." It follows from (1) that the "partial truth" quantity for a "false" state image has to be set to 0, and that for a "true" one to some positive value. The latter has to be a specific determinate quantity, i.e. a certain number of some other determinate quantity chosen as unit. But in this case, there is no such quantity that is external to the given one. Thus the only choice we have for a unit is this determinate quantity itself (or a fraction thereof). It is natural – and proves to be more convenient – to use the whole quantity. So the "true" value of s_i corresponds to $p(s_i|I) = 1$.

[26] As we will discuss a bit later, information has interesting characteristics that require care for accounting for them correctly.

Now suppose the entity A has two overlapping sets of states s_i, $i = 1, \ldots, n$ and r_j, $j = 1, \ldots, m$. For example, an apple can have a certain color and size, so one can obtain information about its color first and then – if necessary – about its size. Consider the "compound" states $s_j \wedge r_j$ (an apple characterized by a color AND a size in our simple minded example). We want to derive a rule for the "partial truth" quantities for such compound states. Let $p(r_j|s_i, I)$ be such conditional quantity for r_j under the assumption that the state s_i is already known to be the actual one (so that s_i becomes an additional "piece" of the prior information, in addition to I). First, it is clear that $p(s_i \wedge r_j|I)$ has to depend on $p(r_j|s_i, I)$. Let us denote this dependence by $f(\cdot)$:

$$p(s_i \wedge r_j|I) = f\left(p(r_j|s_i, I)\right), \tag{2}$$

where the function $f(\cdot)$ is allowed to include arbitrary parameters. Applying the dependence rule (2) to the state $s_i \wedge (r_j \vee r_k)$ we obtain

$$p(s_i \wedge (r_j \vee r_k)|I) = f\left(p(r_j \vee r_k|s_i, I)\right). \tag{3}$$

But, on the other hand, due to sum rule,

$$p(r_j|s_i, I) + p(r_k|s_i, I) = p(r_j \vee r_k|s_i, I). \tag{4}$$

Using the dependence rule (2) in the LHS of (3) and the sum rule (4) in the RHS of it, we obtain:

$$f\left(p(r_j \vee r_k|s_i, I)\right) = f\left(p(r_j|s_i, I) + p(r_k|s_i, I)\right). \tag{5}$$

Denoting $p(r_j|s_i, I)$ by x and $p(r_k|s_i, I)$ by y (which implies that $p(r_j \vee r_k|s_i, I) = x + y$ by virtue of the sum rule (4)), we can now rewrite (5) as

$$f(x + y) = f(x) + f(y), \tag{6}$$

an equation for $f(\cdot)$ that holds for arbitrary non-negative x and y. The only solution of this functional equation (6) is $f(x) = Cx$ where C is some constant that itself can depend on quantities other than $p(r_j|s_i, I)$. So (2) takes the form

$$p(s_i \wedge r_j|I) = Cp(r_j|s_i, I). \tag{7}$$

To determine the value of C in (7), suppose that s_i implies r_j (in the usual formal logic sense). Then (7) reduces to simply $p(s_i|I) = C$ thus determining the value of C and yielding the easily recognizable product rule for probabilities:

$$p(s_i \wedge r_j|I) = p(s_i|I)p(r_j|s_i, I). \tag{8}$$

We see that the quantities $p(\cdot|I)$ are identical to probabilities. We can summarize these findings by stating that (a particular instance of) **information in its universal form is a probability distribution**.

The above statement can be turned around to claim that, most fundamentally, **any probability distribution is some information in the universal form**. Also, it has to be emphasized that the universal form of information is of purely ideal nature. Indeed, all material form has been abstracted away in the course of arriving at information as such. The latter is purely ideal, and the universal form, being a form of *information* – as opposed to that of (formed) matter self-representation – can be nothing but ideal as well.

Before continuing to the next topic, let us establish an important result that will be needed later. Suppose a certain quantity (its nature being unimportant at this point) has different values in different states of the entity represented by some universal form. Let us denote its value in state s_i by v_i. We are interested in the value that should be assigned to this quantity under the condition of incomplete information described by a probability distribution $\{p(s_i|I)\}$. First, note that such value should be "local," i.e. a change in one or several values v_i should affect the overall only by means of contributions confined to the corresponding states. This leads us to an expression of the form $v = \sum_{i=1}^{n} f(v_i, p(s_i|I))$, where $f(\cdot,\cdot)$ is some function of two arguments. Then, obviously, the function f should be linear in v_i since the value we are looking for is the be the value *of the same quantity.* This leads to the general form of $v = \sum_{i=1}^{n} v_i g(p(s_i|I))$ where $g(\cdot)$ is a function of a single argument. Finally, if the value v_i increases by the same amount δv *for all* states s_i then, obviously, the resulting overall value v should increase by that very amount δv. This leads to the condition $\sum_{i=1}^{n} g(p(s_i|I)) = 1$ valid for *arbitrary* values of $p(s_i|I)$. This is only possible if $g(x) = x$ and we obtain the following result

$$v = \sum_{i=1}^{n} v_i p(s_i|I), \tag{9}$$

in which everyone immediately recognizes the standard *expected value* of probability theory and usually denoted $\mathbb{E}_p[v]$, where the subscript p is used to indicate the probability distribution with respect to which the expectation is evaluated.

4.1.2 Form and matter II: abstract information, its universal form and quantity; Kolmogorov complexity as an expression of the latter

Information as it was defined earlier is not – unlike energy – a featureless continuity completely devoid of any determinations. On the contrary, it carries the qualitative and quantitative determinations of the entity A it ideally represents. As we have discussed, in order to resolve the contradiction of information being abstracted from any form of the representing entity B but still carrying determinations of A, a *universal form*, i.e. a form that is not specific to any particular entity A, was introduced and foind to be identical to a probability distribution. A rather obvious question that comes to mind at this point is whether one could meaningfully abstract further from the determinations of the represented entity A expressed via the universal form and obtain another *pure quantity* (in Hegel's terminology), logically similar to energy and matter. To determine if such an abstraction makes sense, let us turn to objective reality and see if the dynamics of information produces such an abstraction by negating determinations of represented material entities.

Indeed, before information is actualized, i.e. is used as such with some (material) effect, it is simply either is found moving in space or accumulating in some location. That happens both in nature and in human activity[27] (i.e. "the broader nature"). While information – always in some material form – travels in space or accumulates in some physical location, its "content," i.e. the specific determinations of the entity A being represented by it, becomes irrelevant (meaning that it does not have any material effect – think about a tree stump with all rings in place while nobody is looking at it). This appears to be the nature's way of negating the determinations of the represented material entity in information. In human practice, we are very well familiar with such negation which happens every time information is transmitted or stored in any form: from libraries and Morse code communications to large scale server memory and high speed fiber optics enabling the internet.

When determinations of the represented material entity are negated, what is left is **abstract information** which now is what Hegel referred to as *pure quantity*, i.e a featureless continuity that can be bounded to arrive at a single determinate quantity. Such a determinate quantity in this case would be the determinate quantity of abstract information. To obtain such determinate quantity and express it as a magnitude, one needs to find another determinate quantity of the same quality external to the quantity in question, to use as a unit. Going back to the analogy with energy that was mentioned earlier, we see that what we have here is very similar. In the case of energy, that external determinate quantity can be, for instance, the quantity of energy needed to heat up 1kg (or any other mass determined by convention) of water by 1K. Information, however, is purely ideal and this distinguishing feature of it gives rise to a natural unit that was absent in the case of energy. Abstract information cannot be incomplete since – being abstract – it has no particular content. One can say that abstract information is just *pure distinction as such.* Rephrasing a well-known

[27]It is the latter sort of instances of information transmission and storage that everyone is readily familiar with, but numerous examples of the former can easily be found. Just think about any kind of so called ecological information.

facetious definition[28] of information given by a prominent specialist in machine learning D. MacKay, one can say that abstract information is a distinction that does not yet make a difference, just a distinction in its purest and self-sufficient form. The most basic distinction is a distinction between *two* states (or any two things whose nature is irrelevant). Thus the basic – smallest – unit of abstract information just has to indicate which one of the two is the actual one. We arrive at the well-known and famous “bit” of computer and information sciences which can be, without any loss of generality, written as either 0 or 1.

So any “piece” of abstract information can be represented as a collection, or “string,” of 0’s and 1’s. Suppose we are given such a string of length n. Does it represent n bits worth of abstract information? Take, for example, a very long (i.e. very large value of n) string of 0’s only. Clearly, the abstract information content of such a string should be a lot less than n bits. Roughly speaking, all zeros – no matter how many – simply do not represent a lot of distinction. Putting it slightly differently, it should be straightforward to “compress” such a string by a large amount, i.e to replace it by a much shorter string that allows a full recovery of the original string with the help of some simple instructions. In this extreme example, the length of an appropriately compressed version of the original string should not be much more than the number of bits needed to express the length n. Take a less extreme example of a long string consisting of 90% zeros and 10% ones. It is clear that any string like that will have some uninterrupted stretches of zeros of at least moderate length (of at least around 10) throughout its whole length of n symbols. This means that the total amount of “pure distinction” (i.e. abstract information) in such a string is still significantly less than n bits meaning that it should be possible to compress it to a smaller size.

The notion of *algorithmic complexity* that was later named *Kolmogorov complexity* [8] was introduced by A.N. Kolmogorov in the course of developing a new approach (along with existing combinatorial and probabilistic ones) to – in the words of the author himself – “quantitative definition of ‘information.’ ” It is interesting to note that the word “information” was put in quotation marks by Kolmogorov, most likely indicating an acknowledgement of vagueness of the notion of information that was available at the time of writing. Kolmogorov complexity of a binary string is defined as the length of a shortest “program” implemented on a “universal computer” (universal partially recursive function in the original version of [8]) that would result in the computer outputting the given string and stopping. The length of such a program (disregarding the necessary “overhead” of fixed size) clearly cannot exceed the length n of the original string but, for some strings (like strings discussed in the examples above), can be much smaller than n. Such shortest program is nothing else but the maximally compressed version of the original string – the version of it

[28]That definition states that “Information is a distinction that makes a difference.”

that has all redundancy removed and the "pure distinction" contained in the original string coming to the surface. Thus we have, in Kolmogorov complexity $K(x)$, nothing else but the *quantity of abstract information* contained in the given string x.

It turned out that Kolmogorov complexity $K(x)$ is very difficult to compute even for something as simple as a binary string. The reason is the so called halting problem which implies that it is impossible to decide whether any given computer program is going to halt. However it is rather straightforward to show that (see Chapter 7 of [9], for example) that $K(x)$ is bounded from above by the expression $nH_0\left(\frac{k}{n}\right) + 2\log n + c$, where n is the string length, k is the number of zeros in the string and c is some constant, and $H_0(p) = -p\log p - (1-p)\log(1-p)$ is the binary Shannon entropy. For long strings, the last two terms in the above expression become negligible, and the upper bound approaches simply $nH_0\left(\frac{k}{n}\right)$ that is equal to n only when $k = n/2$, i.e. when the string x has equal number of zeros and ones. This implies that any binary string of length n for which $K(x) \approx n$ (up to the "overhead") have to have an (approximately) equal number of zeros and ones. Such strings are known as *incompressible*, or *random.* For incompressible strings, the corresponding quantity of abstract information is (approximately) equal to their length.

It is therefore possible to say that a universal form of abstract information is *an incompressible (random) string of symbols.* In particular, if one chose the smallest possible – i.e. *binary* – symbol set for expressing abstract information, one would arrive at the abstract information in the *simplest universal form* that allows for an expression of the smallest discrete "piece" of abstract information – a bit, or the simplest elementary distinction. It is also worthy of note that the resulting universal form of abstract information can be thought of (or arrived at) as a result of *a resolution of a contradiction* that is inherent to the abstract information itself. Indeed, abstract information is, on one hand, a *pure quantity* (in Hegel's terminology), i.e. a formless continuity without any determinations so that the only determination it can have is that or determinate quantity arising by bounding such continuity in an external fashion. On the other hand, abstract information is still information – a purely ideal entity that by its very definition carries determinations of some other material entities. So abstract information is a contradiction: as *abstract* information, it can have no determinations besides an overall quantity, but as abstract *information*, it has to carry some determinations – proportionally to its determinate quantity. The resolution, as we see, is a *random binary string* – a string that has no "structure" – and thus is *uniform and featureless* – but that does not allow a shorter description and thus represents *pure distinction* as such.

This however is not quite the whole story of abstract information universal form. We have seen how to represent a determinate quantity of abstract information equal to a whole number of bits. Put slightly differently, in a random string of bits, the discrete moment of the determinate quantity of abstract information is expressed. But what about its continuous moment? Thus the question that remains is how one can express a *fractional* determinate quantity of abstract information in a universal form. Clearly, to answer this question, it would be sufficient to understand how a fractional quantity of less than one bit looks like in the simplest universal form. Our experience with incomplete (specific) information gives a rather obvious hint: abstract information determinate quantity smaller than one bit can be understood as *incomplete information about one bit*. Since, as we know, incomplete information is expressed by a probability distribution, we would need two probabilities of the bit being equal to, respectively, 0 and 1: $p_0 + p_1 = 1$. Clearly, if either $p_0 = 1$ or $p_1 = 1$, the information about that bit is complete and its determinate quantity is equal to exactly one bit. Question is what distribution would correspond to zero determinate quantity. A simple symmetry consideration suggests the midpoint: $p_0 = p_1 = \frac{1}{2}$. We will revisit this issue later, but this seems to be the correct answer. So, putting everything together, we arrive at the **simplest universal form of abstract information** of arbitrary determinate quantity: **a random binary string with one uncertain bit**.

4.1.3 Form and content II: abstract quantity of specific information, aka Kullback-Liebler divergence

Let us quickly summarize the logical path we have followed in our analysis of information. The starting point was the *universal bond* present in all of (formed) matter that has as its immediate consequence an *ideal self-representation* of matter in which different material entities (relatively isolated instances of formed matter) ideally represent each other. A consideration of the dynamics of such self-representation (or its reflexive motion, in Hegel's terminology) has led us to its essence which, when looked upon as something self-subsistent, became ground. At the level of *form and matter* relation of the ground, information as such was identified with formless matter upon abstraction from any form of matter self-representation. This is what can be called *specific information*, or simply *information*. Such information still carries all determinations of represented material entities and thus is contradictory: it is *formless* matter that nevertheless has some *form*. A resolution of this contradiction leads to the universal form of (specific) information which is nothing else but a probability distribution. Since specific information still carries determinations of represented material entities, it is possible to further abstract from these determinations so that they play the role of form, and information becomes truly formless matter – a uniform featureless continuity, a *pure quantity*. Such information can be called *abstract information*. An analysis of the latter reveals its inherently contradictory nature so that a resolution of this contradiction gives rise to its own universal form – a random binary sequence. Now we can consider information from the angle of the *form and content* relation of ground, just like we did with energy in the previous section arriving at an expression of the energy determinate quantity (its only determination) via the quantitative characteristics of a specific form of motion. In the present case, we therefore should explore the *abstract information content of particular specific information*, i.e. try to determine the quantity of abstract information associated with specific information in the universal form.

Let us consider a simple example. Suppose somebody's task is to recognize a person in a crowded place (like an airport) on the basis of a picture. For definiteness sake, let us assume that there are 100 people in the subject's view, and the task is to either identify one of them as the person of interest or conclude that the latter is not present among the 100 people in the view. Therefore the corresponding universal form of the subject's information will have 101 states in it. Even before seeing the picture, the subject might have some information concerning the task at hand. For example, it might be known already that the person in question is tall, or about 40 years old, or something else of this sort. The abstract information content of the picture can be estimated, for instance, by compressing the corresponding file with the best available algorithm, and for a typical decent resolution color picture will probably be of the order of 10^6 bits. When the subject looks at the picture, about this amount of abstract information will be received. This reception will result in some change of the original universal form of the specific information of interest. On the other hand, it is clear even before working out any numbers, that the universal form in question can not fully "absorb" the whole 10^6 or so bits of abstract information from the picture. If a different picture (from a different angle, for instance) of the person of interest is shown to the subject after the first one, the universal form will likely change some more. If the two pictures were shown in the opposite order, the change of the universal form due to the first picture would likely be smaller than in the first case, as most of the specific information would have already been supplied by the the second picture. What we see in this example is that information *can be redundant* – supplying the same information for the second time does not have any effect on the universal form. We also see that it can be *irrelevant* – in this example all the little details (shades of color etc.) of the picture shown to the subject are not going to have a significant effect on the resulting universal form, in spite of a large quantity of the corresponding abstract information.

We can generalize these observations by stating that (specific) information, by virtue of its purely ideal nature, is fundamentally *reducible*. This means that any two different finite instances of specific information automatically reduce to one single instance upon any information actualization.[29] Nothing of this sort can happen to anything material. Matter is

[29]We will discuss this issue in more detail in the next section where we address the spheres of information

fundamentally *non-redundant*: any two material entities – no matter how indistinguishable they might be – are still not the same as just one such entity. Information is purely ideal and therefore *can be redundant*. Indeed, two copies of the same digital picture, for example, are fully equivalent to just one copy as far as any particular instance of the use of this picture goes.

If specific information in the universal form is already given and some additional information is received (by the same entity or "agent"), that extra received information – no matter what form it took before the reception – has to be "assimilated" by the same universal form that was expressing the original information. The reason is simply that the resulting information has to be some specific information *about the same (aspect of) entity* A as the original one. When new information is received and assimilated into the universal form, all redundancy it contained is automatically removed, or *reduced*. This – as we have mentioned already – is a direct consequence of the purely ideal nature of information and its *reducible redundancy*. On the other hand, all the content of the new received information irrelevant to the given aspect of the entity A (the one constituting the content of the original universal form) is ignored by the process of the new information assimilation (whatever the details of this process might be).

Let us now get back to the task of finding the determinate quantity of additional abstract information assimilated into the given universal form encoding the original specific information. Clearly, this quantity is going to depend on *two* instances of the universal form – that before the assimilation of the new information and after. In order to determine this quantity, let us denote the former (prior) distribution by $q(s_i)$ and the latter (posterior) – by $p(s_i)$.[30] The expression for the quantity of abstract of information we are looking for will then take the form $I(p,q)$, where p and q stand for the corresponding probability distributions. To find the form of $I(p,q)$, first note that it has to be symmetrical with respect to arbitrary permutations of pairs $(p(s_i), q(s_i))$. This is because, since $I(p,q)$ is a result of an abstraction from any content of states s_i, all such states have to enter $I(p,q)$ on a completely equal footing. The second (and main) requirement is – as for any specific quantity – the appropriately understood additivity. To see what such additivity means in the present case, consider information acquisition in stages – separately and sequentially about two different aspects of the entity A. For a simple example, suppose that A is known to be a fruit – either an apple or a pear – the color of which can be either red, yellow or green. At first, one obtains additional information about the type and then about the color. The total abstract

appearance and *actuality*, using the terminology of "The Science of Logic."

[30]Here and later we will often omit the overall prior information I from the notation, for brevity (and write it explicitly only when it is immediately relevant). So, for example, $p(s_i)$ is what previously was denoted by $p(s_i|I)$.

quantity of the information received this way has to be the sum of that for the type and the color information. The information that was originally present consists of “pieces” about type and color as well. If the type information (i.e. probability distribution) is known, the color information is represented by conditional distributions – one for each type. Unless type and color are statistically independent in the usual sense, these two “pieces” of the original information cannot be separated. This property of the information universal form (probability distribution) implies that the additivity of the abstract quantity of the information received has to have the same form: the total abstract quantity of the information received has to be the sum of the abstract quantity of the type information received and the *expected value*[31] – over possible types – of the color information received for each type. To put it in general terms, let u_j, $j = 1, \dots m$, and w_k, $k = 1, \dots, l$ be the two sets of “partial” states so that $s_i = u_j \wedge w_k$, for the appropriate values of the indices. Then the additivity of $I(p, q)$ just described will take the following form:

$$I(p(s), q(s)) = I(p(u), q(u)) + \mathbb{E}_{p(u)}[I(p(w|u), q(w|u))]. \tag{10}$$

It is well known that the only function of two probability distributions that satisfies the condition of symmetry (stated earlier), nonnegativity and additivity of the form (10) is (up to an arbitrary overall scale) the *Kullback-Leibler divergence* originally proposed in [10]:

$$I(p(s), q(s)) = \sum_{i=1}^{n} p(s_i) \log \frac{p(s_i)}{q(s_i)}, \tag{11}$$

so that the additivity (10) reads as

$$\begin{aligned} \sum_{j=1}^{m} \sum_{k=1}^{l} p(u_j \wedge w_k) \log \frac{p(u_j \wedge w_k)}{q(u_j \wedge w_k)} &= \sum_{j=1}^{m} p(u_j) \log \frac{p(u_j)}{q(u_j)} \\ &+ \sum_{j=1}^{m} p(u_j) \sum_{k=1}^{l} p(w_k|u_j) \log \frac{p(w_k|u_j)}{q(w_k|u_j)}. \end{aligned} \tag{12}$$

Thus we have found that the **quantity of abstract information** that needs to be assimilated into some specific information in a universal form to change the latter from $q(s_i)$, $i = 1, \dots, n$, to $p(s_i)$ **is given by the Kullback-Liebler divergence** (11). This quantity has an explicitly relative nature – it is expressed via two universal forms: the one before and one after the reception and assimilation of new information. The question that can naturally be asked at this point is whether it makes any sense to speak about any kind of absolute quantity of abstract information associated with any particular specific information in a universal form. We will revisit this question a bit later.

[31] Recall our discussion of the expected value as the only consistent

4.1.4 Abstract information quantity and inference: Maximum Entropy

Starting with the work of Shannon which suggested an information related interpretation of Shannon entropy of a probability distribution p_i, $i = 1, \ldots, n$, defined as $H(p) = -\sum_{i=1}^{n} p_i \log p_i$, there have been numerous attempts to extend the domain of applicability of Information Theory, originally designed as a mathematical theory of communications, to other areas, including physics and statistical inference. E.T. Jaynes was the first to propose the *principle of Maximum Entropy* (MaxEnt) as a powerful tool of obtaining fundamental results in statistical physics in a very simple way. In particular, in [11, 12], he showed that, for example, Gibbs distribution (which is of central importance to all of statistical physics) can be derived simply by maximizing Shannon entropy subject to the condition of fixed average energy. This work gave rise to the current field of Information Physics which later extended the MaxEnt principle of maximization of Shannon entropy to the ME principle of maximization of relative entropy (which is nothing else but negative Kullback-Liebler divergence).

It is interesting to note that, while it has become clear that entropy maximization approaches worked very well in physics and beyond, researchers had difficulties understanding the reasons for their success. The original interpretation of entropy Jaynes used was the *degree of uncertainty* associated with the corresponding probability distribution. MaxEnt principle, respectively, was understood as that of choosing the most noncommittal distribution among the ones satisfying the known constraints (like that of fixed average energy). In one of his articles, Jaynes recalls an episode when, in his early days, he tried to explain the meaning of MaxEnt to a certain well-known physicist. When he mentioned the degree of uncertainty understood as the amount of missing information interpretation, he immediately was asked whose information that was to which he had no satisfactory sufficiently "objective" answer. So his proposal was rejected on the basis of blatant subjectivity that had no place in natural sciences. Later, according to Jaynes, he was able to answer that question: the information involved was the information (or rather, ignorance) of "a person whose sole knowledge about its microstate consists of the values of microscopic quantities X_i which define its thermodynamic state" ([13], p.28) . We will revisit this question later as it is indeed a somewhat subtle one.

The followers of Jaynes, members of Information Physics research community, later reconsidered the form and interpretation of the MaxEnt principle, putting forward a similar but somewhat different ME principle, in which Shannon entropy maximization is replaced by that of relative entropy, the negative of Kullback-Liebler divergence. They also proposed the *ME principle* as a universal inference method based on incomplete information and put forward a hypothesis that some laws of physics are really inference rules, as opposed to fully objective laws of nature. What's very interesting that they significantly reconsidered Jaynes' information interpretation of entropy and relative entropy. Jaynes, as we have just mentioned, had some difficulties with assigning the "ownership" of information involved. The Information Physics community decided to do away with this interpretation altogether [14], p.133:

> The concept of relative entropy is introduced as a tool for reasoning – it is designed to perform a certain function defined through certain *design criteria or specifications.* There is no implication that the method is "true," or that it succeeds because it achieves some special contact with reality. Instead the claim is that the method succeeds in the sense that it works as designed – and that this is satisfactory because it leads to empirically adequate models.

Entropy becomes, for Jaynes' followers, a number without a carrier, quantity without any quality. Moreover, entropy is claimed to have no meaning, at least not a correct and precise one [14], p.133:

> Similarly, the concept of entropy is introduced as a tool for reasoning without recourse to notions of heat, multiplicity of states, disorder, uncertainty, or even in terms of an amount of information. In this approach *entropy needs no interpretation.* We do not need to know what 'entropy' means; we only need to know how to use it. Incidentally, this may help explain why previous searches failed to find a uniquely correct and unobjectionably precise meaning for the concept of entropy – there is none to be found.

Clearly seeing that entropy maximization works and that this can't be accidental, but failing to find a fully satisfactory explanation for its unyielding effectiveness, they have resorted to what could be called a rather explicit Machism according to which the whole science is looked upon as a pragmatic and economical way of neatly organizing and concisely describing our experiences about nature. So in the same recent review [14], p.140, we read:

> Our goal is to design a method that allows a systematic search for the preferred posterior distribution. The central idea, first proposed in [15], **is disarmingly simple**[32]: to select the posterior first rank all candidate distributions in increasing *order of preference* and then pick the distribution that ranks the highest. Irrespective of what it is that makes one distribution preferable over another (we

[32]The highlighted phrase is very characteristic of all Machist approaches. We can only note that what is disarmingly simple can easily be incapacitatingly shallow.

will get to that soon enough) it is clear that any ranking according to preference must be transitive: if distribution p_1 is preferred over distribution p_2, and p_2 is preferred over p_3, then p_1 is preferred over p_3. Such transitive rankings are implemented by assigning to each $p(x)$ a real number $S[p]$, which is called the entropy of p, in such a way that if p_1 is preferred over p_2, then $S[p_1] > S[p_2]$. The selected distribution (one or possibly many, for there may be several equally preferred distributions) is that which maximizes the entropy functional.

So, in this approach, entropy maximization is just a *design principle* that stems from the desire of a rational agent to rank probability distributions with the purpose of choosing the one that will best represent the agent's belief updated from the prior one upon a reception of some additional information. Therefore entropy becomes simply a way of assigning a real number to a probability distribution. Then the mathematical form of this assignment rule is obtained from a set of consistency requirements that lead to the negative of Kullback-Liebler divergence between the prior and updated distributions. Actually, as far as such consistency requirements go, there is a little flaw in this approach noted earlier by J. Uffink in [16] in his polemics with the similar consistency based explanation of the (relative) Maximum Entropy principle proposed by J.E. Shore and R.W. Johnson in [17].

In a few words, when an agent receives two independent "pieces" of information about two independent subsystems (according to prior belief) of a larger system, the resulting updated beliefs were in [17] assumed to automatically become independent which was noted to be much too strong of an assumption in [16]. It was then shown in [16] that, if such assumption is changed to the one under which independence of updated beliefs takes place only if it was explicitly part of the obtained information, the resulting update rule changes to that of maximization of one of the continuous family of *Rényi relative entropies* that reduces to the Shannon relative entropy only for one value of the continuous parameter (usually 1 or 0 depending on the convention used). Thus the result of imposing consistency requirements on the form of an "update function" is not unique, and a choice of the value of the continuous parameter has to be made separately. A. Caticha in [14] is aware of this problem with the consistency arguments. He proposes two variants of dealing with it. In the first, the privileged role played by independence is part of the design and is explicitly acknowledged. In the second, additional arguments are given based on the universality of the update rule and experimental evidence in favor of the Shannon entropy. In this variant, consistency with the law of large numbers is also used as extra supporting evidence.

Let us now try to understand why entropy maximization turns out to be such an effective tool in dealing with information, without resorting to mysterious numbers that have no meaning. In short, the main reason is the fundamental property of information which is a direct consequence of it being *purely ideal* – namely, its *reducible redundancy* mentioned earlier. Consider a simple example. Suppose a school student's projects involves making a comprehensive list of all tree species found in a certain forest. He has already made a partial list, but the deadline is approaching and he has no time left for wandering in the woods. Some reliable source tells him that this forest has *all* evergreen trees from a certain book chapter. How should he update his list from its prior state (that contains names of trees he himself has found) to the updated state that incorporates the new information? Clearly, he has to make sure to include all tree names from the book chapter but avoid doubling-up on any that were already in his original list. Equivalently, he can just go for the list that has *the smallest size difference from the original one* while satisfying the requirement (i.e. constraint) of including all tree names from the book.

What takes place in this example is very much reminiscent to what happens when information is acquired with the resulting update of the universal form. Figuratively speaking, let us imagine that some amount (i.e. determinate quantity of abstract information) of new information is received and used to update an existing universal form (i.e. a probability distribution) of certain specific information of some broadly understood "agent." Imagine also that the agent has the ability to take that newly received information, bit by bit, and classify each bit in three categories: 1) irrelevant to the existing universal form; 2) relevant but redundant (i.e. already accounted for by the existing universal form); 3) relevant and non-redundant. Quite obviously, the agent then will drop the bits belonging to the first two categories and add the bits of the third category to the ones already contained in the original universal form of the specific information. The resulting increase of the abstract information content of the agent's specific information will be equal to the number of bits of the third category present in the new information received.

In general, it might be difficult to classify all bits of the new information into such categories. The task becomes a bit simpler if the originally available (prior) specific information is already found in the universal form (a probability distribution), and precisely this information needs to be updated implying that the resulting specific information has to be represented in the universal form over the same set of states. Such stipulation takes care of the irrelevant part of the new information: it simply won't affect the given probability distribution. It also ensures that the redundancy present in the new information relative to the prior is reduced: there will be no redundancy in the resulting updated information. The latter fact is the direct consequence of adding the new information to the prior so that the result appears *as a single universal form.* Any redundant bits in the new information are going to simply get ignored if they are already present in the prior. When the new information is used to augment the prior by means of "absorbing" it (the new information) in the universal form, a certain (determinate) quantity (given by (11)) of abstract information ends up getting added to that already present in the prior. Adding more (i.e. a greater quantity of) abstract information would imply imbibing the resulting (posterior) universal form with some specific information not present in either prior or the new set. Often – if not always – new information can be cast in the form of a condition (a constraint, or a set thereof) imposed on the universal form in question.[33] If the prior distribution already happens to satisfy the constraints expressing the new information, the latter is found to be fully redundant (already contained in the prior), and no abstract information addition takes place as a result. These considerations lead to the simple quantitative (mathematical) formulation of the information update problem. If all specific information states are given in the universal form, and if any new information appears as a set of constraints on the universal form, the updated universal form can always be found by *minimizing the abstract information quantity of the updated specific information universal form relative to that of the prior, subject to the constraints expressing the new information.* Indeed, for any smaller abstract information quantity, the constraints expressing the new information will not be satisfied, and, for any greater quantity thereof, information not contained in either the prior or the new set will be incorporated into the universal form. But this is nothing else but the ME principle of maximum relative entropy as described in [14].

Let us use the example with tree species mentioned earlier for a simple illustration. Suppose, for simplicity, that there are only four possible species: pine, elm, oak, and maple. The student has already found pines and oaks in the forest. The book chapter contains the evergreens: elms and pines. The corresponding universal form is going to contain a total of 15 states corresponding to all possible subsets (save the empty one) of the set of the four tree species. The student's own investigation revealed that the probabilities of all states not including either pine or oak in the corresponding subset had to be set to zero leaving only four states with a nonvanishing probability. Suppose all the background information possessed by the student made probabilities of all these four states equal – and thus equal to 0.25. The new information from the book chapter implies that all states not including either elm or pine have to be assigned zero probability. Given the prior universal form, it is easy to see that the abstract information quantity (given by the Kullback-Liebler divergence) will be minimized by the universal form (probability distribution) assigning equal values (i.e. equal to 0.5) to each of the two states corresponding to the two possible subsets including elm, pine, and oak. The resulting value of the relative abstract information quantity is equal to $0.5 \log \frac{0.5}{0.25} + 0.5 \log \frac{0.5}{0.25} = \log 2 = 1$. Adding maple to the list of trees as well would result

[33] For example, if the newly available information consists of some certainty concerning some elements of the content in question, the corresponding constraints would simply set the probabilities of the states of the universal form disagreeing with the new information to zero.

in the state corresponding to the full set acquiring the probability of 1, and, respectively, in the relative abstract information quantity of $1 \cdot \log \frac{1}{0.25} = \log 4 = 2$. In our simple example, the interpretation is straightforward: the book chapter contains one (corresponding to the elm) bit of information on top of what's already known to the student. Putting maple in the report would imply adding one more bit for which neither the prior nor the new specific information has any basis.

We see that the ME principle as described in [14] remains valid but loses that one-sidedly "subjective" flavor ascribed to it by the Information Physics community. This principle has objective content as well, and any "agent" using it to come up with the most preferred probability distribution makes use of that objective content. The ME method "succeeds and works as designed" (and "leads to empirically adequate models") because it "achieves some special contact with reality," and not regardless of the latter. It is also true that the method achieves that "special contact" to its full extent largely via rational activity of such agents. Also, we do need to know (or, at least, it is highly advisable to know) what 'entropy' means since only in that case we can be sure to know how to use it.[34]

4.1.5 Information Theory

As has been already mentioned in the introduction, the originator of the modern Information Theory C. Shannon and his prominent collaborator W. Weaver both believed that the title "Information Theory" applied to the theory they developed was unjustifiably too broad and their theory should have been called "a mathematical theory of communications" instead. W. Weaver is credited with the following quotation: "The word 'information' relates not so much to what you do say as to what you could say. The mathematical theory of communication deals with the carriers of information, symbols and signals, not with information itself. That is, information is the measure of your freedom of choice when you select a message." Indeed, Information Theory grew out of an effort to develop methods of error-free communication over imperfect channels, i.e. communication channels that can introduce errors in transmitted signals. Before Shannon's main work, such communication was considered theoretically impossible. Shannon was able to overcome the previously existing obstacles by introducing redundant coding of long strings of transmitted symbols. Another question that Shannon was trying to answer was that of *most efficient* error-free communication, i.e. how a transmission should be done so that the received signal is not simply sufficient for an unambiguous reproduction of the message sent, but also so that the length of the transmitted

[34]The latter comment can be argued to be valid for much of modern science (especially fundamental physics) which has shown strong tendency towards "numbers magic," as we will discuss in more detail in Appendix B.

signal is minimal. In other words, the main goal was *optimal* error-free communication. It is this – rather natural in the view of fast increasing volumes of communications – optimality requirement that "forced" Shannon to, figuratively speaking, "get in touch" with the *determinate quantity of abstract information* in the course of his work on a mathematical theory of communications, as he and W. Weaver correctly noted.

Let us briefly review the main ideas and results of the classical Information Theory. In his groundbreaking article [18], C. Shannon addresses the problem of efficient communication explicitly acknowledging the irrelevance of any other aspect of information to the problem at hand [18], p.379:

> The fundamental problem of communication is that of reproducing at one point either exactly or approximately a message selected at another point. Frequently the messages have *meaning*; that is they refer to or are correlated according to some system with certain physical or conceptual entities. These semantic aspects of communication are irrelevant to the engineering problem. The significant aspect is that the actual message is one *selected from a set* of possible messages. The system must be designed to operate for each possible selection, not just the one which will actually be chosen since this is unknown at the time of design.

He considers the discrete noiseless channel in Part I of the article and the discrete channel with noise in Part II. Using the modern Information Theory language, Part I is about optimal compression and Part II is about optimal transmission.

In Part I, the starting point is a discrete source of information, the latter being understood now as a collection (a string) of symbols from some alphabet. C. Shannon states [18], p.383:

> We now consider the information source. How is an information source to be described mathematically, and how much information in bits per second is produced in a given source? The main point at issue is the effect of statistical knowledge about the source in reducing the required capacity of the channel, by the use of proper encoding of the information.

So the main idea here is simple: as the frequency of some symbols in a typical use of this alphabet is higher than that of others, it should be possible to assign shorter codes to them thus minimizing the total length of code expressing an average message. This is the same kind of thinking that was used in the design of the famous Morse code where, for example, the letter "e" is encoded by a single dot, but "j" – by a dot and three dashes. Shannon shows that it is possible to obtain larger savings in coded message length by taking more statistical (frequency) knowledge of the source into account. For example, one could use the frequency data on not just single letters, but letter pairs, triples etc. If such frequency data is available, one can design a code minimizing the length of a long coded message by solving a simple optimization problem which results – for either a prefix-free or uniquely decodable code – that the length of an optimal code for a symbol (or a sequence of symbols) of relative frequency $f_i^{(n)}$ should be equal to $\left\lceil \log \frac{1}{f_i^{(n)}} \right\rceil$. The resulting average code length per symbol (or a sequence of them of length n) calculated as $\sum_i f_i^{(n)} l_i^{(n)}$, where $l_i^{(n)}$ is the code length of symbol (or a sequence thereof of length n) i, will be between $H_n(f^{(n)})$ and $H_n(f^{(n)}) + 1$. Here $H_n(f^{(n)}) = \sum_i f_i^{(n)} \log \frac{1}{f_i^{(n)}}$ is the celebrated Shannon (or Bolzmann-Shannon) entropy of the empirically determined frequency distribution $f^{(n)}$ of all symbol sequences of length n. Choosing n to be large, it is possible to obtain the average code length *per symbol* arbitrarily close to $\frac{1}{n} H_n(f^{(n)})$ which can be shown to always not exceed $H_1(f^{(1)})$ – the entropy of one symbol frequency distribution – and approach this limit under some reasonable assumptions. It is interesting to note [18, 9] that, for the English language, $H_1(f^{(1)})$ can be estimated to be around 4.0 bits per letter while, for example, $\frac{1}{4} H_4(f^{(4)})$ is close to 2.8 bits per letter, reflecting the rather obvious observation that, in a natural language, various letter frequencies depend on the preceding letters.

Note that all such calculations do not require an introduction of probabilities and thus are of a purely combinatorial nature, the known statistics of the messages being expressed as the corresponding empirical frequency distributions. Shannon however, while acknowledging this, chose to model an information source as a stochastic process, thus explicitly introducing probabilities into consideration. Then he went on, seemingly just for the sake of self-entertainment, to search for a "measure" of information "in some sense" [18], p.392:

> We have represented a discrete information source as a Markoff process. Can we define a quantity which will measure, in some sense, how much information is "produced" by such a process, or better, at what rate information is produced?

Once he formulates the properties such measure should reasonable have and states the result (which is Shannon's entropy of a probability distribution p), he goes on to discuss the real status of this result in the context of the developed theory [18], p.393:

> This theorem, and the assumptions required for its proof, are **in no way necessary for the present theory**. It is given chiefly to lend a certain plausibility to some of our later definitions. The real justification of these definitions, however, will reside in their implications.

It is somewhat ironic that Shannon's theory which was explicitly developed as a mathematical theory of communications received such huge following outside the intended audience *as a theory of information*, largely due to the developments – almost side remarks – that were "in no way necessary for the present theory." The name that the theory eventually acquired – Information Theory – is a result of the ensuing enthusiasm of the wider scientific and engineering community about the real or implied content of Shannon's theory. The general feeling was – even though it could not be expressed precisely at the time – that the theory developed by Shannon was much more than just a quantitative theory of coding for efficient communications. Many researchers in various fields felt that Shannon's theory had in it the basics required for the proper understanding of information with its inherent qualitative and quantitative characteristics, with far reaching implications for science and engineering in general. Even though the original hopes haven't fully materialized yet, a number of important and promising developments outside of the communications field were subsequently made. To name just a couple of our favorites, these are Kolmogorov complexity in computer science and the whole field of Information Physics originated by E.T. Jaynes.

From the point of view of the true nature of information we have discussed earlier in the present work, the results obtained by Shannon in Part I of [18] can be most easily understood as follows. If the goal is to transmit a sequence of symbols originated by some source over a noiseless channel with a given transmission capacity (measured, for example, in bits) as quickly as possible, one has to determine the quantity of abstract information that needs to be transmitted. The reason is that information acts as abstract while being transmitted (and stored) since its content does not play a role in transmission. Let us consider the receiving end of the channel. Since the channel is noiseless, all transmitted symbols are received unchanged. The specific information present here is just the information about the message to be received. Before it is actually received, the receiver already has some information about the message. The assumption made by Shannon is that the language of the message with all of its statistical properties (expressed by all possible letter sequence frequencies) is known – but nothing else. Such frequency data can be converted into a probability distribution representing the universal form of the receiver's information about the message before its reception, in an obvious way: the probabilities are simply equated to the corresponding frequencies.[35] Once the message is received, the receiver's universal form of information about it changes from the prior distribution $p^{(p)}$ to the one expressing complete information about the received message – we denote it by $p^{(c)}$. So the probability of the message r actually received changes from its prior value of $p^{(p)}(r)$ to 1, while all the remaining probabilities of all other possible messages of the same length become 0. Thus

[35]See E.T. Jaynes' book [21] for an extensive discussion about the relation between frequencies and probabilities.

the quantity of abstract information received is given by the Kullback-Liebler divergence between $p^{(c)}$ and $p^{(p)}$:

$$I(p^{(c)}, p^{(p)}) = \log \frac{1}{p^{(p)}(r)}. \tag{13}$$

This implies that, with the best coding scheme, the channel will have to transmit that many bits for the message to reach the receiver. However, it would mean coding of the whole message in one code word which is obviously impractical.

If transmitted messages are going to be long, the expression (13) can be approximated by one with a more universal applicability. Namely, the prior probability of the received message $p^{(p)}(r)$ can be written as a product of (conditional) probabilities of individual symbols $x_1, x_2, \dots x_n$ comprising the message:

$$p^{(p)}(r) = p^{(p)}(x_1)p^{(p)}(x_2|x_1)\dots p^{(p)}(x_n|x_{n-1}\dots x_1).$$

Since symbol statistical dependencies rarely extend beyond several past symbols, the above expression can be well approximated by truncating the conditioning sequences to some moderate fixed value k (where, for most languages, k does not have to exceed 4 or 5 for a good approximation) to obtain

$$p^{(p)}(r) = p^{(p)}(x_1)p^{(p)}(x_2|x_1)\dots p^{(p)}(x_{n-1}|x_{n-2}\dots x_{n-k-1})p^{(p)}(x_n|x_{n-1}\dots x_{n-k}).$$

Then, if a message is long, there will be many identical factors in the above expression. For example, number of factors $p^{(p)}(x_n|x_{n-1}\dots x_{n-k})$ will be approximately equal to $np^{(p)}(x_n x_{n-1}\dots x_{n-k})$. Substituting the resulting expression into (13) then yields

$$\begin{aligned} I(p^{(c)}, p^{(p)}) &= n \sum_{x_{k+1}, x_k, \dots, x_1} p^{(p)}(x_{k+1}x_k\dots x_1) \log \frac{1}{p^{(p)}(x_{k+1}|x_k\dots x_1)} \\ &= nH^{(p)}(x_{k+1}|x_k\dots x_1), \end{aligned} \tag{14}$$

where the summation is over all values of symbols $x_{k+1}, \dots, x_1$ and $H^{(p)}(x_{k+1}|x_k\dots x_1)$ is the conditional Shannon entropy for the prior distribution of symbols. Thus we have found that the quantity of abstract information *per symbol* that needs to be received in order to reproduce the message sent over a noiseless channel is approximately equal to the entropy of a symbol conditional on k preceding symbols. As the number k is allowed to increase, it can be shown – assuming that symbol frequency statistics do not change as more messages are generated – to approach a limit called the *entropy rate* of a stochastic process.

One can note that, as opposed to (13), the expression (14) for the quantity of abstract information needed to uniquely reproduce the sent message does not depend on the actual message but only on its length and the statistics of the language used that constitutes the prior information of the receiver about the message to be received. From the practical perspective, this is obviously more convenient as it allows for a design of near-optimal codes that are universal (in the sense of working equally well for any sufficiently long message), use only moderate block lengths and thus are simple to decode. What we want to emphasize here is that both expressions (13) and (14) have the clear (to us now) meaning of the *(determinate) quantity of abstract information* needed to update the universal form of the specific information about the received message from the prior state to that of certainty. Therefore this is the *minimum number of bits* that needs to be transmitted in order to obtain that state of certainty, i.e. the message that was sent. This is precisely what Shannon found.

In Part II of [18], Shannon addresses the problem of optimal coding for transmission over a discrete channel with noise. Such noisy channel is assumed to affect transmitted symbols in a random fashion [18], p.406:

> The case of interest here is that in which the signal does not always undergo the same change in transmission. In this case we may assume the received signal E to be a function of the transmitted signal S and a second variable, the noise N.
>
> $$E = j(S, N)$$
>
> The noise is considered to be a chance variable just as the message was above. In general it may be represented by a suitable stochastic process.

Even though Shannon insisted on purely auxiliary nature of the apparent connections between entropy and information earlier in his article, he continues using such connections in his reasoning [18], p.407:

> Evidently the proper correction to apply to the amount of information transmitted is the amount of this information which is missing in the received signal, or alternatively the uncertainty when we have received a signal of what was actually sent. From our previous discussion of entropy as a measure of uncertainty it seems reasonable to use the conditional entropy of the message, knowing the received signal, as a measure of this missing information. This is indeed the proper definition, as we shall see later. Following this idea the rate of actual transmission, R, would be obtained by subtracting from the rate of production (i.e., the entropy of the source) the average rate of conditional entropy.
>
> $$R = H(x) - H_y(x)$$
>
> The conditional entropy $H_y(x)$ will, for convenience, be called the equivocation. It measures the average ambiguity of the received signal.

A couple of pages later, he further develops this "intuitive" line of reasoning [18], p.409:

> The rate of transmission R can he written in two other forms due to the identities noted above. We have
>
> $$\begin{aligned} R &= H(x) - H_y(x) \\ &= H(y) - H_x(y) \\ &= H(x) + H(y) - H(x,y) \end{aligned} \tag{15}$$
>
> The first defining expression has already been interpreted as the amount of information sent less the uncertainty of what was sent. The second measures the amount received less the part of this which is due to noise. The third is the sum of the two amounts less the joint entropy and therefore in a sense is the number of bits per second common to the two. Thus all three expressions have a certain **intuitive significance**.

The last phrase is very characteristic of the whole of Shannon's seminal work in that he feels that these quantities have a rather direct relation to information as such in some way he cannot yet rationally express – in particular, since he does not know what information is. So the significance he assigns to corresponding expressions receives the "intuitive" designation.

Shannon then defines the noisy channel capacity as the maximum of the rate (15) taken over all possible distributions of the channel input x. In the next section of [18], he goes on to show an existence of a code that allows for a transmission at any rate below the channel capacity so defined. To achieve that goal, Shannon makes use of one of several innovations developed by him in his seminal article. Namely, instead of constructing a specific code with arbitrarily small decoding error frequency, he shows that the latter can be made arbitrarily small when averaged over all codes in a certain set. This is done by using a random association of the messages to be sent and channel inputs. The obvious implication is that at least one code with the desired property is guaranteed to exist even though an actual construction of such a code can be difficult.

Let us now see how Shannon's capacity result could be obtained by a direct consideration of information transfer over the channel, without any reference to "intuitive" measures, but also without going into rather complicated arguments about encoding and decoding schemes. If the channel is assumed to be memoryless, i.e. to affect any transmitted symbol in the same statistically described fashion, it is sufficient to consider the quantity of abstract information sent over the channel in one use of it. Suppose symbol x_i was sent and symbol y_j is received on the other end. The channel itself is characterized by a set of conditional probabilities $p(y_j|x_i)$. Before y_j is received, the receiver has some information about the symbol x_i that was sent. The universal form of this information is given by the probability distribution $p(x_i)$ which is determined by the chosen information input code and thus known to the receiver. When the corresponding symbol y_j is received, the (specific) information about x_i changes to that with the universal form given by the distribution $p(x_i|y_j)$ that can be found from $p(y_j|x_i)$ and $p(x_i)$ by an application of Bayes' law. The quantity I_j of abstract information required for this probability update is given by the Kullback-Liebler divergence:

$$I_j = \sum_i p(x_i|y_j) \log \frac{p(x_i|y_j)}{p(x_i)}.$$

Taking expectation of this quantity over all possible received symbols y_j (or, equivalently in this case, taking a long run average), we obtain the average abstract information transferred over this channel per single use of it:

$$I = \sum_j p(y_j) \sum_i p(x_i|y_j) \log \frac{p(x_i|y_j)}{p(x_i)},$$

which is nothing else but what is now called the *mutual information* of channel input and output. Then the channel (abstract information transmission) capacity can be obtained by taking the maximum of I over the distribution of the channel input $p(x_i)$. It is interesting to note that such maximum is achieved for the input distribution $p(x_i)$ that makes the abstract information quantity I'_i given by the expression

$$I'_i = \sum_j p(y_j|x_i) \log \frac{p(y_j|x_i)}{p(y_j)} \tag{16}$$

the same for each input symbol x_i.

Indeed, the mutual information I can be rewritten in the following form:

$$\begin{aligned} I &= \sum_i p(x_i) \sum_j p(y_j|x_i) \log \frac{p(y_j|x_i)}{p(y_j)} \\ &= \sum_i p(x_i) \sum_j p(y_j|x_i) \log \frac{p(y_j|x_i)}{\sum_l p(y_j|x_l) p(x_l)}, \end{aligned}$$

where $p(y_j|x_i)$ is given by the channel characteristics and $p(x_i)$ play the role of decision variables in the maximization problem. Since $\sum_i p(x_i) = 1$, this is a constrained optimization problem that can be solved using the Lagrange multiplier method. Introducing a Lagrange multiplier λ, we obtain the Lagrange function $f(p(x_i), \lambda) = I - \lambda \sum_i p(x_i)$. Taking the partial derivatives $\frac{\partial f(p(x_i),\lambda)}{\partial p(x_k)}$ and equating them to 0, we obtain

$$\sum_j p(y_j|x_k) \log \frac{p(y_j|x_k)}{p(y_j)} = 1 + \lambda,$$

and thus independent of k.

The quantity I'_i is that of abstract information about the channel output y_j delivered by the corresponding channel input x_i. We have found that, when the channel input is adapted to the channel to maximize capacity, all possible channel inputs x_i deliver the same quantity of abstract information about the channel output. That quantity is then obviously equal to the channel capacity. If the channel is not symmetric (i.e. it affects different input symbols in a different way), the same in general is not true for different output symbols. Namely, the quantities I_j are generally different, and the channel capacity is equal to their average over all possible output symbols. Let us consider a simple example of a channel that is not symmetric. Suppose there are only two symbols that can be transmitted, and the channel always transmits 0 perfectly but has the opposite effect on 1: if 1 appears as an input, the output can be either 1 or 0 with equal probabilities. A quick calculation shows that, in order to make sure that $I'_0 = I'_1$, the probabilities of input symbols have to be set to $p(x = 0) = \frac{3}{5}$ and $p(x = 1) = \frac{2}{5}$. Then the probabilities of output symbols can be found to be $p(y = 0) = \frac{4}{5}$ and $p(y = 1) = \frac{1}{5}$. Thus, if the input is equal to 0, the distribution of the output gets updated from $(\frac{4}{5}, \frac{1}{5})$ to $(1, 0)$ since 0 is always transmitted perfectly. The corresponding quantity of abstract information is equal to (approximately) 0.32 bits. If the channel input is equal to 1, the output distribution goes from $(\frac{4}{5}, \frac{1}{5})$ to $(\frac{1}{2}, \frac{1}{2})$, for the same quantity of abstract information transmitted. On the other hand, if the output is equal to 0, the distribution of the corresponding input gets updated from $(\frac{3}{5}, \frac{2}{5})$ to $(\frac{3}{4}, \frac{1}{4})$ which is rather clearly not a large change. The corresponding quantity of abstract information is only about 0.07 bits. If however the output symbol is 1, the distribution of the corresponding input symbols goes from $(\frac{3}{5}, \frac{2}{5})$ to $(0, 1)$ – indeed, if 1 is received, 1 had to be sent since 0 input would have given 0 output with certainty. This is a significant distribution change, and the corresponding quantity of abstract information is equal to 1.32 bits. Such a large abstract information gain happens with relative frequency of $p(y = 1) = \frac{1}{5}$ if the channel is used repeatedly. The resulting *average* quantity of abstract information gain concerning the channel input is the same 0.32 bits per channel use that was found for the "forward" direction.

The information contained in the channel input about channel output can be called *predictive information*, i.e. information about some object or process that does not yet exist as such at the time the information is read. On the other hand, the information contained in the channel output about the channel input can be called *restorative information* – about some entity that already does not exist in that particular form. We see that, in the case of a noisy channel, when the input is adapted to the channel so that the average capacity is maximized, the predictive information gets equalized for all input symbols but the corresponding restorative information is received – as far as the quantity of abstract information is concerned – in "pulses" where a relatively large amount alternates with much smaller one (like in our example where one channel use brings either 1.32 or just 0.07 bits of restorative information – when either 1 or 0 symbol is received, respectively). It is interesting to note in this regard that, if the channel is not symmetric like in our example, the physical process responsible for information transmission is not the same for different input symbols. But, if the average channel capacity is maximized, the channel input symbol frequency is chosen in such a way as to equalize the (abstract) quantity of the predictive information, i.e. the information that "goes forward in time" reflecting the output symbols that are yet to appear on the other end of the channel. At the same time, the restorative information that "goes backward in time" exhibits uneven behavior with regards to the corresponding abstract information quantity. The reason for such equalization of the abstract information quantity "pushed forward" in every use of the channel is simply that if it hadn't been equal, it would have been possible to increase the average quantity of abstract information flowing through the channel by increasing the frequency of the input symbol that "pushes" more information. But the frequency of the input symbols has to be equal to make sure the input can't further compressed, i.e. represents abstract information in the universal form. The output symbols, on the other hand, are not subject to such requirement, so the quantity of abstract information "pulled" by different output symbols can be different. This observation underlines the ideal (i.e. not material) nature of information as opposed to any material process that plays the role of its "carrier" in any particular instance of information transmission.

4.2 Information essence, appearance and actuality. Semantic information

Before embarking on a further search for information fundamentals, let us take a quick look back on what we have been able to find so far. *Information* itself was identified with the universal self-representation of (formed) matter abstracted from any particular material form, i.e. from any particulars – determinations in Hegel's language – of the *representing* material entity. Further abstraction from the content of information, or, equivalently, from any details of the *represented* entity, yielded *abstract information*, with quantity being its only determination. If we now go back to the specific information (or simply information) characterized by some particular content and look at its dynamics, we will see a constant self-negating motion in which the given specific information constantly undergoes changes, with additional "pieces" of it getting added to what was already there while other "pieces" are equally constantly getting lost. It is this motion of information that we want to consider next.

4.2.1 Information essence

Again, following Hegel's sequence of logical analysis of any self-negating motion that uncovers the essence of the subject in question, we begin with a simple statement of an existence of the essential and the inessential. It is important to note, however, that here the subject of study is (specific) information which, in its turn, was obtained by uncovering the essence of the universal self-representation of matter. So what we are looking for now is an essence of an essence – "essence of the second order." As we will see later in this section, this "secondary essence" nature of semantic information has indeed been a source of considerable difficulties in the past.

1A. The essential and the unessential. Just like before, at this level of analysis, we simply point out that our subject – specific information – has the essential and the unessential sides to it that are distinct.

1B. Shine. Here, just like before again, we note that the essence is not simply different from the immediate being of our subject – specific information taken in its generality – but is negatively defined by it. The essence shines through the surface of information everywhere information is present. One more time though, one needs to point out that information itself is not immediate but rather was obtained as the essence of matter self-representation. So when we speak of "the surface of information," this moment has to be kept in mind.

1C. Reflection. Recall again that reflection, according to Hegel, is understood as the objective motion of the subject of study itself. In the present case, the subject is specific information. In its objective motion information constantly undergoes changes. Since our subject is information, we have already abstracted from any particular form it is "recorded" in various material entities. Still, any specific information keeps changing thus constantly negating itself. That constant change is the *reflective motion* of information.

a) *Positing reflection.* As Hegel says on p.346 of [1]: "Reflection is at first the movement of the nothing to the nothing, and thus negation coinciding with itself." Positing reflection is a pure negating motion of the subject of study in its objectivity. In our case, the subject is some specific information. Its positing reflection captures the moment of constant change any specific information undergoes.

b) *External reflection.* A closer look at the purely negating positing reflection reveals that the immediate negated by the reflection is, in spite of being purely derivative from it, is still opposite to it and thus indirectly defines it in an external fashion. In Hegel's own words, [1], p.348, this observation is expressed as follows:

> The immediacy which reflection, as a process of sublating, presupposes for itself is simply and solely a *positedness*, something *in itself* sublated which is not diverse from reflection's turning back into itself but is itself only this turning back. But it is at the same time determined as a *negative*, as immediately *in opposition* to something, and hence to an other. And so is reflection *determined.* According to this determinateness, because reflection *has* a presupposition and takes its start from the immediate as its other, it is *external reflection.*

The external reflection in this case points at what is being negated by the positing reflection: namely, any particular state of the given specific information.

c) *Determining reflection.* Determining reflection, according to Hegel, is the unity of positing and external reflection. In his own words, ([1], p.351): "In its determining, external reflection posits another in the place of the sublated being, but this other is essence; the positing does not posit its determination in the place of an other; it has no presupposition." Thus determining reflection begins with an immediate of the subject in question and negates that immediate which, in turn, loses its status of the beginning of the reflection and becomes just its artefact. The determining reflection obtains its self-subsistence not from the immediate that serves as a beginning of its external moment but rather from its self-equality grounded in negation [1], p.352:

> Positedness gets fixed in determination precisely because reflection is self-equality in its negatedness; the latter is therefore itself reflection into itself. Determination persists here, not by virtue of being but because of its self-equality. Since the being which sustains quality is unequal to the negation, quality is consequently unequal within itself, and hence a transient moment which disappears in the other. The determination of reflection is on the contrary positedness *as negation* – negation which has negatedness for its ground, is therefore not unequal to itself within itself, and hence *essential* rather than transient determinateness. What gives subsistence to it is the *self-equality of reflection* which has the negative only as negative, as something sublated or posited.

In our case, the subject of study is some (any) specific information. The external moment of the determining reflection begins with that specific information in some particular form where the form is not any material form from which we have abstracted in the process of "distilling" information from matter self-representation, but rather the form of existence of information itself. Such "ideal" form has to do with what "pieces" of the specific information are present in its given "incarnation." The positing moment of the determining reflection negates any such form and the determining reflection as a whole is that constant form-negating motion of the objective reality that has self-equality of this negation as the basis for its self-subsisting existence. The reflection therefore *is* that negating motion.

Once the reflection of the subject is understood, it is time to study its determinations, or essentialities. The first such essentiality is the identity.

2A. Identity. Just like before, the identity of essence is the same as self-identity of the determining reflection. The latter keeps negating all "ideal" forms of any given specific information, that negation itself being something that stays identical to itself in the process of constant negation. If we consider some particular specific information as our subject, then what stays constant throughout the process of form negation is *that specific information regardless of its (ideal) form.*

2B. Difference. Any identity that is not a trivial tautology necessarily has a moment of difference in it. The difference we are discussing here is just simple difference, without any further specifications.

a) *Diversity.* Diversity is just simple difference with no determinations, a difference "in some regard" determined externally. In our case, that external consideration clearly is related to the ideal form of the specific information in question. Different "versions" of the same specific information are different in some details of what is there and what is not.

b) *Opposition.* As we have seen before, diversity upon closer examination becomes opposition between two poles – the positive and the negative. In the present case, the *positive* (that is likeness reflected on itself) is the given specific information, taken it its self-identity and in abstraction from any change of its ideal form. The *negative*, on the other hand, is just pure "concentrated" change of its ideal form.

2C. Contradiction. Contradiction is, as we know, in the most immediate sense, unity of the opposite. A contradiction has to be resolved into something else. As we have seen, two modes of a contradiction resolution can be distinguished: a resolution into the null and a resolution into some new essence. Resolution into the null is always there and is simply a motion of the subject of study, taken in its main determinations. In our case, that is the specific information in all its variations. This is the contradiction resolution mode we are interested in here.

Hegel's objective reflection is, in a modern language, a dynamic process of change of the subject of study. The essence of the subject can be seen by means of such change.

Typically, it is not something that has a determinate being of its own and thus can be seen or otherwise experienced directly as such. Rather, it is what remains intact throughout any transmutations. Roughly speaking, if the object A became B and then C, then there is something in all of them that stayed the same since otherwise no transformation would have been possible. Depending on the subject of our analysis, that something could be more or less general. For instance, if that subject is all objective reality the essence is identified with the philosophical matter from N. Wiener's definition of information. If the subject is water in its different aggregate states, the essence is the chemical substance H_2O. The category of absolute ground is used then to capture the essence from its self-subsistent side, considered as an unquestionable basis for the immediacy of the subject in all multitude of its forms. The reflective motion of the subject is contained in ground but in a sublated fashion.

3A. Absolute Ground. In our case, absolute ground as such is just the specific information taken in its self-identity and self-subsistence and as such devoid of change and serving as the basis for all its modifications that are encountered in objective reality.

a) *Form and essence.* At this level, form and essence are one and the same. As Hegel states on p.391 of [1]: "Consequently, form has essence in its own identity, just as essence has absolute form in its negative nature." In our case, any specific information in any of its possible ideal forms is that particular specific information, and the specific information always shows up in some particular ideal form.

b) *Form and matter.* At this level of analysis, essence is separated from the form so that they are both considered in their own right. The form "takes with it" all specific determinations, leaving essence formless. The latter then becomes matter. In Hegel's own words [1], p.392: "It (the form) posits itself as sublated; it therefore *pre*-supposes its identity; according to this moment, essence is the indeterminate to which form is an other. It is not the essence which is absolute reflection within, but essence determined as formless identity: it is *matter*." In our case, the *matter* is just a *perfect image of the entity in question*, or, more precisely, a perfect image of some particular aspect of that entity. Note that matter here is not a perfectly formless continuity, not what could be called *pure quantity*. Rather, it can be a quite intricate image of the material entity A that was originally imprinted in some other entity B from any features of which we have abstracted to obtain (specific) information in the first place. This matter is however free of any change as far as it is considered as such. The perfect ideal image of the chosen aspect of entity A stays the same in the course of any transmutations the specific information undergoes in its natural course.

c) *Form and content.* At this level, form and matter that were indifferent to each other at the previous level join to yield a unity of differentiated sides. Matter is now formed and becomes content [1], p.396: "What was previously the self-identical – at first the ground, then subsistence in general, and finally matter – now passes under the dominion of form and is once more one of its determinations." The perfect ideal image of (a particular aspect of) entity A is now considered in unity with its particular form. We recall that such image never exists in separation from its form, contrary to how it was at the previous – *form and matter* – level. But, while realizing this, we still keep in mind that the image and any particular form it appears in are not identical.

4.2.2 Information appearance and actuality

In Hegel's logical system, once essence is uncovered and studied in its own right, it is time to go back to the surface of things and see how the essence shows itself there and forms the immediate which, as a consequence, is no longer treated as an immediate but rather something that has its roots in the essence [1], p.418:

> Thus essence *appears*. Reflection is the *internal shining* of essence. The determinations of this reflection are included in the unity purely and simply as posited, sublated; or reflection is essence immediately identical with itself in its positedness. But since this essence is ground, through its self-sublating reflection, or the reflection that which returns into itself, essence determines itself as something real; further, since this real determination, or the otherness, of the ground-connection sublates itself in the reflection of the ground and becomes concrete existence, the form determinations acquire therein an element of independent subsistence. Their *reflective shine* comes to completion in *appearance*.

The first category encountered on this logical path is that of *concrete existence*, or simply *existence*. This category parallels, to some extent, that of *shine*. The latter is the immediate looked upon from the "prism" of the realization that there is something more fundamental behind the immediate – namely, the essence – that somehow shines through it, forms it and gives it its determinations. This is done *before* the essence is uncovered and studied in its own right. Existence (concrete existence), on the other hand, is understood as the essence – which at this point is known – that has come to the surface. So the corresponding determinations of the form (the multitude that is seen on the surface) acquire in the existence a moment of self-subsistence that nevertheless has a clear "imprint" of the essence on it. That "imprint" however is still abstract meaning that it is just acknowledged but is not "derived" from the essence. When such "derivation" is done existence becomes appearance [1], p.437:

> Concrete existence is the immediacy of being to which essence has again restored itself. *In itself* this immediacy is the reflection of essence into itself. As concrete

> existence, essence has stepped out of its ground which has itself passed over into it. Concrete existence is this *reflected* immediacy in so far as, within, it is absolute negativity. It is now also *posited* as such, in that it has determined itself as *appearance*.

The first logical step in studying appearance of a subject is that of the law of appearance. In Hegel's logic, "appearance is the concrete existent mediated through its *negation*, which constitutes its *subsistence*" ([1], p.438), i.e. appearance is the same as existence (concrete existence) but, while at the level of existence the essence is taken as sublated, at the level of appearance, the essence is considered explicitly as the basis of the latter. Appearance is thus the multifarious surface of the subject considered explicitly from the angle and the point of view of the underlying unity. Thus one can now single out some element of this multitude that persists in all change. That element is the *law of appearance* [1], p.440:

> The law is thus the *positive element* of the mediation of what appears. Appearance is at first concrete existence as *negative* self-mediation, so that the concrete existent, through its own non-subsistence, through an other and again through the *non-subsistence of this other*, is mediated with itself.

"The law is the *reflection* of appearance into self-identity" ([1], p.441). It is what remains intact in the ever-changing multitude of the immediacy. So the appearance as a whole is wider than its law [1], p.441-442:

> In the law, concrete existence returns to its ground; appearance contains both of these – the simple ground and the dissolving movement of the appearing universe, of which the law is the essentiality.
>
> Appearance is an aggregate of more detailed determinations that belong to the this or the concrete, and are not contained in the law but are rather determined each by an other.
>
> The kingdom of laws is the *restful* content of appearance; the latter is this same content but displayed in *restless* flux and as reflection-into-other.

In our case, on the surface of things, there is a bewildering "mosaic" of all possible "bits" of (specific) information about various aspects of different material entities. They are in a constant state of flux, gaining and losing extra bits as (formed) matter is engaged in its ceaseless perpetual motion. What is constant though is that – as far as any particular specific information is concerned – this change revolves around that "fixed" ideal image which therefore persists through the change. This is the *law of appearance of specific information* which can be concisely formulated as follows.

Any specific information is an ideal reflection of some aspect of some material entity.

This formulation appears to be rather simple and almost obvious given what we already know. The reason for its simplicity is again an utmost generality of its subject.

A closer look at the relation of appearance to its law reveals that the "restless flux" content of appearance different from its "restful" content (that is the law) is not entirely self-subsistent but rather is just a moment of a much wider unity – it is "reflected into itself," in Hegel's language. The law therefore gets wider and encompasses the whole of appearance becoming what Hegel refers to as world which is in and for itself, or *suprasensible world* that is opposed to the world of appearance, or the *sensible world* [1], p.444:

> The kingdom of laws contains only the simple, unchanging but diversified content of the concretely existing world. But because it is now the total reflection of this world, it also contains the moment of its essenceless manifoldness.

This suprasensible world is the world of essence, the world of unity of the subject, or, put slightly differently, the *world of relations* between the subject's immediate multitude. Hegel (on p.446 of [1]) figuratively describes this world as the *inversion* of the immediate world of appearance. Using the modern scientific language one could also refer to it as the *dual* of the world of appearance. Since all content of the world of appearance is interrelated, the content of this dual world is – figuratively speaking again – is *isomorphic* to that of the immediate world of appearance. In this suprasensible world, we have again rediscovered the ground, but at the next logical level that prepares us for the systematic study of the subject dynamics [1], p.446:

> But concrete existence becomes appearance; ground is sublated in concrete existence; it reinstates itself as the return of appearance into itself, but does so as sublated ground, that is to say, as the ground-connection of opposite determinations; the identity of such determinations, however, is essentially a becoming and a transition, no longer the connection of ground as such.

The two worlds – the world-in-itself and the world of appearance – are opposites of each other. Thus even though they are isomorphic, they complement each other, and the whole of the subject is the indivisible unity of both and can only be adequately understood as such. Each of these two worlds as at the same time the whole and a moment of the latter [1], p.448:

> Both, in the first instance, are self-subsistent; but they are this only as totalities, and this they are inasmuch as each essentially contains the moment of the other in it. Hence the distinct self-subsistence of each, one determined as *immediate* and one as *reflected*, is now so posited as to be essentially the reference to the other and to have its self-subsistence *in this unity of the two*.

What therefore obtains is the essential relation in which the essence and the existence come together so that the former can be used to properly understand the dynamics of the latter [1], p.449:

> The essential relation is therefore not yet the true *third* to *essence* and to *concrete existence* but already contains the determinate union of the two. Essence is realized in it in such a way that it has self-subsistent, concrete existents for its subsistence, and these concrete existents have returned from their indifference back into their essential unity so that they have only this unity as their subsistence.

The essential relation, most immediately, appears on the surface as that of whole and parts. In our case, this is clearly seen. If one takes particular specific information about some aspect of a certain entity as the subject, the different (incomplete) bits of this information are parts of the whole which in this case is just the complete ideal image of the given aspect. Also, the whole world of information consists of an infinite number of various parts, but all these parts in their totality represent the complete ideal image of all matter in the totality of its form. The whole – the ideal image – does not exist separately from parts. On the other hand, the parts in their totality constitute the whole. Thus parts and whole are identical in the sense that both sides of this relation “make sense” only in their unity and each side, upon closer examination, reveals that it is at the same time the whole and one of its moments – thus amounting to a contradiction [1], p.453:

> The truth of the relation consists therefore in the *mediation*; its essence is the negative unity in which both the reflected and the existent immediacy are equally sublated. The relation is the contradiction that returns to its ground, into the unity which, as turning back, is reflected unity but which, since it has equally posited itself as sublated, refers to itself negatively and makes itself into existent immediacy.

As a result of this contradiction resolution, the essential relation becomes that of force and its expressions [1], p.455:

> *Force* is the negative unity into which the contradiction of whole and parts has resolved itself; it is the truth of that first relation. That of whole and parts is the thoughtless relation which the understanding first happens to come up with; or, objectively speaking, it is a dead mechanical aggregate that indeed has form determinations and brings the manifoldness of its self-subsisting matter together into one unity; but this unity is external to the manifoldness. – But the relation of *force* is the higher immanent turning back in which the unity of the whole that made up the connection of the self-subsisting otherness ceases to be something external and indifferent to this manifoldness.
>
> In the essential relation as now determined, the immediate and the reflected self-subsistence are now posited in that manifoldness as sublated or as moments, whereas in the preceding relation they were self-subsisting sides or extremes.

In our case, the totality of ideal images of the material world play the role of *force* that produces and forms the various particular instances of information present everywhere in the universe. In particular, if one wishes to study the dynamics of information this view can be of use. In Hegel's own words (p.455 of [1]): "*force* passes over into its expression, and what is expressed is a disappearing something that returns into force as its ground and only exists as supported and posited by it."

In this activity of forming the totality of existent information, the force (i.e. the totality of ideal images) stays the same while the resulting various "bits" of information undergo constant change following the multifarious complicated dynamics of their material carriers. In Hegel's words: "the movement of force is not as much a *transition* as a *translation*, and in this alteration posited through itself it remains what it is."

But even though force seems to play a leading role in this information forming process, one should always remember that this force is itself a relational, or "reflected," entity, and not something that exists separately and independently of the totality of information "bits" that it appears to produce and form. As Hegel puts it: "this reflected, self-referring unity is itself also sublated and a moment; it is mediated through its other and it has this as condition."

Once we realize that the force itself (totality of ideal images) and its expressions (totality of various information "bits") are the two different moments of the same totality, that force outside expressions are identical to the force itself, the relation of force and its expressions turns into that of the <u>relation of outer and inner</u> [1], p.460:

> The *inner* is determined as the form of *reflected immediacy* or of essence over

> against the *outer* as the form of *being*; the two, however, are only one identity.

This identity of the inner and the outer, or, equivalently, of essence and appearance is what gives rise to the sphere of actuality [1], p.464:

> Therefore, what something is, that it is entirely in its externality; its externality is its totality and equally so its unity reflected into itself. Its appearance is not only reflection-into-other but immanent reflection, and its externality is therefore the expression of what it is in itself; and since its content and its form are thus absolutely identical, it is, in and for itself, nothing *but this: to express itself*. It is the revealing of its essence, and this essence, accordingly, consists simply in being self-revealing... The essential relation, in this identity of appearance with the inner or with essence, has determined itself as *actuality*.

Actuality, in Hegel's system, is understood as the absolute totality that is the "unity of essence and existence," or, equivalently, of the inner and the outer. At the most abstract level, actuality is the *absolute* [1], p.465:

> This unity of the inner and outer is *absolute actuality*. But this actuality is, *first*, the absolute as such – in so far as it is posited as a unity in which the form has sublated itself, making itself into the *empty or external distinction* of an outer and inner. *Reflection* relates to this absolute as *external to it*; it only contemplates it rather than being its own movement. But it is essentially this movement and is, therefore, as the absolute's negative turning back into itself.

In our case, the absolute is the totality of the world of information of which the totality of ideal images of material entities and the totality of various "bits" of specific information in various states of completeness thereof are just moments. An absolute *attribute* is understood as the "*relative absolute*," or the "absolute in some *form determination*." The absolute proper is an abstraction that has no determinations whatsoever including even the determination of self-identity. It is an all-encompassing unity that has subsumed its own dynamics and all its determinations. An absolute attribute, on the other hand, encompasses the whole content of absolute, but taken in some particular determination, looked at from some particular angle. For example, the totality of all ideal images of material universe that used to be the inner of information at the previous logical stage can now be considered an absolute attribute. This view emphasizes the totality of the world of ideal images inside the whole of information: there is nothing beyond it since it accounts for the whole information content, and the world on information "bits" (that used to be the outer of information before) does not exist somewhere besides and alongside the world of ideal images but is identical to it content-wise. The particular determination of the world of ideal images is seen as sublated even though inherent to the world of information as a whole which plays the role of absolute here [1], p.469:

> But because absolute identity has only this meaning, that not only all determinations have been sublated but that reflection itself has also sublated itself, all determinations are thus *posited* in it *as sublated*. Or the totality is posited as absolute totality. Or again, the attribute has the absolute for its content and subsistence and, consequently, its form determination by which it is attribute is also posited, posited immediately as mere reflective shine; the negative is posited as negative.

When reflective motion of the absolute is considered "fragmentally" or "locally" in its own right while at the same time unquestionably as a vanishing moment of the absolute, such motion is treated as *mode* of the absolute. As Hegel argues, mode can be considered as an inseparable negative moment of the attribute [1], p.470:

> The attribute is *first* the absolute in simple self-*identity*. *Second*, it is *negation*, a negation which is *as such* formal immanent reflection. These two sides constitute at first the two *extremes* of the attribute, the *middle term* of which is the attribute itself, since it is both the absolute and the determinateness. – The second of these extremes is the *negative as negative*, the reflection *external* to the absolute. – Or inasmuch as the negative is taken as the *inner* of the absolute and its *own* determination is to posit itself as mode, it is then the self-externality of the absolute, the loss of itself in the changeability and contingency of being, its having passed over into its opposite *without turning back* into itself, the manifoldness of form and content determinations that lacks totality.

In fact, absolute as just an absolute is a high-order abstraction that has all determinations and all dynamics (reflective motion) sublated. Only taken with all its attributes and modes, the absolute "becomes alive" while still remaining an ultimate self-subsistence that it fundamentally is. All incessant activity inherent to the absolute is then categorically described as modes that are just expressions of the absolute itself that emanate from and return back to it. Thus even though they are transient, they are moments and expressions of the absolute itself and thus are not just some secondary derivative entities (not just "positedness") but at the same time have an absolute side to them [1], p.470-471:

> In actual fact, therefore, the absolute is first posited as absolute identity only in the mode; it is what it is, namely self-identity, only as self-referring negativity, as *reflective shining* which is posited as *reflective shining.*
>
> Accordingly the true meaning of mode is that it is the absolute's own reflective movement; it is a *determining* by virtue of which the absolute would become, not an *other*, but what it already *is*; a transparent externality which is a *pointing* to itself; a movement *out* of itself, but in such a way that *being outwardly* is just as much inwardness, and consequently equally a positing which is not mere positedness but absolute being.

Going back to our subject, modes of the absolute can be identified with any finite expressions of information as a whole (the totality of ideal images together with all specific information "bits" that form the single whole). For instance, any particular specific information – whether it is considered just as a complete ideal image or a (generally incomplete) spatially localized version of this image (a particular "bit") – is a mode of the absolute.

Actuality as such in Hegel's system is understood as the "reflected absoluteness," i.e. the unity of the immediate and the essence (the reflected) in which both are explicitly treated as just sides, or moments [1], p.478:

> This unity, in which concrete existence or immediacy and the in-itself, the ground or the reflected, are simply moments, is now *actuality.* The actual is therefore *manifestation.* It is not drawn into the sphere of *alteration* by its externality, nor is it the *reflective shining* of itself in *an other.* It just manifests itself, and this means that in its externality, and only *in it*, it is *itself*, that is to say, only as a self-differentiating and self-determining movement.

Actuality can be thought of as the immediacy taken inseparably together with the essence shining through it so that the resulting whole is unquestionably a whole, a unity. When it is treated as such, the moments that at the preceding levels were taken in their own right become, respectively, an *actuality* and a *possibility* [1], p.478:

> Actuality, as itself *immediate* form-unity of inner and outer, is thus in the determination of *immediacy* as against the determination of immanent reflection; or it is an *actuality* as against a *possibility.* The connection of the two to each other is the *third*, the actual determined both as being reflected into itself and as this being immediately existing. This third is *necessity.*

It is notable here that both the whole and its moment of immediacy go under the same name of actuality. This is likely to emphasize that the whole is all seen (and acts) in its externality, with its universal bond moment expressed by essence being one with the whole and not something distinct from it.

Most immediately, both actuality and possibility are *formal* moments of the whole. Formal actuality and formal possibility are "simple determinations which are a totality only as an immediate unity, or as an immediate conversion of the one into the other, and thus lack the shape of self-subsistence" ([1], p.482). This incessant conversion of one moment into the other is *contingency*[36] and the identity of any of the two in the other is *necessity*. The world of information and that of ideal images of material entities is one totality of which these two worlds are moments that are distinct but only as moments of the same whole. As the material world moves and evolves, these two moments flow back and forth into each other. That flow is the moment of randomness. At the same time, they are essentially the same as moments of one totality. This is the moment of necessity which at this stage is also formal and is to be made more specific in the next step.

After formal actuality and formal possibility are considered as such, the next logical step is to make them real by considering their specific content. Most immediately, *real actuality* is understood as "a *manifold* content in general" [1], p.482:

> Real actuality is *as such* at first the thing of many properties, the concretely existing world; but it is not the concrete existence that dissolves into appearance but, as actuality, it is at the same time an in-itself and immanent reflection; it preserves itself in the manifoldness of mere concrete existence; its externality is an inner relating only to *itself*.

What is absolutely essential in real (finite) actuality of a subject is its *effect* in a wider context, the way it *acts on something other that itself* [1], p.482:

> What is actual *can act*; something announces its actuality by *what it produces*. Its relating to an other is the manifestation of *itself*, and this manifestation is neither a transition (the immediate something *refers* to the other in this way) nor an appearing (in this way the thing only is in *relation* to an other); it is a

[36] What is translated as "contingency" in [1] is called "zufälligkeit" in the original. The author of the translation prefers the translation "accidentality" but does not use it to avoid confusion with the accidentality that is opposed to substance in the same book. In our opinion, the translation that would most accurately convey the meaning of Hegel's "zufälligkeit," especially to someone with training in science and engineering is "randomness."

> self-subsistent which has its immanent reflection, its determinate essentiality, in another self-subsistent.

Thus to determine real actuality of some specific information one needs to establish how it can act on something *other than information* and manifest itself via such action. Before we attempt answering this question, let us see what comes out of real actuality.

With real actuality comes real possibility and real necessity. "Real," just before, means finite and possessing some specific content. Real actuality, just like its formal predecessor, has actuality within itself as a moment of being-it-itself [1], p.482:

> This possibility, as the in-itself of *real* actuality, is itself *real possibility*, at first the in-itself *full of content*.
>
> This real possibility is itself *immediate concrete existence*, but no longer because possibility as such, as a formal moment, is immediately its opposite, a non-reflected actuality, but because this determination pertains to it by the very fact of being *real* possibility. The real possibility of a fact is therefore the immediately existent manifoldness of circumstances that refer to it.

The real possibility of a particular instance of information lies in the ideal image of the corresponding material entity and thus in the material entity itself that clearly is a "source" of its own image. We see that a consideration of the sphere of actuality of information naturally leads us outside of the scope of information and back to the material world.

Real possibility of some entity transitions into its real actuality. Thus the distinction between two real entities – the one which represented the real possibility of the other and the other itself whose real possibility has transitioned into its real actuality – has been sublated. Such sublation and the resulting identity constitutes *real necessity* [1], p.484:

> The *negation* of real possibility is thus *its self-identity*; inasmuch as in its sublating it is thus within itself the recoiling of this sublating, it is *real necessity.*

Real necessity however is – by virtue of its finiteness – still relative and contains randomness (contingency) in it [1], p.485:

> The relativity of real possibility is manifested in the content by the fact that the latter is at first only the identity indifferent to form, is therefore distinct from it and a *determinate content in general.* A necessary reality is for this reason any

> limited actuality which, because of its limitation, is in some other respect also only something *contingent*.
>
> In actual fact, therefore, *real necessity* is *in itself also contingency*. – This first becomes apparent because real necessity, although something necessary *according to form*, is still something limited according to content, and derives its contingency through the latter.

If some material entity is present, so is its ideal image, and thus information about any aspect of this entity will be present as well with necessity. However, particular details of completeness of any particular instance of information about that material entity that can be found in a particular place is subject to contingency on potentially infinitely many various influences that can never be fully predicted. If one now considers that real actuality and real possibility in their totality and incessant mutual transformations, what results is the *absolute necessity* [1], p.487:

> Absolute necessity is therefore the truth in which actuality and possibility in general as well as formal and real necessity return.

Absolute necessity, in Hegel's logical system, plays the role of a link between real determinations of the actuality sphere and the absolute relation which first appears as the relation of substantiality. The relation of absolute (infinite) necessity, in our case, shows itself in the simple observation that there can be no material entity without information about it being present somewhere in some form and vice versa, there is no single instance of information without its material "prototype."

The absolute relation is what absolute necessity becomes when considered in its own terms [1], p.489:

> Absolute necessity is not so much the *necessary*, even less *a* necessary, but *necessity* – being simply as reflection. It is relation because it is a distinguishing whose moments are themselves the whole totality of necessity, and therefore *subsist* absolutely, but do so in such a way that their subsisting is *one* subsistence, and the difference only the *reflective shine* of the movement of exposition, and this reflective shine is the absolute itself.

The absolute relation is then considered abstractly at first and more specifically – from the point of view of finite content – after that. In the former instance, it appears as the relation of substance and accidents and, in the latter, as the relation of causality that transitions into that of reciprocal action, or interaction, in the more modern language [1], p.489:

> This relation in its immediate concept is the relation of *substance* and *accidents*, the immediate internal disappearing and becoming of the absolute reflective shine. If substance determines itself as a *being-for-itself* over against an *other* or is absolute relation as something real, then we have the *relation of causality*.

Substance, in Hegel's system, is the same as the absolute but looked upon as an essentially *active* entity that has its source of motion within itself whereas the absolute was the unity whose determinations still belonged to an external reflection. Thus substance is truly self-subsistent and self-producing. As such, it is an absolute unity of being and essence so that the latter two are no longer separate in any way but rather are just two moments of the self-subsistent totality and the whole totality at the same time [1], p.490:

> Absolute necessity is absolute relation because it is not *being* as such but *being* that is *because* it is, being as the absolute mediation of itself with itself. This being is *substance*; as the final unity of essence and being, it is the being in *all* being. It is neither the unreflected immediate, nor something abstract standing behind concrete existence and appearance, but the immediate actuality itself, and it is this actuality as being absolutely reflected into itself, as a *subsisting* that exists in and for itself. – Substance, as this unity of being and reflection, is essentially the *shining* and the *positedness* of itself. The shining is a *self-referring* shining, thus it *is*; this being is substance as such. Conversely, this being is only the self-identical *positedness*, and as such it is *shining totality, accidentality*.

Accidentality of substance is the substance itself looked upon as active substance. Accidentality is in no way distinct from the substance itself. The whole of substance is in its accidents. When the substance acts – via its accidentality – *it acts on itself* and not on something distinct or separate from it [1], p.490:

> This movement of accidentality is the *actuosity* of substance as the *tranquil coming forth of itself*. It is not active *against* something, but only against itself as a simple unresisting element.

On the next page, in the following paragraph, we read:

> Substance, as this identity of the reflective shining, is the totality of the whole and embraces accidentality in itself, and accidentality is the whole substance itself. Its differentiation into the *simple identity of being* and the *flux of accidents* within it is one form of its shining.

Since substance is understood as a totality that is active only towards itself, only the whole of the universe is substantial in this absolute most abstract sense, due to the presence of the universal bond. This is what Hegel refers to as "absolute substance" later in the book and what was originally termed "substance" by Spinoza. However, with some degree of approximation, one can speak of less general substances. In our case, if we treat the whole world of information as substance, then any particular instance of this world – be it some information in a particular ideal form or a complete ideal image of some material entity – becomes an accident. These accidents come and go, but the substance as such persists, unchanged. At this – still rather abstract – level, the substance itself gives rise to all ever-changing accidents, itself remaining fully intact. So the action moment is essentially assigned to some "middle term" [1], p.492:

> When substance, as self-identical being-in-and-for-itself, is differentiated from itself as a totality of *accidents*, it is substance itself, as *power*, that mediates the difference. This power is *necessity*, the positive *persistence* of the accidents in their negativity and their mere *positedness* in their subsistence; this *middle* is thus the unity of substantiality and accidentality themselves, a middle whose *extremes* have no subsistence of their own.

If one wishes to consider the active moment of substance more specifically so that accidents are not simply treated as abstract fleeting unsubstantial "flashes" while the substance itself is not simply viewed as an abstract self-identity, one has to look at the accidents a bit closer to discover their characteristics. The accidents are now viewed as entities explicitly created by the substance and the latter as their specific source. The relation of substantiality becomes the relation of causality [1], p.492:

> Substance is power - *power reflected into itself*, not transitive power but power that posits *determinations* and *distinguishes them from itself*. As self-referring in its determining, *it* is *itself* that which it posits as a negative or makes into a positedness. This *positedness* is, as such, sublated substantiality, the merely posited, the *effect*; the substance that exists for itself is, however, *cause*.

The relation of causality is first considered formally. What used to be an accident at the previous level is now an *effect*. The *cause* of this effect is, formally, the whole substance [1], p.493:

> This effect is, therefore, *first* the same as what the accidentality of the relation of substance is, namely substance as *positedness*; but, *second*, an accident is substantially such only by vanishing, only as transient; but as effect it is positedness

> as self-identical; in the effect the cause is manifested as the whole substance, that is to say, as reflected into itself in the positedness itself as such.

In our case, if the substance is again identified with the whole world of information, any specific finite instance of that world is now an effect endowed with all its specific qualities and quantities. It is considered as having been caused by that whole world of information which becomes the *cause*. These cause and effect here are formal so we can certainly agree that [1], p.493:

> *Consequently, an effect contains nothing whatever that the cause does not contain.* Conversely, *a cause contains nothing that is not in its effect.* A cause is cause only to the extent that it produces an effect; to be *cause is nothing but this determination of having an effect, and to be effect is nothing but this determination of having a cause.*

The world of information causes all of its specific instances and, conversely, the world of information as a whole is equal to the totality of its instances, and there is nothing in this world that is not present somewhere in a specific (ideal) form.

Having considered the relation of causality in general, formally, we can become still more specific and consider finite (determinate) causes and effects. This is Hegel's determinate relation of causality. Here cause and effect have specific and in general distinct *content*. Finite causality naturally leads to an infinite chain of causes and effects where anything finite can be considered a cause of something else but also an effect of some other cause. This infinite regression of causes or, equivalently, an infinite progression of effects is what Hegel considers an example of "bad infinity." Hegel's general stance towards such bad infinity is very critical and, in the case of determinate (finite) causality, he argues that the latter is in fact a superficial abstraction of what is truly an infinite *interaction*. In his discussion of finite casuality, Hegel makes an interesting remark that appears to be – somewhat indirectly – relevant to our goal (a clarification of information actuality sphere) [1], p.496:

> But it is the *inadmissible application* of the relation of causality to *the relations of physico-organic and spiritual life* that must be noted above all. Here that which is called the cause does indeed show itself to be of a different content than the effect, *but this is because* anything that has an effect on a living thing is independently determined, altered, and transmuted by the latter, *for the living thing will not let the cause come to its effect*, that is, it sublates it as cause.

His main point here is that the relation of finite casuality in which an effect is identical with the cause is not applicable to the consideration of the general dynamics of forms of matter at the organic and higher levels of organization. As we will see a bit later, these are precisely the forms of matter where information appears to come to its actualization.

Since linear cause-and-effect chains where a cause becomes an effect which then acts as a cause to produce another effect etc. is just a crude abstraction with rather limited applicability, the relation of causality has to be considered more closely. Such a consideration reveals that what in the finite causality is considered just an effect stands in a *conditioning* relationship to its cause and thus acts on the cause just like the cause acts on it [1], p.496:

> Causality thus *pre-supposes* itself or *conditions itself*. The previously only *implicit identity*, the substrate, is therefore now *determined as presupposition* or *posited as against the efficient* causality, and the *reflection hitherto only external* to the identity is now *in relation* to it.

This is the action and reaction relation of causality. We have found, following Hegel's lead, that the cause is conditioned, its action presupposes something on which it is supposed to act. That something is therefore casuality in a latent form ("in itself"). Hegel himself describes that something as follows [1], p.500:

> This other is, as we have seen, the *substantial identity* into which formal causality passes over, which now has determined itself *as against this causality* as its negative. Or it is the same as the substance of the causal relation, but a substance which is confronted by the power of accidentality as itself *substantial activity.* – It is the *passive* substance.

Going back to the world of information which we previously treated as substance, it is time now to remember that it has – being just the self-representation of matter abstracted from its material form – the world of matter as its sole source. Thus we can say that the world of matter *posits* the world of information by means of its inherent universal bond. Thus the world of information appears to be something secondary, created by the material world that plays the role of its source. This suggest the identification of the world of information with the *passive substance* of this fundamental matter-information (or the material-ideal) relation. Further, the world of information is not separate from the material world but rather is an inseparable – universal and fundamental – *moment* of it. So by acting on the world of information, the material world acts on itself. More specifically, the acting cause can be identified with the universal motion of the material world [1], p.500:

> This cause now *acts*, for it is the negative power *over itself*; at the same time it is its own *presupposition*; thus it acts upon itself as *upon an other*, upon the *passive*

> *substance.* Hence, it *first sublates the otherness* of this substance and returns in it back to itself; *second*, it *determines* this same substance, posits this sublation of its otherness or the substances turning back into itself as a *determinateness.* This positedness, because it is at the same time the substance's turning back into itself, is at first *its effect.* But conversely, because as presupposing it determines itself as its other, it then posits the effect in this *other*, in the passive substance.

The material world as a whole gives rise to the ideal, the world of information. The latter is *posited* by the material world in its universal motion. So it is something posited. We can say that the world of information is the self-representation *of the material world.* On the other hand, being a reflection of the material world, being posited by it is its *own* fundamental property, its *own* determination. Just like there is no ideal without material, there is equally no material without ideal since no matter without universal bond and not engaged in the universal motion ever existed or going to exist. We can also say, with equal conviction, that the world of information is *the self-representation* of the material world. Self-representation of matter is impossible without matter, but matter is also impossible without self-representation. Hegel expresses this point in the following words [1], p.502:

> Passive substance, therefore, is only given its due by the action on it of another power. What it *loses* is the *immediacy* it had, the substantiality *alien to it.* What *comes to it as an alien something*, namely that it is determined as a *positedness*, is its own determination. – But now in being determined in its positedness, or *in its own* determination, the result is that it is not sublated but rather that it *only rejoins itself* and *in its being determined* is, therefore, an *originariness.*

Thus the world of information takes on its own existence while being the ideal twin of the material world. In being originated by matter by virtue of being its self-representation, the world of information finds its own fundamental attribute, its own definition. What was a passive substance becomes a self-subsistent entity, a cause in its own right that can act and produce effects [1], p.502:

> Now, because the passive substance has been converted into a cause, it follows, *first*, that the effect is sublated in it; therein consists its *reaction* in general.

We arrive at the general relation of <u>reciprocity of action</u> or, in the more modern language, that of <u>interaction</u>. Hegel characterizes this – the most developed – relation of the sphere of actuality in the following simple words [1], p.503:

> At first, the reciprocity of action takes on the form of a reciprocal causality of *substances* that are *presupposed* and that *condition each other*; each is with respect to the other *both* active *and* passive *substance*. Since the two are thus passive and active at once, their difference is thereby already sublated; it is a totally transparent reflective shine; they are substances only in being the identity of the active and the passive.

Matter in its universal motion interacts with itself and leaves its own "imprint" on itself in the process. This "imprint" in its totality is the world of information. Put slightly differently, matter in its motion plays an active part in this "imprinting" process, and matter in its "static" aspect plays the passive role – the role of an acceptor of the active matter's action in the form of the ideal[37] "imprint." The world of information, in its turn, being an "imprint" of the constantly moving material world, is in constant motion of its own. So it can play an active role towards the material world. The passive aspect of matter conditions the action of the active aspect of matter on it. This gives rise to information. Thus the information world is a condition for the activity of the material world towards itself. The material world acts as cause which has the information world as its effect. This causality is the direct consequence of the universal motion of matter. This universal motion is imparted on the information world and, since the material world has a passive aspect to it, the information world can take on an active role and become a cause which has its effect in the material world. As Hegel puts it [1], p.503:

> Causality is conditioned and conditioning. As *conditioning*, it is *passive*; but it is equally so as *conditioned*. This conditioning or passivity is the *negation* of the cause through itself in that it makes itself essentially into an *effect* and is cause precisely for that reason. *Reciprocity of action* is, therefore, only causality itself; the cause does not just *have* an effect but, in the effect, refers *as cause* back to itself.

The material and and ideal (information) worlds are thus one single substance. They always come together and cannot be separated even for a moment. The universal motion is a fundamental attribute of this single substance, and the reciprocal causality that takes place between these two inseparable and distinct at the same time worlds is a direct result of the universal motion. Both of these two worlds can appear to be original or derivative[38] (posited) depending on the angle of view, but both are indeed one – two distinct moments

[37] Recall that this "imprint" is purely ideal once we abstract it from any material form. It is nothing else but information.

[38] Thus, for instance, an information-centric point of view can easily lead to the *"It from bit"* illusion.

of a single substance. This fundamental fact is revealed by a proper consideration of their joint dynamics [1], p.504:

> Causality is this *posited* transition of original being, of *cause*, into reflective shine or mere *positedness*, and, conversely, of positedness into originariness; but the *identity itself* of being and reflective shine still is the *inner* necessity. This *inwardness* or this in-itself is sublated by the movement of causality; the result is that the substantiality of the sides that stand in relation is lost, and necessity unveils itself.

Given the current state of scientific knowledge, we can say a bit more about the fundamental interaction of these two inseparable (relative) substances that are two moments of the absolute substance (which is the substance of Spinoza). At the lower levels of matter organization, information acts as essentially one with matter, as its permanent "shade." So its actuality sphere is indistinguishable from that of matter. A byproduct of this state of affairs is that it should be in principle possible – epistemologically speaking – to study the dynamics of matter by looking at its informational "twin" – at the "level of abstraction" at which all material entities are considered as purely informational ones. Starting from the organizational level of organic life, information "separates" from its material counterpart and begins playing a more independent role. It becomes possible for information to have material effects that would not be possible otherwise – without informational intervention. This is where the world of information begins acting as an active substance and the material world plays the passive substance role. Thus, as far as we can tell at this stage of scientific knowledge, **the proper sphere of actuality of information (where the actuality is no longer just "in-itself," just a potential) belongs to the realm of organic life and higher forms of matter organization.** Recall that, according to Hegel, this is precisely the realm of nature where finite casuality in its simplest form (in which the cause and its effect are identical) is no longer valid. One can also recall that, as we have discussed earlier in this section, that, according to Hegel, "What is actual *can act*; something announces its actuality by *what it produces*." Namely, at the level of real (finite) actuality, any finite instance of information actualizes in a proper sense when *it has its effect* which can happen at sufficiently high level of matter organization. One can say in this regard that, as far as we can see from our current vantage point,[39] the universe is filled to the brim with information the vast majority of which does not reach its actualization but is always ready to be actualized and, figuratively speaking, is waiting for its chance.

[39] Which unfortunately is not yet very high as we as a whole haven't yet reached the stage of fully intelligent matter organization.

4.2.3 Semantic information and its quantity

We are know sufficiently equipped to discuss the nature of semantic information and its qualitative and quantitative characteristics. According to Oxford Dictionary, the adjective *"semantic"* is understood as "connected with the meaning of words and sentences." Respectively, in the current literature, the word combination "semantic information" is taken as the particular aspect of information that has to do with information meaning or "content" (see, for example, [19]). In the same article, we read:

> Semantic information is, in turn, defined and analyzed differently by different people and is fraught with philosophical difficulties. Two approaches, among several, dominate contemporary discussion and will suffice as examples for this summary.
>
> Dretske (1981) follows Bar-Hillel and Carnap (1952) in taking a probabilistic approach that capitalizes on the notion of the uncertainty of a piece of information in a given probability space. Taking into account what Barwise and Seligman (1997) identify as the inverse relationship principle, this position is closely linked to the notion of information entropy, though applied here to the quantification of semantic content and thus demonstrates a tighter relationship between semantic information and the mathematical quantification of data than previously envisioned by Shannon. The inverse relationship principle says that the informativeness of a piece of information increases as its probability decreases.
>
> This probabilistic approach to semantic information is quite different again from Floridi's approach (2011) where semantic information is defined as "well-formed, meaningful, and truthful data."

We see that these two most popular approaches are indeed quite different. The first one takes an explicit and radical quantitative stance attempting to identify the quantity of a particular semantic information without clarifying its quality (what it is in its immediacy) first. The second approach begins with an attempt to establish that quality and tries to relate semantic information to data that satisfies some additional requirements. L. Floridi, the originator of the second approach, describes its motivation as follows [20]:

> It is common to think of information as consisting of *data*. It certainly helps, if only to a limited extent. For, unfortunately, the nature of data is not well-understood philosophically either, despite the fact that some important past debates – such as the one on the given and the one on sense data – have provided

> at least some initial insights. There still remains the advantage, however, that the concept of data is less rich, obscure and slippery than that of information, and hence easier to handle. So a data-based definition of information seems to be a good starting point.

L. Floridi thus takes a more measured approach choosing to begin with something hopefully easier to understand, compared to information as such – data. He then imposes some constraints on data – they have to be well-formed, meaningful, and truthful – in order to arrive at a concept of (semantic) information albeit of a somewhat narrow nature.

Let us see if we can come up with a more general notion of sematic information using the developments presented earlier in this article. Like we have noted before, the qualitative aspect of semantic information has to be understood first. Then we can discuss its quantitative characteristics. To see the semantic aspect of any information, we have to concentrate on its meaning – according to the meaning of the word "semantic." This implies that we should limit ourselves to information related to some form of human activity – since otherwise it would be difficult to speak about meaning. For information to have meaning, it is necessary for it to have some effect – at least potentially. Thus information must reach its *actuality* sphere – it has to be *actualized*, or at least *actualizable*. Since we already know what information is, we have the luxury of not having to resort to either the notion of data or the "numbers magic" approach (popular, in particular, in modern physics) where one tries to guess a quantity first and then to find some "interpretation" for it. Thus we arrive at the following definition of semantic information.

Definition 6 *Semantic information is any information actualized in some form of human activity, taken from the side of its actuality.*

In this definition, actualization is understood in the (proper philosophical) sense explained in the previous section. We could generalize this definition in an obvious way by allowing information that is actualized outside of the sphere of human activity. This way, one could speak of, for example, semantic information in biology, like genetic information.

Let us now turn to possible quantitative characterization of semantic information. From what we already know, it is rather clear that what makes information semantic, what gives it the semantic attribute is its *effect* in the material world. Therefore our ability to determine quantitative characteristics of semantic information – or rather to determine semantic quantitative characteristics of some specific information – *hinges on our ability to quantitatively characterize its effect* (or potential effect). The latter task might be more or less difficult depending on the specific effect in question. In some cases, it can be rather straightforward.

For example, if the information in question is a set of recommendations on driving whose aim is to maximize fuel economy, then, for instance, the realized relative decrease in fuel consumption resulting from following these recommendations would represent the quantity of semantic information contained in them. Let us now consider an example in which the task of semantic information "quantification" is a bit less straightforward.

R.P. Feynman, in his Lectures on Physics [7] which we have quoted from earlier, gives quite a remarkable example. What is even more remarkable than the example itself is the fact that he uses just the language the correctness of which we are trying to expound on here.

> If, in some cataclysm, all of scientific knowledge were to be destroyed, and only one sentence passed on to the next generations of creatures, what statement would contain the most information in the fewest words? I believe it is the atomic hypothesis (or the atomic fact, or whatever you wish to call it) that all things are made of atoms – little particles that move around in perpetual motion, attracting each other when they are a little distance apart, but repelling upon being squeezed into one another. In that one sentence, you will see, there is an **enormous amount of information about the world**,[40] if just a little imagination and thinking are applied...

Here, it is easy to agree with Feynman that the amount of semantic information contained in the sentence "All things are made of atoms" is indeed large – in spite of the small corresponding quantity of abstract syntactic information. On the other hand, it appears to be rather difficult here to come up with a single number expressing this determinate quantity. The reason is that the task implied by Feynman in the excerpt shown above is the quickest recovery of the present scientific knowledge. Even if we used the corresponding recovery time as the determinate quantity characterizing this task, it would be very hard to get any reliable estimate of this time.

As another example, consider two well-known philosophy books on a similar topic: "The Science of Logic" by G.W.F. Hegel and "The Logic of Scientific Discovery" by K. Popper. They have comparable size and would be close in size upon file compression. Thus the quantity of abstract syntactic information is similar. What about the quantity of semantic information contained in these two books? Again, we have to consider the sphere of information actuality to answer this question and therefore should determine an effect these books might have. What kind of effect would be the most appropriate in this comparison?

[40] Note that if we just added the adjective "semantic" to the noun "information" here, R.P. Feynman's statement would exactly agree with our definition.

This question might actually not have a unique answer. The task at hand could be simply passing a test by a philosophy student. Depending on the nature of the test – whether it is on the classical German philosophy or on the 20th century positivism (or postpositivism) – the semantic information quantity comparison for the two books would be obvious simply by virtue of one of the two books possessing a near-zero quantity of semantic information relative to the task at hand. (Still, coming up with a number expressing the quantity of semantic information contained in the "winning" book would be far from obvious.)

If one turns to a task of a more fundamental nature – something along the lines of facilitating the progress of humanity – the question becomes that which of the two books gives someone working on a task related to such progress more relevant knowledge. Here, again, the answer to this question is – in our opinion – rather clear. The reason is simply that – in spite of its promising title and undeniable literary virtues – K. Popper's work tells its reader precious little about just the kind of logic announced on the cover. Instead, the whole book – which is almost a pleasure to read, by the way, with its clear well rounded style of exposition – is devoted to the problem of testing the content of existing theories against experiment. One of the main points made by the author is that, while it is impossible to "verify" (to prove correct) a theory with certainty by any finite number of experiments, it is possible to "falsify" (to prove wrong) it by even a single experiment.[41] Moreover, potential "falsification" in principle (or being "falsifiable") is even elevated to the status of a fundamental criterion of a scientific theory. Still, assuming the previous theory is deemed unsatisfactory, the reader stands to learn next to nothing on the most intriguing topic – the namesake of the book's title: what the logic is of the movement to the next theory. Hegel's main book, on the other hand, has a lot of mostly yet untapped potential for bringing the level of rational thinking up to par to the currently achieved level of empirical knowledge. On a somewhat personal and humorous note, the author of the present article can vouch that the superior amount of semantic information in Hegel's book can be easily "felt" by anyone reading it: while it is fully possible to digest K. Popper's work decently well by reading it on a train to and from work in about a fortnight's time (partly owing to its clear exposition), it takes a comparatively truly Herculean effort to make sufficient sense of Hegel's main creation (that is notorious for its dense impenetrable style of expression), with easily several years worth of time investment in the quiet of a library or your personal study.

As to expressing the quantity of semantic information relative to the effect named above in either book as a number, it is rather clearly a very difficult – if not impossible – task. This

[41] Here we can note in passing that, while the first of these statements is correct due to, roughly speaking, the world being infinite and having infinitely many "sides" to it, the second one is less so – again due to the same fundamental infinity of the world. This simple fact was pointed out on more than one occasion after K. Popper's work came out.

observation though is not that surprising. The reason for such difficulty or impossibility is that – as has been a commonplace for as long as sciences became a recognized activity – that there are numerous scientifically and practically relevant entities that resist attempts at their "quantification." Indeed, according to Hegel [1], p.282:

> Quantity is being that has returned to itself in such a way that it is a simple self-equality indifferent to determinateness.

This concise but very accurate definition of quantity implies that, in order to quantify something, one needs first to reduce it a "simple self-equality indifferent to determinateness," i.e. some uniform featureless continuity. Such a reduction (abstraction from determinateness) has to make some sense in the context of the subject of study and not to be vacuous. A simple example of a well-defined quantity is a spatial extension (length, area, volume etc.) of any entity that is localized in space. Here, to quantify it, one simply abstracts from all features of the entity in question except its spatial extent. Obviously, in most cases, such quantification gives one a very limited characterization of that entity. On the other hand, in many cases, it turns out to be possible to compare two entities in a seemingly quantitative fashion, but the quantity on the basis of which the comparison appears to be taking place proves to be elusive. For example, it is often possible to say that X is a better piano player (bicycle racer, mathematician, philosopher, carpenter etc.) than Y. In such cases, clearly, one abstracts from all other qualities of X and Y and uses just one of them for the purpose of comparison. Both X and Y are assumed therefore to possess the *same single quality* but to a supposedly *different degree.* So they appear to differ from each other only *quantitatively* with respect to that particular quality. The problem is that the quality in question still has a lot of determinateness left "inside" of it. Thus, for example – if we compare X and Y as bicycle racers – X could be a better climber, but Y a better sprinter. We are facing a situation that is often described as one with a "trade-off." The whole field of multi-objective optimization owes its existence to such trade-offs being identifiable. It could also be more complicated than that, so that even any trade-off could be very difficult to identify. The interesting point is that, even in such complicated cases, a meaningful comparison can often be made. In practice, this phenomenon shows itself in the use of various rankings where multiple entities are compared along a certain "dimension" (i.e. with respect to a certain quality) in a (quasi)-quantitative fashion. Such rankings may make more or less sense, but it would be hasty and not very prudent to deny their rational content.

It therefore appears to be the case that, besides quantity, one can meaningfully talk about *quasi-quantity* which, rephrasing Hegel's definition of quantity cited earlier, would read something like this: *Quasi-quantity is being that has returned to itself in such a way* *that it is a simple self-equality relatively indifferent to its other determinateness.* Quasi-quantity – due to its lack if being indifferent to other determinateness – does not enjoy all advantages of being a true quantity. In particular, it could be impossible to come up with a well-defined "procedure" of adding a fixed amount of the quasi-quantity to the already present one. Therefore it could also be impossible to count the number of some chosen "units" that are contained in the given determinate quasi-quantity – and hence to express it as a number. Determinate quasi-quantities though can be compared to each other in a relatively reliable manner, and the relations of the type "greater," "less," "equal" ("almost equal") can be established – although not a manner that is as clear as that of comparing proper determinate quantities.

Recall that, in Hegel's system, *measure* is most immediately understood as a unity of quantity and quality or, more specifically, as a determinate quantity of a certain quality. Analogously, we could define *quasi-measure* as a *number assigned to the determinate quasi-quantity of a certain quality.* Quasi-measures can be used to facilitate comparison of various quasi-quantities. This provisional definition implies that, for a given quasi-quantity, there does not exist a unique quasi-measure. Typically there will be several (possibly many) quasi-measures that are appropriate in some way. As a matter of fact, quasi-measures – as we have provisionally defined them – are already used extensively in science and engineering. For example, the main method used for solving multi-objective optimization problems is to optimize a suitable quasi-measure. Probably the simplest and the most well-known instance of the usage of a quasi-quantity in conjunction with a quasi-measure is that of a random variable *variability* as a quasi-quantity for which the *variance*[42] is the most widely used quasi-measure. The *standard deviation* (the square root of variance) is another such popular quasi-measure. In fact, if one quasi-measure is chosen, any monotone function of it often can also serve as another quasi-measure for the same quasi-quantity of the same quality. This feature of quasi-measure is often exploited when the "quantification" of various characteristics of the system of study is discussed.

So we can now summarize our findings on the semantic information quantity, or, more precisely, semantic quantity of any actualized information.

- The semantic quantity depends directly on the effect in which the information in question actualizes (or could potentially actualize). The same specific information therefore can have more than one semantic quantity.

- Semantic information content of two different information "pieces" can only be com-

[42]Since the variance is additive for mutually independent random variables, it might actually turn out to be a true quantity associated with a suitably defined quality.

pared relative to the same effect. Semantic information contents taken relative to different effects are not commensurable.

- Depending on the effect, semantic information can possess either a quantity or a quasi-quantity.
- In the latter case, a suitable quasi-measure can sometimes be used to obtain an estimate of semantic information content.

4.3 Objectivity of information and its forms

Debates on the objective/subjective dilemma concerning information and its forms have so far revolved mainly around probabilities – partially due to clearer status and wide theoretical and practical applicability and immediately recognizable importance of the latter compared to information as such that has so far been considered to be a rather fuzzy concept. These debates on the nature of probabilities resulted in a formation of two main schools with regards to their interpretation and their objectivity. The views taken on and advocated by the two schools are now well known and we just give a very brief summary below.

Recall that the "objective" school of thought interprets probabilities as limits of relative frequencies of different outcomes of "random experiments," i.e. experiments that produce different outcomes even if conducted in the same way in identical (within achievable control limits) conditions. This view leads to fully objective probabilities independent on any personal opinions, traits, prior histories etc. The main weak point of this interpretation is the kind of difficulties it has with answering – or even making sense of – questions like "What is the probability that there is life on Mars?" or even "What is the probability of rain tomorrow?" that appear to make perfect sense and be practically important based on experience.

The "subjective," or Bayesian, school of thought interprets probabilities as degrees of belief that, respectively, can depend on whose beliefs they are. Thus probabilities acquire a necessary subjective component that becomes the main source of the criticism leveled against this interpretation by its opponents. On the other hand, questions about probability of life on Mars or rain tomorrow can be naturally and easily made sense of and answered. Relatively recently, however, a school of thought came to existence which, while still residing within Bayesian overall paradigm, made a concerted attempt to overcome the (excessive) subjectivism of the original subjective interpretation. The direction became known as "probability as logic" and is associated with names of H. Jeffreys, R.T. Cox, and E.T. Jaynes, whose book [21] can be considered a definitive reference for this overall paradigm.

The field of Information Physics grew from the work of Jaynes and his followers. A recent review [14] is a very good reference. The following quotation from p.3 of this review gives a good idea of the view the Information Physics community holds on probability.

> We shall find that while the subjective element in probabilities can never be completely eliminated, the rules for processing information, that is, the rules for updating probabilities, are themselves quite objective. This means that the new information can be objectively processed and incorporated into our posterior probabilities. Thus, it is quite possible to continuously suppress the subjective elements while enhancing the objective elements as we process more and more information.
>
> Thus, probabilities can be characterized by both subjective and objective elements and, ultimately, it is their objectivity that makes probabilities useful. There is much to be gained by rejecting the sharp subjective/objective dichotomy and replacing it with a continuous spectrum of intermediate possibilities.

In this quotation – and in this whole direction – we can see a move towards the point of view that Hegel would likely approve since it goes against "*an understanding that abstracts and therefore separates, that remains fixed in its separations*"[43] – the tendency that has been and still is present in much of all sciences. Before we explain the view on probability objectivity that follows from the approach presented in this article, let us briefly review some previous attempts at clarifying the objectivity of information as such.

This particular issue recently attracted some attention of members of the Information Science research community. In 2006, for example, M.J. Bates [22] attempted to use the previously proposed definition of information which sounds like a follow-up to the famous N. Wiener negative definition that served us as a starting point. That definition claims that "Information is the pattern of organization of matter and energy," and M.J. Bates in [22] first makes an argument for the validity of this definition and then expands on it. In M.J. Bates' expanded version of that definition, it acquires two parts: Information 1 defined as above, and Information 2: "Some pattern of organization of matter and energy given meaning by a living being (or its constituent parts)." M.J. Bates then states the relation between the two parts of information as follows:

> Meaning is ascribed to some of the Information 1 in the world by living beings, that is, living beings interpret some of the information in the universe as signs.

[43] This quotation is from [1], p.25.

> An enormous part of all the Information 1 in the universe, however, has never been interpreted as a sign by any living being.

So, in M.J. Bates' view, information as such is fundamentally objective and most of information present in the universe (Information 1) does not ever (to the best of our knowledge) acquire any subjective side to it. Some fraction of it that comes into contact with some living beings and happens to be somehow processed by them does acquire that subjective side thereby becoming Information 2. Here we have an example of an approach[44] where information is treated as having both an objective and a subjective side to it.

Somewhat curiously, M.J. Bates' approach received rather vigorous criticism shortly after its publication, from one of her colleagues [23]. The main objection of B. Hjørland to M.J. Bates' work had to do with her objective information – Information 1:

> Arguments will be put forward that Bates' understanding of information as an objective phenomenon is not fruitful for our field and that it is urgent for us to base Information Science on an alternative theoretical frame.

The root of B. Hjørland's objections to M.J. Bates' approach though – as he explicitly states in [23] – is of "pragmatic" nature: he is interested not in "an objectivist and universalist theory of information," but in a concept that could have immediate applicability in library and information science which he believes should be situation specific. Thus B. Hjørland does not deny the objective nature of information per se but simply considers this side of information not useful for his field.

In order to properly resolve the objective/subjective dilemma of information and its forms (like probabilities), one should approach the issue with the degree of thoroughness such a fundamental concept as information demands. In particular, one has to conscientiously avoid lapsing into empiricism which is always rather easy. The following quotation from [1] (p.125) can be used as a starting point.

> The opposition of the forms of subjectivity and objectivity is of course itself one of finitudes; but the *content*, as taken up in sensation, intuition[45], or also in the more abstract element of representation and thought, contains such finitudes in full, and these, by the exclusion of that one mode of finitude alone (of the form of

[44]The definition of information itself used by M.J. Bates' (borrowed by her in the previous literature) – while very empirical and philosophically naive – has an important rational core in it. It is also quite remarkable how far she was able to advance from such undeveloped staring point.

[45]In our opinion, a better translation of Hegel's *Anschauung* would be "contemplation."

subjective and objective), are still not done away with, and even less have they fallen off on their own.

In other words, the problem with subjectivity and objectivity of information arises when we begin taking some finite entity (say, for its study) and thereby "cutting its ties" to the rest of the universe. When this is done in any manner, something is lost and can be recovered only to some degree. This has to be kept in mind when any kind of thinking – especially about something very general, such as information – is done. Another typical problem with adequate understanding of the nature of objective/subjective dilemma stems from somewhat incorrect interpretation of the term "subjective." As Hegel puts it [1], p.42:

> Since *subjective* brings with it the misconception of "accidental" and "arbitrary" and also, in general, of determinations that belong to the form of *consciousness*, no particular weight is to be attached here to the distinction of subjective and objective. This is a distinction which will be more precisely developed later in the logic itself.

Indeed, up to this day, "subjective" often is meant to imply "random," "wilful" or "irrational." The term is frequently used to describe some kind of "free expression" of an isolated individual. This kind of connotation consciously or otherwise attached to the term "subjective" tends to skew its interpretation. In our view, the proper meaning of the term is to be associated with conscious activity of intelligent form of matter[46] (i.e. humanity) as a whole. That activity is not opposed to nature, i.e. the objective world. Rather, it grows out of it and constitutes a form of its logical development. Once such form of matter and its motion comes into existence, it begins changing the nature itself by creating what is known as technosphere etc. In doing so, it actually gives rise to some physical, chemical (i.e. lower order) forms that have not existed in nature before (like some transuranic elements). One can say, following Spinoza, that intelligence is a necessary attribute of matter, just like spatial extension. While being just a form of matter and its motion, the intelligent form has some attributes specific to it. The specific manifestations of this form is what has become known as the subjective. It can be opposed to the objective only in a relative sense and not absolutely.

Let us begin with the information that is present in the universe but has not yet come into any contact with humanity and thus has not had any chance to get actualized in human

[46]In this regard, it should be also kept in mind – especially when dealing with fundamental matters – that the humanity as we know it at this time is still a kind of a transitional form: from the biological to the intelligent in the full proper sense. Figuratively speaking, we as a whole are still *homo economicus* on our way to *home sapiens proper*.

activity. This is what would be considered purely Information 1 in M.J. Bates' approach [22]. At first, it seems rather clear that all this information would have to be considered purely objective but at the same time irrelevant to us simply because we can't yet get hold of it in any way. But upon a more careful consideration, keeping in mind that the universe is a *unity in multitude*, one can realize that, even though any information from such remote areas can't physically reach us (or we might be yet unable to receive it), we can still get at least some of it indirectly. For example, we are fairly certain that there are stars of the same classes we know of beyond the reach of the best available telescope. Thus we already have some information about them even though we can't "see" them in any way. As Hegel could probably say, these remote stars can't yet be reached with our senses but can already be reached by our intellect. Thus even that information acquires a subjective moment to it. Simply put, what different individuals can say about these remote stars is going to depend on their background knowledge of physics, astronomy and other related areas. Moreover, what we as a whole can say about these remote stars depends on the currently achieved level of knowledge. Slightly more specifically, it is going to reflect on the information from other, somewhat less remote areas of the universe previously received and processed by the current humanity as a whole.

As to information that is actualized in the sphere of human activity, i.e the information that has acquired a semantic[47] moment to it. For all such information, its subjective moment is even more prominent. Let us consider the tree stump example one more time. As we remember and everyone knows, a tree age can be easily read off from a stump, by counting the number of rings. If one has the whole stump of a slice of a tree available, complete information about the age of that tree is available as well. That information can be described by a single number. But even here, if one wants to write this information in the universal form, i.e. as a probability distribution, the question of a number of states in such a distribution immediately arises. If the information is complete, only one of these states is going to be assigned nonzero probability alleviating the problem somewhat, but if one wants to obtain the information *abstract quantity*, the problem returns. It is clear that the number of states necessary to give the tree age information in the universal form is determined by the highest possible tree age which, in turn, depends on what class of trees is of interest. And the latter sounds decidedly subjective. We see that, even when easily accessible complete information is available, a simple question of its abstract quantity gives rise to a subjective moment.

If the corresponding information is incomplete, things get even more convoluted. Suppose, for example, that just a piece of a round slice of a tree is available for its age deter-

[47]Semantic information in a wider sense as defined here corresponds to Information 2 from M.J. Bates' approach.

mination. Then a lower bound on the age can be obtained immediately, by counting the number of different ring fractions on the slice. But, clearly, more than that can be gained from a typical slice piece. For instance, measuring the curvature of remaining ring fractions, one can deduce, with some error, how many smaller (older) rings the whole slice could have contained. The tree type could also be detected from the slice piece, and previous knowledge of typical ring width depending on its age could be used to make the above estimation more accurate. If a piece of bark can be found on the piece, that would become an indication of the largest ring being present already and thus remove the uncertainty about the number of larger (more recent) rings missing from the piece. The list of additional observations and respective deductions that can be made for more accurate estimation of the tree age – and thus for changing the universal form of the corresponding information – can easily be continued. Such steps would depend of what other information (i.e. not directly obtainable from the given slice) is available and thus would possess a subjective moment.

At the same time, all information that could possibly be obtained and used for the tree age determination starting from a piece of the stump slice is information, i.e. part of the universal self-representation of matter that exists objectively (in M.J. Bates' terminology, one could say that any instance of Information 2 has some Information 1 as its origin), and therefore any information used in our example has an objective moment to it as well. Other information (i.e. other than just the number of rings found on the slice) that can be used to improve the tree age estimation (and thereby change the respective probability distribution) and that can be extracted from either the slice itself or from elsewhere (like the information about the tree type involved or even some history of the forest that tree came from) is also objective – it is out there to be extracted if needed and is extractable as long as the person extracting it is sufficiently knowledgeable. It does not matter who that person is if the necessary knowledge is there. B. Hjørland, in his polemics with M.J. Bates about objectivity of information, emphasizes the point of any practically useful information being situation specific and highly subjective [23]:

> No thing is inherently informative. *To consider something information is thus always to consider it as informative in relation to some possible questions.* We do not always realize this because it is mostly implied... In the wider sense, background knowledge[48] is *always* important to establish the informativeness of any object (including documents and texts).

B. Hjørland here is fully correct: in any sufficiently complicated situation – like any situation

[48]Knowledge is mentioned here. Since knowledge and information are not identical, we will briefly discuss the nature of knowledge later in this section.

that can be encountered in any reasonably advanced human activity including science and engineering – any object of study is not immediately informative per se but requires a lot of background knowledge (that relies on information obtained elsewhere). Obtaining and making efficient use of such background knowledge is a necessary activity that has to involve an intelligent subject and hence is subjective. Generally speaking, any actualization – and thus "semantizaton" – of information requires an active participation of conscious subjects which means that no semantic information can possibly avoid having a subjective side to it.

To summarize our general discussion on information objectivity, we can say that information taken as a whole as the infinite world of information – the ideal twin of the material world – is neither objective nor subjective. Rather, it is simply *one (relative) substance*[49] and as such contains an infinitude of various determinations within it, in a *sublated* fashion. When any *finite* (or determinate) information is considered, some of these determinations appear on its "surface." Concerning specifically information objectivity/subjectivity, depending on the situation, one or the other side comes more to the fore, while the other is still there. Hegel would probably express this point by stating that the distinction between subjective and objective information (or probability distribution as its universal form) depends on which of the two is the *posited* determinateness and which is only *in-itself.* He would likely also say that any finite information is an inseparable unity of distinct moments: objective and subjective.

To give another specific example of the objectivity/subjectivity dilemma as it arises in the case of *finite* information, let us now turn to the field of science where it has already created a rather vigorous debate that is still alive – and appears to be far from a definitive resolution. The field is that of statistical physics.

4.3.1 The ideal vs the material or whose information is it?

In his review of a collection of works of N.S. Krylov on the foundations of statistical physics, E.T. Jaynes gives the following brief summary of the existing "dichotomy" of the two opposing views on the fundamental content of that branch of science [24]:

> Since the beginning of statistical mechanics in the last century, two different streams of thought have been competing for that foundation status. The "er-

[49]By substance here we mean a proper philosophical substance as introduced earlier, not to be confused with substance in the more everyday sense still used in scientific and engineering literature – substance understood as a synonym of a "thing" or "weighty matter." We qualify information as *relative* substance to emphasize its opposition to the *absolute* substance that includes both material world and its ideal "twin" in their indivisible unity.

> godic" view, associated with James Clerk Maxwell, sees it as a part of mechanics, the goal being to deduce the probability distributions for systems of many molecules by application (albeit rather sophisticated) of Newton's laws of motion.
>
> A very different view, associated with J. Willard Gibbs, sees the goal as merely making the best predictions possible of observable facts, from incomplete information; that is, it is just a branch of statistical inference, not essentially different from what is needed in econometric and engineering. (Ludwig Boltzmann can be quoted on both sides.)

E.T. Jaynes himself, as we have already mentioned, is the founder of the (sub-)field of Information Physics and a big proponent of the second view. He is also the originator of the general interpretation of probability theory as the logic of science that has the Maximum Entropy principle as one of its indispensable tools used for probability assignment in situations of incomplete information. In one of his works [13], E.T. Jaynes recalls that shortly after C. Shannon's famous work on Information Theory came out, he realized that much of the statistical physics formalism could be recovered very simply by an appropriate maximization of Shannon's entropy which was then given the interpretation of the amount of missing information. E.T. Jaynes – then a young faculty member – tried to discuss the new ideas with his more experienced colleagues of which attempts he gives the following account [13], p.27:

> In the Summer of 1951, Professor G. Uhlenbeck gave his famous course on Statistical Mechanics at Stanford, and following the lectures I had many conversations with him, over lunch, about the foundations of the theory and current progress on it. I had expected, naively, that he would be enthusiastic about Shannon's work, and as eager as I to exploit these ideas in Statistical Mechanics. Instead, he seemed to think that the basic problems were, in principle, solved by the then recent work of Bogoliubov and van Hove (which seemed to me filling in details, but not touching at all on the real basic problems) – and adamantly rejected all suggestions that there is any connection between entropy and information.
>
> His initial reaction to my remarks was exactly like my initial reaction to Shannon's: "*Whose* information?" His position which I never succeeded in shaking one iota was: "Entropy cannot be a measure of 'amount of ignorance,' because different people have different amounts of ignorance; entropy is a definite physical quantity that can be measured in the laboratory with thermometers and calorimeters." Although the answer to this was clear in my own mind, I was unable, at the time, to convey that answer to him. In trying to explain the new idea I was, like Maxwell, groping for words because the way of thinking and habits of

> language then current had to be broken before I could express a different way of thinking.
>
> Today it seems trivially easy to answer Professor Uhlenbeck's objection as follows: "Certainly, different people have different amounts of ignorance. The entropy of a thermodynamic system is a measure of the degree of ignorance of a person *whose sole knowledge about the microstate consists of the values of the macroscopic quantities X_i which define its thermodynamic state.* This is a completely 'objective' quantity in the sense that it is a function only of the X_i, and does not depend on anybody's personality. Then there is no reason why it cannot be measured in the laboratory."

Whose information? This is the question we want to consider here from the standpoint of knowing the true nature of information that was still obscure to both the young E.T. Jaynes and his opponent from the above excerpt. To make our discussion more specific, let us limit ourselves to just one simple instance – monatomic ideal gas in thermal equilibrium. We will be interested in velocities of its constituent molecules. There is a well-known classical result – the Maxwell-Boltzmann distribution – possible justifications of which we are going to discuss with a view towards information.

J.C. Maxwell was the first to derive this distribution [25] in 1860. His original reasoning was sufficiently simple to be almost fully reproduced here. We are looking for a *stationary isotropic* (i.e. direction independent) velocity distribution in three dimensions. Due to isotropy, the distribution function can depend only on the absolute value (or, equivalently, square) of the molecule velocity: so it has the form $f(v^2)$ where $f(\cdot)$ is the function to be found. Let us now introduce an arbitrary Cartesian coordinate system. In that system, a molecule velocity has three orthogonal components: v_x, v_y and v_z. In this system, the distribution function we are looking for can be written as $\hat{f}(v_x, v_y, x_z)$ where $\hat{f}$ is some function of three arguments. Due to a fundamental property of mechanical motion (its "vector" nature), orthogonal components of the velocity do not affect each other. Therefore the distribution function $\hat{f}$ can be written as a product[50]: $\hat{f}(v_x, v_y, x_z) = \tilde{f}(v_x)\tilde{f}(v_y)\tilde{f}(v_z)$ where $\tilde{f}(\cdot)$ is some other function of a single argument. Furthermore, since positive and negative directions of any velocity component are equivalent, the function $\tilde{f}(\cdot)$ can only depend on the absolute value of its argument or, equivalently, only on the square of the velocity component. Finally, we obtain that $\hat{f}(v_x, v_y, x_z) = \check{f}(v_x^2)\check{f}(v_y^2)\check{f}(v_z^2)$, where the new

[50]This point in J.C. Maxwell's original derivation received the most criticism which was apparently one of the reasons he proposed an alternative derivation we are going to consider next. It's beyond the scope of the present article to consider this issue more closely. Let us simply note that it could be an interesting topic to reconsider Maxwell's arguments and his opponents' objections.

function $\check{f}(\cdot)$ is defined by $\check{f}(x) = \tilde{f}(x^2)$. Since, whether we look at the distribution function in components or not, it is still the same function, it has to be identically true that

$$f(v^2) = \check{f}(v_x^2)\check{f}(v_y^2)\check{f}(v_z^2).$$

Then it becomes an elementary exercise to show that the only way to satisfy this requirement is to set $\check{f}(x) = Ce^{-\beta x^2}$ and, respectively, $f(x) = C^3 e^{-\beta x^2}$, where β and C are some constants. The last step is to use the normalization condition to deduce that $C = \sqrt{\frac{\beta}{\pi}}$ and then to find that, with this distribution, the average kinetic energy of a particle motion in one dimension is $\frac{m\langle v_x \rangle^2}{2} = \frac{m}{4\beta} = \frac{1}{2}kT$ where we have used the standard thermodynamics definition of temperature. So, we obtain $\beta = \frac{m}{2kT}$ and $C = \sqrt{\frac{m}{2\pi kT}}$.

In J.C. Maxwell's second derivation [26] published several years later, he explicitly considered the dynamics of molecule collisions. He also invoked the assumption of *detailed balance* between molecule speeds in equilibrium. Specifically, if two molecules collide and their respective velocities change from $\vec{v}_1$ and $\vec{v}_2$ to $\vec{v}_1'$ and $\vec{v}_2'$ as a result of the collision, then, in the steady state, the number of molecules that change their velocities from $\vec{v}_1$, $\vec{v}_2$ to $\vec{v}_1'$, $\vec{v}_2'$ per unit time should be equal to that of the molecules that change in the opposite direction – from $\vec{v}_1'$, $\vec{v}_2'$ to $\vec{v}_1$, $\vec{v}_2$. In any such collision, the total kinetic energy of the two molecules stays unchanged – since otherwise a steady state could not possibly be obtained. So it follows from the detailed balance that

$$f(\vec{v}_1)f(\vec{v}_2) = f(\vec{v}_1')f(\vec{v}_2'),$$

for any such velocities that $\frac{mv_1^2}{2} + \frac{mv_2^2}{2} = \frac{mv_1'^2}{2} + \frac{mv_2'^2}{2}$. Then it is relatively straightforward to show that the only function satisfying this requirement is $f(\vec{v}) = Be^{-\beta v^2}$ where the constants B and β can be determined in the same way as before to yield the same final result (so that the value of β is exactly the same and $B = C^3$).

Now let us use Jaynes' Maximum Entropy principle. We make a single molecule the system in question and discretize the problem so that the values of kinetic energy of the molecule form a discrete (infinite) set: $E_1, E_2, \ldots$. Let $p_1, p_2, \ldots$ be the respective probabilities. We have to maximize the entropy

$$-\sum_i p_i \log p_i$$

subject to the constraints $\sum_i p_i = 1$ and $\sum_i p_i E_i = \langle E \rangle$, where the second constraint expresses the condition of constant average energy. The use of the standard Lagrange multiplier technique to perform maximization leads to the well-known result: $p_i = \frac{1}{Z}e^{-\beta' E_i}$, where Z (the statistical sum) and β' are some constants that can be determined by ensuring the resulting probability distribution satisfy the constraints of the optimization problem we have just solved. Remembering that the energy in this case is the kinetic energy $\frac{mv^2}{2}$ and going back to the continuous description, we obtain the same result as in both Maxwell's derivations with $\beta' = \frac{2}{m}\beta = \frac{1}{kT}$ and the same normalization constant.

We see that, in Maxwell's original derivation, energy conservation in a collision is not even explicitly invoked. It is still there in an implicit fashion "embedded" in the requirement that the resulting distribution be stationary given that the ideal gas is considered in isolation from other matter. The specificity of mechanical motion of gas molecules is taken into account precisely in the condition of independence of orthogonal velocity components – the point challenged by opponents the most. In Maxwell's second derivation, kinetic energy conservation in any collision is imposed explicitly, but the main specific characteristic of the mechanical form of motion – its "vector" nature implying the lack of interaction of orthogonal velocity components – has gone into the background. The Maximum Entropy derivation focuses on a single molecule as it goes through its mechanical journey in the gas. The only constraint imposed on the probability distribution of the molecule's states is that of a fixed value of its average energy (which is the kinetic energy in our example).

As a molecule moves through the gas, it collides with other molecules. These collisions change its velocity so that conservation of momentum and kinetic energy holds in every collision. These other molecules imparting some of their momentum and kinetic energy on the molecule in question thereby relay to it the corresponding information. More precisely, since, as we know, in the simplest forms of matter motion (up to the organic form and possibly some transitional forms between chemical and organic), information is just the ideal "twin" of the material side of the whole (the substance) inseparable from the latter, the information[51] transfer from other molecules in the gas to the given molecule completely coincides with the momentum and kinetic energy transfer. Over time periods much longer than the typical inter-collision time, the only information that remains with the molecule is that on its *average energy* the value of which stays constant in gas at constant[52] temperature. So Professor Uhlenbeck's somewhat dismissive question cited by E.T. Jaynes earlier could be actually answered in an even more "objective" fashion than what was later proposed by Jaynes himself. Namely, the information dealt with in the Maximum Entropy approach is not only the information "of a person whose sole knowledge about the microstate consists of the values of the macroscopic quantities which define its thermodynamic state," but it is also the information **that persists in the system itself** as the latter goes through its

[51] The information being discussed here is information on the molecule's mechanical motion only. Clearly, a molecule – as a rather complex entity connected to the rest of the world – carries a lot more information than that in general.

[52] Even if the temperature of gas is changing, assuming the time of appreciable change is much longer than the inter-collision time (which is of microscopic scale), this argument still applies.

motion.

Generally speaking, in the case of sufficiently simple (like physical, for example) systems, that information – as we have already mentioned a few times – is an inseparable ideal "twin" of the material system itself. So any analysis of the system and its qualitative and quantitative characteristics conducted by a sufficiently informed and knowledgable person can in principle be done from the "material" and from the 'ideal" standpoint. In the latter case, one would be looking at the relevant information. For a problem about a mechanical motion of a couple of rigid objects that is solved with the use of Newton's laws, both approaches would look identical. But for a problem of a more "statistical" nature, i.e such that there are a lot of mechanical degrees of freedom and, correspondingly, a lot of information is produced so that most of it turns out to be irrelevant for the problem in question, the two approaches might look somewhat different. This is the case in our molecule velocity distribution problem first solved by Maxwell in [25]. Still, even though they look different, their similarity is still evident, especially if one compares Maxwell's second derivation given in [26] with the Maximum Entropy one.

As a second example, let us consider the *Brandeis Dice Problem*, named so to celebrate the place of its origination during E.T. Jaynes' 1962 Brandeis University lectures ([13], p.33). During these lectures, E.T. Jaynes used a die tossing example to illustrate the Maximum Entropy principle. In short, he assumed it to be known that the mean number of points such experiments produced was equal to 4.5, i.e. 1 point in excess of what would have been expected from a perfectly balanced die. Maximizing the entropy of the number of points distribution subject to this constraint only, one obtains the probability distribution of the form $p_i = \frac{1}{Z}e^{-\lambda i}$ for $i = 1, \ldots, 6$ with $\lambda = -0.37$ and $Z = 26.7$, i.e the probabilities (uniquely) determined thereby form a geometric progression with the ratio of $e^{-\lambda} = 1.45$ so that $p_1 = 0.054$ and $p_6 = 0.347$. This result received some energetic criticism, one of the main objections being that it seemingly managed to obtain a whole probability distribution (i.e. 5 independent parameters) from just a *single* condition (that the mean number of points be equal to 4.5). The whole Maximum Entropy principle was being rejected by the opponents on the basis of that observation. In particular, one of Jaynes' critics, J.S. Rowlinson [27], wrote:

> ...is there anything in the mechanics of throwing dice which suggests that if a die is not true the probabilities of scores of 1,2,...,6 should form the geometric progression?

He then cited the famous Wolf data[53] which obtained the average of 3.5983 from 20,000 tosses of a die, compared the observed frequencies with the Maximum Entropy result obtained with a single constraint of a fixed average with that value, observed the obvious difference between the two and concluded about the lack of validity of the Maximum Entropy principle due to its "ignoring the physics of the problem." But the discrepancy observed by J.S. Rowlinson had – according to E.T. Jaynes – a simple explanation. Namely, in Jaynes' original Brandeis University lectures example, it was never claimed that the single constraint of a known value of the average number of points had to be used for evaluating probabilities of a real die. Instead, in the latter case, we *have* to take the physics into account by figuring out the constraints that are *operative* in the experiment in question by virtue of them being just (in Hegel's terminology) *the other* (i.e. the ideal "twin") of the material dynamics of the real die toss. In Jaynes's own words [13], p.57:

> But our probabilities will agree with measured frequencies only when we have recognized and put into our equations the constraints representing *all* the systematic influences at work in the real experiment.

So we see that, in this case, just as in the ideal gas example, the relevant information that needs to be explicitly taken into account in Maximum Entropy principle is the information reflecting the dynamics of the physical system under consideration. E.T. Jaynes then demonstrated how the frequencies observed in Wolf data could be obtained from the Maximum Entropy principle by using just *two* constraints expressing the relevant die toss dynamics: (i) one expressing slight reduction of faces weight due to material removal to create dots and (ii) the other related to a possible difference of one external dimension of the die from the two others. Jaynes showed that taking into account just these two asymmetries it was possible – using the Maximum Entropy principle – to produce probability assignment in perfect (according to the standard statistical criteria) agreement with the observed frequencies in Wolf data.

In fact, Jaynes in [13] gave two derivations of the probability distribution for the die used in Wolf data. The first one does not refer to information and even probabilities. Instead, Jaynes makes use of near-symmetry of the die and the knowledge of possible small deviations from perfect symmetry. The two kinds of such deviations identified by Jaynes correspond to exactly the two constraints mentioned in the previous paragraph. Then, taking into account the smallness of the deviations from perfect symmetry and retaining only linear terms, one

[53]From about 1850 to 1890, astronomer R. Wolf conducted a mass of random experiments that included some 20,000 tosses of a die.

can obtain the following expression for the frequencies g_i, $i = 1, \ldots, 6$:

$$g_i = \frac{1}{6}\left(1 + 6\alpha\epsilon f_1(i)\right)\left(1 + 3\beta\delta f_2(i)\right), \tag{17}$$

where $f_i(i) = i - 3.5$ and, in case the "3-4" dimension of the die is slightly longer than the other two (which was apparently true for the die used in Wolf data), $f_2(i) = 1$ for $i = 1, 2, 5, 6$ and $f_2(i) = -2$ for $i = 3, 4$, ϵ is the small displacement of the center of mass of the die from its geometric center due to one spot discrepancy between the opposite faces, δ is the amount by which the linear dimension of the die in the "3-4" direction exceeds the other two, and α and β are the two parameters that would be very difficult to calculate from a die toss dynamics model but rather straightforward to estimate from the empirically observed frequency data.

On the other hand, if one uses the Maximum Entropy principle with the two constraints mentioned earlier, the constraints can be written as ones on the given expected values of the same functions $f_1(i)$ and $f_2(i)$. For Wolf data, these expected values can be estimated to be equal to $3.5983 - 3.5 = 0.0983$ and 0.1393, respectively. The resulting distribution takes the form

$$p_i = \frac{1}{Z}\exp(-\lambda_1 f_1(i) - \lambda_2 f_2(i)). \tag{18}$$

The values of λ_1 and λ_2 are obtained from the known expectations of functions $f_1(i)$ and $f_2(i)$. The result for Wolf's dice data is $\lambda_1 = -0.0317$ and $\lambda_2 = -0.0718$ which reproduces the observed frequencies within statistical error.

It is easy to see that the two derivations presented by E.T. Jaynes stand in a relation to each other very similar to that of the Maxwell's first (1860) derivation of the gas molecule velocity distribution and the Maximum Entropy one of the same. Namely, both of the corresponding "non-informational" derivations manage to obviate any detailed consideration of the whole system dynamics by taking advantage of symmetries and the "vector" nature of mechanical motion in the former case and the smallness of the die's deviation from a perfect cube, in the latter. The Maximum Entropy derivation in both cases takes advantage of scarcity of the relevant information about the system's dynamics. In both cases, it turns out to be possible to cast the relevant information in the form of a known value of *expectations* of some simple functions. The latter feature ensures an exponential form of the expression for the corresponding probability distribution. In the die toss problem, the similarity between the expressions (17) and (18) is quite obvious, especially taking into account the smallness of parameters ϵ, δ and λ_1, λ_2, respectively. To obtain the former, we have used the general knowledge of rigid body dynamics in the presence of gravity: when a cube shaped die comes to rest after numerous revolutions in the air and bounces on the surface, it tends to do so that its center of mass is lower. Then, taking into account the effect of the face lightening due to point excavation and the discrepancy in the cube dimensions in different directions (augmented with the anticipation of what kind of discrepancy a typical technique of die production could result in), we are able to arrive at the expression (17). This expression already contains the information relevant for an outcome of the die toss experiment. The Maximum Entropy approach that leads to (18) is just a consistent explicitly informational way to take such information into account.

To summarize: in problems concerning simpler forms of the universal motion (like any problems in physics, for example), where information still plays a passive role (i.e. acts just as ideal "shadow" of its material *other*), it does not matter how the person (or a group thereof) solving the problem chooses to make use of the information *persisting in the object (process) in question*. It can be done either implicitly or explicitly. In the former case, one obtains a more "traditional" solution based on the corresponding laws of physical motion. In the latter case, an "information-centric" solution is obtained that often naturally takes the form of the Maximum Entropy principle application. The information having to be explicitly taken into account in that case is both the *information possessed by the person* solving the problem and the *information persisting in the system* in question over the relevant time scale. If the two are not the same, a correct solution will not be obtained. In the example of molecules in an ideal gas, the information carried by any molecule consists of its own location and velocity at any given time. For time periods large compared to molecules' typical inter-collision time but small relative to the time during which the gas as a whole exists in the given thermodynamic state, the only *information carried by the molecule* that remains unchanged is that of its *average kinetic energy*. It is also worth noting that, for problems lacking irrelevant (non-persisting) information (like, for example, any problems concerning mechanics of a small number of bodies), the two approaches would look identical, and, in particular, the Maximum Entropy principle would not have to be invoked. The latter becomes very handy, however, – for reasons explained earlier in this section – for ensuring that only the *relevant* (persisting over the appropriate time scale) information is taken into account.

4.3.2 Maximum entropy revisited

As we have already discussed, the Maximum Entropy principle, comes in two basic flavors: the "older" one that was pioneered and championed by E.T. Jaynes – termed MaxEnt in [14] – and the newer "updated and improved" one that supposedly subsumes MaxEnt making the latter its particular case – the principle called ME in [14]. The MaxEnt principle relies on a maximization of Shannon's entropy subject to the known constraints expressing the available information – to obtain the resulting probability distribution. The ME principle proceeds in the same way replacing Shannon's entropy with relative entropy that is nothing else but the negative of the Kullback-Liebler divergence between the initial probability distribution encoding the prior information and the resulting (posterior) distribution. The ME principle reduces to MaxEnt when the prior distribution is discrete uniform typically associated with complete lack of initial information. On the other hand, the ME principle can easily take into account any prior distribution and does not lead to any difficulties in the continuous case.

Earlier, we have discussed the content and the meaning of the ME principle. Recall that, in a nutshell, the reason for its universal effectiveness is that it makes sure that the amount of abstract information added to the existing one is minimal possible which in turn guarantees – due to purely ideal nature of information – that only the specific information that was present either in the prior distribution (the specific information universal form) or in the imposed constraints makes it into the posterior distribution. Now suppose that no prior distribution is given: one has only possible states and some information in the form of a set on constraints on the universal form (probability distribution). Question is what the universal form should be if only this information is "assimilated" into it. The well-known answer to this question is that the probability distribution with the desired property is the one maximizing Shannon's entropy subject to the given constraints. Let us see how one could justify this recipe. Let p be the probability distribution expressing the available information in the universal form, and let $p^{(c_i)}$ be the one describing the i-th state of complete information, i.e. the one for which $p_i^{(c_i)} = 1$. As we know, the quantity of abstract information required to update from p to $p^{(c_i)}$ is given by the Kullback-Liebler divergence:[54]

$$I(p^{(c_i)}, p) = \log \frac{1}{p_i}. \tag{19}$$

The expression (19) is the quantity of abstract information required to update from p to complete information *from the standpoint of that complete information*, i.e. given that the complete information is already available. On the other hand, if one is interested in the quantity of *abstract information missing from its state where the universal form is given by the distribution* p, one has to take the *expectation*[55] of (19) with respect to p – the distribution that describes the actual information available. Thus one obtains

$$\mathbb{E}_p \left[\log \frac{1}{p} \right] = \sum_{i=1}^{n} p_i \log \frac{1}{p_i} \equiv H(p) \tag{20}$$

[54] The expression (19) is what has been typically interpreted as the amount of information associated with i-th outcome of a random experiment described by a probability distribution p – not far from truth, as we see. In the context of Information Theory, this (when rounded up) is the number of bits (binary symbols) that would be required to signal an occurrence of i-th outcomes using an optimal coding scheme.

[55] As we have seen before, expectation is the only expression of the *same quantity* as the given one in a state of incomplete information.

for the quantity of abstract information missing from the universal form described by the probability distribution p. To see what kind of universal form has the largest quantity of missing abstract information, one can maximize (20) over p. The result is well-known: it is the uniform probability distribution $p_i = \frac{1}{n}$ for all i. Thus the state of information described by the uniform distribution as the universal form possesses the *highest quantity of missing abstract information* – the conclusion that was reached in the earlier days of Information Theory and, in fact, goes back to Laplace's Principle of Insufficient Reason (PIR) stating that, in the absence of any information, equal probability should be assigned to all known possibilities. What we see here is that the specific information state described by the uniform probability distribution can be considered the one containing the *minimal amount of abstract information* pertaining to the given specific information (i.e. the given set of states for the universal form). It is then natural to consider that minimal amount zero whereupon recovering the PIR in its original sense.

Now we can revisit the question of the *absolute quantity of abstract information* contained in the given specific information in the universal form. Since the *smallest* such amount belongs to the state of specific information whose universal form is the uniform distribution, the latter plays the role of zero. Then the abstract information content of an arbitrary specific information with the universal form described by the probability distribution p can be naturally associated with the quantity of abstract information required to update to p from the uniform distribution $p^{(U)}$. The latter is simply $I(p, p^{(U)})$:

$$I(p, p^{(U)}) = \sum_i p_i \log \frac{p_i}{1/n} = \log n - H(p), \tag{21}$$

where $H(p)$ is the Shannon's entropy of the probability distribution p. We see, in particular, that, as has been mentioned earlier, maximization of entropy is formally equivalent to the minimization of (21). Note that, even though we called this abstract information quantity "absolute," it clearly has a relative moment to it – it is determined relative to the uniform distribution. Its absolute moment[56] stems from the minimality of the abstract information content (or, equivalently, maximality of the missing information a.k.a. *uncertainty*) property possessed by the uniform distribution.

To wrap up the discussion about the absolute abstract information content of a specific information in the universal form, let us take a look at it from the Information Theory

[56]Generally speaking, it is very important to not fall into the trap of forgetting one moment of any categorical pair (like absolute/relative) and concentrating exclusively on the other. In the past, it led to countless instances of confusion and a lot of resulting misguided research efforts. In one of such instances, the relative moment of mechanical motion was – ironically enough – proclaimed to be absolute, and the consequences of the resulting confusion were grave indeed, as we discuss in more detail in Appendix B.

(i.e. the mathematical theory of communications) point of view. It is well known that the Kullback-Liebler divergence $I(p,q)$ can be interpreted as the *savings in the number of bits* that has to be transmitted over a noiseless channel to communicate an i.i.d. source generated by the distribution p optimally, relative to that resulting from using a code designed for a source generated by the distribution q. Using this interpretation in our case, we can see that the expression (21) shows how many fewer bits would be needed on average to encode (and communicate) an outcome of a random experiment (or i.i.d. source) *taking full advantage of its distribution*, relative to not taking any advantage of it (i.e. encoding all outcomes equally). Since a string of bits – when their number is optimized – is just the (simplest) universal form of abstract information (or, figuratively speaking, an incarnation of abstract information), those savings in the abstract information quantity can be attributed to the corresponding quantity *already contained* in the distribution itself.

Now, we would like to argue that, in spite of its formal reducibility to ME, the original Jaynes' MaxEnt principle is not fully subsumed by its younger "brother" but has its own meaning and justification. Too see this, let us recall what the essence of the given information is. As we established earlier, the (specific) information essence obtains when one considers the dynamics of information (which is already proper information abstracted away from its material form) and looks at what – roughly speaking – remains intact throughout the constant change of the information *ideal form* which can be thought of a "list" of the particular "bits" of that specific information present in that particular place. Thus, if one abstracts from that, what remains is simply the *complete ideal image* of the (given aspect of) the material entity in question. Now we can't help noticing that it is precisely the *complete information* that is the starting point of MaxEnt as the latter's point is to *maximize the abstract quantity of missing information* thereby making sure that what is left is *minimal* and thus no *irrelevant* information has been taken into account. So it appears that *MaxEnt functions at the level of information essence* whereas the logical place of *ME is at the level of being.*

Recall now that information being comes endowed with information ideal form (i.e. can be more or less complete) and usually takes place as a representation of a material entity in *other* material entities. Information essence, on the other hand, is always complete and is logically associated with the represented entity *itself*. So in situations where the information in question does not go through any stages of gradual acquisition, where it belongs to the system itself, not reflecting anything outside the system, where it is just explicitly *the other* (in Hegel's language) of the system's material dynamics, the approach based on information essence is the most appropriate. Such an approach begins with the complete (self-)information the system can possess and determines the part of such information that is *preserved* by the system's dynamics. It accomplishes that goal by maximizing the *abstract quantity* of information that is *missing* in the system relative to complete information, i.e. by maximizing the quantity of abstract information *lost* in system's dynamics.

Let us take molecules in an ideal gas again, for an illustration. Any given molecule – as far as its mechanical motion is concerned – has three spatial components of the vector of its velocity as the relevant information. In gas, the velocity of any molecule undergoes a myriad drastic changes every second so that only the *average kinetic energy*[57] is preserved over time periods relevant for the gas macroscopic properties such as pressure. Thus information about its own motion carried by any molecule of the gas over macroscopically relevant time periods consists of the known value of the average kinetic energy. The rest of the complete information about its mechanical motion – expressed by the values of all three components of velocity – is not preserved by the dynamics. Thus the resulting universal form (probability distribution) of incomplete information about a molecule's velocity can be obtained by maximizing Shannon's entropy (the quantity of missing abstract information) of that probability distribution subject to the fixed value of the average kinetic energy. The result is – as we have seen – the well-known Maxwell's distribution.

Let us now consider E.T. Jaynes' Brandeis dice problem. The die has six sides, and we are interested not in all the details of the dynamics of its toss but only in the final outcome: which side is going to show up on top when the die comes to rest. The relevant information is that on which side it will be – giving us six possible states. The logical starting point – just like in the previous example with a gas molecule – is the complete information about the side ending up on top. If no information about the toss dynamics is available, the result of MaxEnt application is the uniform distribution – the case of a perfectly symmetrical die. If some information about the die asymmetry is obtained, an application of MaxEnt – as shown in [13] by Jaynes – gives a different probability distribution (the universal form of the die toss experiment self-information) which is confirmed by the observed frequencies if the information obtained reflected all relevant details of the die toss dynamics.

In the latter example, beginning with the uniform distribution and using the ME version of the maximum entropy approach to obtain the updated distribution seems rather natural. Indeed, the result obtained would be identical with that yielded by MaxEnt (since MaxEnt is mathematically equivalent to ME with the uniform prior distribution) but, if one wants to emphasize the *objective* aspect of the experiment, MaxEnt is the more logical choice. The

[57]This conclusion is very important here and reasons why this is true have to be investigated and established. This is what the research on ergodicity beginning with the original work of L. Boltzmann [28] is trying to accomplish. It could be true that just the mechanical motion *weak stability* (see its discussion in [29]) is sufficient.

reason is that the information in question is the *self-information* of the tossed die dynamics, so its ideal form (which is the attribute of information being) is irrelevant here. The relevant part is exactly the *information preserved* by the dynamics, i.e. the information at the level of its essence, the immediate ideal "twin" of the system's material dynamics. The logical starting point for the latter is the *complete information* (i.e. the perfect ideal image thereof) about the aspect of interest – the upper side of the die when it comes to rest. In the former (gas molecule velocity) example, the preferred status of MaxEnt compared to ME is even more obvious. Indeed, in that case, a prior uniform distribution over possible energy levels does not appear in any natural way at all. On the other hand, any molecule definitely possesses some specific value of kinetic energy in any time period between collisions. Such energy constantly changes but in such a way that, over longer time periods, the average energy has a definite value. This is the self-information about the molecule's mechanical motion preserved by its dynamics in the gas.

Summarizing, we can say that the ME method (based on the minimization of the abstract information quantity added by taking additional specific information into account) emphasizes the subjective moment of information by assuming an intelligent agent whose information gets updated in stages. On the other hand, the original E.T. Jaynes' MaxEnt method (based on the maximization of the abstract quantity of missing information) puts more explicit emphasis on the objective moment of the information in question, by operating at the level of information essence devoid of its subjective ideal form. Hegel would have probably said that, in ME method, the subjective moment is posited and the objective one is in-itself, and, in the MaxEnt one, the opposite is true.

4.4 Information and knowledge

No sufficiently general account of information is complete without at least a brief discussion of the nature of knowledge and its relation to information as such. According, for example, to M.J. Bates [22], knowledge is "information given meaning and integrated with other contents of understanding." In slightly different words, knowledge, for M.J. Bates, is semantic information taken as some totality (integrated) which implies connections between various parts of semantic information. An advantage of such approach is a holistic view it takes from the beginning. Another example of a concept of knowledge is a popular *justified true belief* (JTB) one that, according to some writers, goes back to ancient Greeks.

Fully admitting the extreme difficulty of the task of developing a proper comprehensive theory of knowledge, its evolution and various phases it has gone through and is bound to go through in the future, we will offer only a brief outline of the nature of knowledge and thought, and their relation to information as it was presented in this article. The key to developing an adequate understanding of the general nature of thought and knowledge – just like is the case with any general notion – is careful avoidance of the tenets of empiricism and analytism and strict adherence to the view[58] that never forgets the unity in any multitude.

When we speak about knowledge, we will imply *human* knowledge. While it can certainly can be argued that some animals already exhibit rather well developed "thinking" capacity and hence can also possess knowledge, we will – fully admitting the validity of such arguments – specifically concentrate on knowledge and thinking as attributes of human beings, for the sake of definiteness. As we already know, semantic information is any information actualized in the sphere of human purposeful activity (practice). So, as many authors – including M.J. Bates cited above – noted, knowledge stands in close relation to semantic information. What separates humans from the rest of nature – including higher animals – is the *universal nature-transforming activity*[59] (often referred to also as *practice*) they are capable of.[60] *Universality* of such activity is key here: whereas bees or beavers, for example, are capable of rather sophisticated "construction" activity, it is very specific to the given species; only human activity has universality as its defining characteristic. Such universal nature-transforming activity (practice) comes with rather developed ideal moment. As we know, at this stage of matter – or, more precisely, substance – development, the ideal can play an active role towards its material counterpart. It is the **ideal moment of the universal nature-transforming activity taken in its totality** that has become known as **thought**.

Speaking of knowledge, if we take into account the common usage of that word and its relation to the words "thinking" and "thought," we end up concluding that **knowledge in its totality** can be best understood as the **summary and the result of** (the process of) **thinking that has taken part up to now**. This implies that thinking acts as a generating process of knowledge. Knowledge therefore is a dynamic process itself. The knowledge accumulated so far is constantly used to guide and facilitate further universal nature-transforming activity (that possesses both material and ideal moments inseparable within the activity process), which in turn generates new knowledge. Now, once we have established what **knowledge in its totality** is, let us discuss *finite* knowledge that has been the subject of approaches like JTB and that has generated significant controversy starting

[58]It goes without saying that a long period of empiricism and gradual – and often painful – accumulation of empirical knowledge in the course of multiply repeated practices and experiences has to pass before we find ourselves in a position to take the appropriately philosophical (i.e. seeing unity in multitude) stance towards a subject.

[59]Here nature is understood in the broadest sense as including humans as well.

[60]There is a lot of empiricism in this claim. But at the level of the discussion here (and possibly at the level of our present knowledge) it is hardly avoidable.

with E.L. Gettier's work [30].

When one looks at a finite "piece" of knowledge recorded in the form of a proposition p, the question can be asked as to what conditions are necessary and sufficient to say that a certain subject S has the knowledge expressed by the proposition p, i.e. under what conditions "S knows that p" becomes a true proposition itself. The JTB proposal states that (i) the proposition p has to be a belief of S, (ii) p has to be true and (iii) p has to be justified. The condition (i) means simply that the finite knowledge expressed by p has to be actualized in the head of at least one human (the subject S), and (ii) and (iii) are self-explanatory. E.L. Gettier proposed a simple (imaginary but easily realizable) example of two office dwellers, one of which is about to get a promotion. The first one believes, based on some insider information, that it is the second one who is getting promoted. He (the first) also knows that the second has a certain object (like a coin) in his pocket. So he concludes that "the promoted person will have this coin in his pocket," which is the proposition in question. It turns out that the first office inhabitant himself is promoted and happens (accidentally) to have the same coin in his pocket. So the proposition turns out to be true and justified (albeit in somewhat accidental fashion). So, according to JTB, it should qualify as knowledge but, on the other hand, the accidentality of its justification would seem to deny it such lofty status.

A vigorous exchange followed in the literature, with some writers trying to defend JTB against attacks of this kind by either rejecting Gettier's examples or introducing some modification to the JTB definition, and some others inventing new crafty examples to defeat the modified versions. The result, to the best of our knowledge, is that no definitive conclusion was reached. Since the main source for the problems was the justification requirement, some researchers proclaimed that the offending requirement could be dropped thus effectively modifying the JTB definition to a "TB" one. Such position became known as *epistemic minimalism*. Here, it is interesting to note that M.J. Bates, for example, who is an expert in Information Sciences and not an (analytic) philosopher like most of the writers involved in the JTB controversy, believes that even truthfulness is not a necessary requirement for knowledge – all that is required for a belief to qualify as knowledge is being *meaningful* [22]:

> Note that truth is not a requirement of knowledge as described here; knowledge is a kind of meaningful belief. We may or may not be able to offer various kinds of evidence to support such beliefs, and we may or may not be able to claim fairly, by the understandings of our culture, that these beliefs are true to the reality of the world.

Indeed, even a brief review of the history of any science gives numerous examples of either factually false or incorrectly justified beliefs that endured for a long time and should certainly be counted as knowledge. Let us consider just one of such examples – from the history of physics.

Sadi Carnot developed his famous Carnot cycle and obtained the well-known formula for the efficiency of an ideal heat engine using closed cycle with the same working body. He did so from the viewpoint of the *caloric theory* that postulated the existence of a universal substance – the caloric (*calorique* in French) – supposed to be the carrier of heat solely responsible for its transfer from one physical body to another. The resulting formula for the efficiency of an ideal (i.e. devoid of parasitic losses) heat engine read:

$$\eta = \frac{T_H - T_C}{T_H}, \tag{22}$$

where T_H is the (absolute) temperature of the hot reservoir and T_C that of the cool reservoir. The reasoning S. Carnot used to arrive at the expression (22) was pretty much analogous to what would be used to find the maximum work that could be obtained by lowering a mass from the height of T_H to that of T_C, with the absolute lowest height being equal to zero. Later, it became known that caloric did not exist, and heat was just the energy of chaotic mechanical motion of molecules constituting the working body (ideal gas in Carnot model). Still, the formula (22) is a correct one – *for any heat engine working on a closed cycle with the same working body.* The reason is that, in order to produce work, some heat has to be transferred to the cool reservoir, and thus the efficiency (22) is strictly smaller than unity *even for an ideal heat engine.* But *this is not some fundamental deficiency of heat* as a "low quality," "chaotic" energy, but rather *the need to close the cycle* with the same mass of gas. Nevertheless, to this day, many textbooks claim the former reason to be the correct one.

This is just one of many such examples. Some of the fallacies of the past knowledge in physics have been subsequently corrected and some new ones created. Such is the real process of scientific knowledge development – at least this has been the case so far. Still, if we refuse to grant the status of knowledge to what the content of physics is, we will be left with very little, if any at all, knowledge left. Somewhat sadly, the path of science has been a zigzagging one, with steps forward interspersed generously with steps in the opposite direction. This implies that we can require neither truth nor correct justification of any *finite* knowledge. Figuratively speaking, *knowledge makes sense as a continuous process, not in a piecemeal fashion.* In the process of its development, it goes from one contradiction to another. These contradiction then get resolved,[61] and new contradictions emerge to be

[61] It should be noted that in the "real" world where the knowledge in question is that of humans that are currently in a transitional stage to the properly intelligent form of the universal motion, the appearing contradictions get masked and thus postponed as often as they get properly resolved.

resolved later. When we forcefully extract a piece of knowledge from the larger context, it immediately acquires many "finitudes" (in Hegel's language) and becomes unavoidably self-contradictory. L. Gettier's analysis simply revealed that phenomenon by using a simple example. It is somewhat remarkable that L. Floridi, in chapter 9 of his book [31], came to the same conclusion in a different way.

Let us now further clarify the relation between information, thought and knowledge as they were described here. Recall that thought is just the ideal moment of human universal nature-transforming activity (practice). Since the latter is a material process (even though it cannot exist without its ideal moment), all thought is information. What has to be noted in this regard though is that *not all of thinking that actually takes place is reflected upon in somebody's head*, i.e. there is thought that does not immediately contribute to the fully articulated part of knowledge (but does contribute to the broader knowledge that also includes its "implicit" component). Our interpretation of thought may appear to be somewhat unusual, but it was already explicitly used by Hegel and is indeed key for his logical system. A simple example of thought that happens in an "intra-personal" way just as an ideal moment of human (collective) activity is that of societal relations that form "behind people's backs" and independently of their thoughts, but at the same time only and exclusively via their collective activity. Such relations, once established, become everyday reality for all people in the given society and may in fact escape an accurate conscious reflection – and thus contribution to the body of explicitly articulated knowledge – for a long time. These days, for instance, anybody can take a brief look at any man-made object (such as a passenger automobile) and immediately think about its value (which looks like market price on the surface). That value, however, is a purely ideal entity reflecting not anything in the physical construction of the automobile, but only social relations of the society in question. Thus, even though most people can easily recognize and estimate the value, most have no conscious knowledge of its true nature.

Our definition of semantic information (as information actualized in the sphere of human activity) leaves it a bit unclear whether that "inter-personal" thinking not yet actualized in a conscious way should be considered semantic information or not. It appears that we could go both ways without lapsing into nonsense. We feel more inclined to go with the wider definition of semantic information (which is still narrow in the sense of including only information actualized in the sphere of *human* activity). If such a choice is made, then all of thought becomes semantic information, with some of it still waiting to be made properly intelligible. So there is more semantic information than what makes it into the fully articulated knowledge. We can also note in this regard that, as we move towards the proper intelligent form of matter and the universal motion (*homo sapience proper*), this “gap” is going to grow narrower, with spontaneous (alienated) social forces not understood and controlled by people eventually disappearing.

To wrap up our brief discussion on the nature of knowledge, let us briefly comment on the differences between thought and knowledge, and their typical exposition in textbooks. As we have mentioned earlier a few times, knowledge plays the role of the summary of the process of thought that has taken place before that particular time moment. So when the knowledge has been formed enough to put it in a book, one has a choice of including in it more or less of the underlying thought process (to the extent it has been understood) that led to the given knowledge. It is safe to say that the latest trend has been to fill books with the information pertaining more to the “ready” knowledge rather than the process of thinking (and the corresponding practice) that had led to it. One of the reasons for such an approach is clearly the fast growth of the sheer volume of practice and the respective thinking that is inseparable from it. It is simply more economical to present a summary of the results (together with the most concise form of possible justifications and derivations) than to try to describe the whole controversial path that had historically led to them. That is why it is generally considered a good idea to read not just the latest textbooks, but also the original works in the field, and generally study its history in order to get a better appreciation of the current issues and the ways they can be resolved. Oftentimes, when difficult questions arise, they are not fully and satisfactorily resolved before the field in question and the research community “move on,” thus leaving important issues behind in that unresolved state, thereby invariably hindering further progress. Examples in the field of fundamental physics, for instance, are numerous and profound in their consequences, as we will discuss in Appendix B.

4.5 Information paradoxes

Related to the notion of semantic information and previous attempts to define the latter in a somewhat Kantian (quantity first) fashion, are some well-known paradoxes described in [19] as follows.

> We can concretely illustrate the kinds of philosophical problems that the philosophy of information confronts by examining three paradoxes that have received much attention in the literature. The inverse relationship principle, as identified by Barwise and Seligman (1997) [32] above, may seem intuitive at first glance, but as it stands, it leads to two problems with counter-intuitive outcomes. The first was framed by Jaakko Hintikka (1970) [33] which he named the “scandal of deduction.” The second was identified by Bar-Hillell and Carnap (1952) [34] and is accordingly called the Bar-Hillell-Carnap Paradox. The third involves Nor-

bert Wiener's (1950) [35] conflation of meaning with information and appears in Dretske (1981) [36].

The first of these paradoxes – the scandal of deduction – is recounted by A. Beavers in the following paragraph [19]:

> Consider again the inverse relationship principle, that the informativeness of a piece of information increases as its probability decreases. If this is so, then we run into problems with tautological derivations like those in math and logic. The probability that a given (correct) conclusion or answer will follow from a logic or math problem defined in a formal language is 100 percent. It is therefore, according to the inverse relationship principle, maximally uninformative. Yet, as Hintikka notes, "in what other sense, then, does deductive reasoning give us new information? Isn't it perfectly obvious there is some such sense, for what point would there otherwise be to logic and mathematics?"

The other two paradoxes are closely related to the first and even closer – to each other. Namely, they both are just the opposite of the "scandal of deduction." The former arises when the inverse relationship principle appears to force one to assign zero informativeness (or semantic information content) to a piece of information whose probability is equal to 1. On the other hand, the latter two are due to the seemingly inevitable assignment of increasingly large informativeness to pieces of information of vanishing probability, culminating in the maximum (infinite?) informativeness being associated with a contradiction.

Since, as we have seen, the amount (either quantity or quasi-quantity) of semantic information is not directly related to the quantity of abstract (syntactic) information, all possible paradoxes arising from the inverse relationship principle (IRP) have no reason to occur. Out of the three paradoxes described above, the first one is arguably the most obvious and robust with respect to assumptions. Indeed, if a probability of some result is equal to 1, it is easy to think of a situation where some quantity of abstract information would vanish and thus it would appear – regardless of whether the IRP is adapted or not – that any quantity of the corresponding semantic information should vanish as well. As has been mentioned, Hintikka, for example, believes that such a paradoxical situation arises most readily in the realm of logic and mathematics. What he has in mind is sometimes referred to – following I. Kant – as "analyticity" of these fields, meaning that, once a field and the corresponding rules of manipulations within it are established, all other truths associated with it – and not crossing its borders – can be derived in a unique fashion.

Take number theory, for example. There are still many unsolved problems – which supposedly have well-defined definite answers that are still unknown to mathematicians. The *twin prime conjecture*[62] is a good specific example of one such unsolved problem. As is stands, it is either true (most likely, according to the current knowledge) or false. Had it been already solved, we would have known that the number of twin primes (assuming the conjecture is indeed true) is infinite, and the probability of that answer would have been obviously equal to 1 – the basic complete information case. The corresponding quantity of abstract information (given by (19)) would have been equal to zero. This would not have led us to any paradox though since there would have been no new information created. On the other hand, in reality, as of today, the conjecture is still a conjecture. So the probability p_T that it is true – given the current knowledge – can be estimated to be somewhere between 0.5 and 1. If it happens to be proved true, the corresponding quantity of (new) abstract information gained is going to be equal to $0 < \log \frac{1}{p_T} < 1$. So it would be positive. The quantity (or quasi-quantity) of the corresponding semantic information would depend on the task with respect to which such quantity is determined and can in principle have a rather wide range. So a nonzero abstract information quantity corresponds to a nonzero semantic information quantity, and no paradox arises.

The way a paradox of this kind can formally be obtained is by setting the probability p_T (or its analogue in a different setting) to unity *before* actually acquiring the information confirming such an assignment. Everyone would likely agree that, in most situations, such action would not be justified. However, the situation encountered in the "scandal of deduction" indeed seems to be a valid exception to this general rule. Specifically, it seems to make perfect sense that, for any system of knowledge closed under the rules of formal logic in any of their incarnations, all possible conclusions have to be contained in the premises already – since otherwise their derivation from the premises would not be valid. On the other hand, it has been known for a long time that finding a correct derivation of anything of nontrivial nature is almost never a simple task. In fact, as was shown by S. Cook in [37], the problem of determining whether a given propositional formula is a tautology is NP-hard, i.e. unlikely to be solvable in polynomial time, or, put simply, computationally intractable for a sufficiently large size. The author of the "scandal of deduction" paradox, J. Hintikka, proposed to distinguish between "depth" and "surface" information, with the implication that, while the quantity of the depth information stays constant during a derivation, that of the surface information keeps increasing and may potentially equal the quantity of depth information.

[62]This conjecture states that there does not exist the largest prime p such that $p + 2$ is also prime. Put slightly differently, it claims that the number of prime pairs $(p, p + 2)$ is infinite.

M. D'Agostino and L. Floridi in [38] explored a similar approach, the main goal of which was to shed some light on the source of the known difficulty of formal proofs and deductions in (formal) logic and mathematics. Following the general method of "natural deduction" originally proposed by G. Gentzen [39], they modify it to arrive at a system of natural deduction with signed formulas (i.e. propositional sentences with an attached binary truth value) for classical propositional logic, formulated as a set of *nineteen* "natural deduction" rules. They then take a closer look at these rules with a view towards the ones that are not truly "analytical" but have a "synthetic" or "augmentative" moment in them. They identify exactly *four* such non-analytical rules out of nineteen. Having identified these four analyticity violating rules, they proceed to modify them in such a way that the resulting system is still complete. It turns out that it is sufficient to remove one of the "offending" rules (the rule termed RA in [38]) and replace the remaining three with their appropriate strictly analytical counterparts. The result is a formal logic system that is consistent but weaker than the classical propositional logic. The four non-analytical rules eliminated from the original system rely – according to the definition adapted in [38] – on *virtual information* [38]:

> The reasoning agent who applies these rules has to make an effort to go (temporarily) beyond the information which is actually given to her, use some "virtual" information and then come back. This stepping out and in again of the given informational space is what makes the informativeness of classical propositional logic so invisible and yet present.

Indeed, in everyday practice of mathematics, the phenomenon described in [38] is encountered on a regular basis. To give just one well-known example, the recent proof of Fermat's Last Theorem by A. Wiles and his collaborators relied heavily on the theory of modular forms (i.e. complex analysis) whereas both the premises and the conclusion of the theorem lie within the scope of number theory. A remarkable result of [38] is that the modified strictly analytical logical system is no longer intractable: the revised deducibility is decidable in polynomial (quadratic) time.

Going back to the general concept of information developed in the present article, at a first glance, it may even appear to not be applicable to the matters discussed here. Indeed, at a first glance, there is no material object, process, or any entity that is represented by abstract mathematical of formal logical objects. Thus, before we can discuss our general position with respect to the information paradoxes, some additional explanations have to be made. These explanations are going to be rather brief as going any deeper into the general topic of the relation in which abstract notions of mathematics stand with respect to the material world is beyond the scope of this article. However, due to the explicitly general nature of the theme of our discussion, such brief explanations should be sufficient for the task at hand.

In a nutshell, abstract objects and constructs of mathematics – just like those in any other science – represent the ideal moment of (the totality of) purposeful human practice that takes place in the material world. In the previous subsection, exactly that was the definition of thought. So – not very surprisingly – all the intricate abstract constructs of mathematics are constituents of thought taken in its totality. The problem that is often cited in this regard is that, if we take any specific mathematical object, its relation to any particular aspect of material human practice may appear slim if not non-existent. To a superficial observer, it may indeed appear to be something akin to "a free invention of the human intellect."[63] At the same time, given the success of mathematics in natural sciences, the objective content of its constructs appears almost indisputable. Without making any attempt of recounting the various views on the true nature and philosophical meaning of mathematics, we will make some remarks directly related to the connection between the content of mathematics and the concept of information proposed in this article.

In our view, the main source of the recurring confusion about the ontological and gnoseological status of mathematical constructs is that they indeed have – as any finite entities appearing in the sphere of human nature-changing purposeful practice – both objective and subjective moments. In pure mathematics, the latter can be especially prevalent, naturally enticing views similar to those held by the early A. Einstein about the laws of nature. The reason is that, while mathematics begins as a rather direct ideal reflection of human practice (think about the early days of geometry), it later ventures into the realm of what Hegel refers to as *formal possibility*, i.e. anything that does not contradict itself but not necessarily accompanied by the totality of conditions making it possible in the real world, i.e. promoting it to the status of *real possibility*. To illustrate this point in a simple way, consider the real three-dimensional space in which all of matter exists with its universal motion and universal bond. Once the human practice comes to the realization that a coordinate system may be introduced in real space so that all geometry phenomena can be described in the language of algebra (and later analysis), it becomes a matter of simple external addition to consider configuration spaces with an arbitrary number of dimensions. Such multidimensional spaces do not exist[64] as configuration spaces in the real world but find practical use, for instance,

[63]This view was held by A. Einstein – especially in his earlier years of staunch adherence to Machist philosophy.

[64]String theorists would not agree with such statement as, in their currently prevalent view, the real world possesses 9 or 10 spatial dimensions (respectively, 10 or 11 if one counts time as one of them) in such a way that 6 or 7 of them are "compactified" on a ultra-miniature (Planck scale) manifold, at every point of the observed three-dimensional configuration space. We are going to say more about these issues in Appendix B.

in optimization, where they become spaces spanned by decision variables. When mathematicians working in the field of optimization design new algorithms, they do it using the tools of algebra and analysis, but the geometric analogy between real three-dimensional and arbitrary higher-dimensional spaces often play an important heuristic role. The use of such geometric analogy, for example, makes it immediately obvious that, in linear optimization, optimal solutions are to be found among the vertices of the feasible region polytope (the idea that gave rise to the Simplex algorithm).

Such "expansion" in the realm of formal possibility is what gives mathematics much of its power and leads to discovery of important interconnections that would otherwise stay hidden for a longer time. This observation on the mode of operation of mathematics emphasizes the *universal integrator* role that the human practice plays in the material (or, perhaps, more precisely, substantial) world taken as a whole. Namely, it speeds up and sometimes completes the universal motion of matter understood as the constant transmutation of all its forms. The unity of all material world – together with its ideal side – comes to light fully in the purposeful human practice, however primitive and undeveloped the latter may still be in the present quasi-intelligent transitional stage of the intelligent form of the universal motion evolution. The intelligent human practice – even though being in its infancy as such – is still a rather developed form of the universal motion as far as such forms go. Being such a form, it possesses a developed ideal moment that is no longer just a "shade" of its material counterpart, but takes on existence and dynamics of its own that are relatively independent of – but still inseparable from – those of the material moment of the whole. It is that relative independence which is the main cause of the typical difficulties one experiences in trying to directly relate the content of mathematics to anything in the real world. The relation is there but it is typically heavily mediated (as opposed to immediate).

Speaking specifically about the "scandal of deduction" paradox viewed from the standpoint of the proposed concept of information, there is really no compelling reason to single out the situation of formal logical deduction from any other such associated with an acquisition of additional information in the course of purposeful practice. The whole reason the paradox in question has arisen is that there is a strong "intuitive" sense that the information obtainable by a formal deduction of this kind is objectively "already there," so that the deduction itself is not "creating" it but only "revealing" in a significantly weaker sense. Most likely, what makes the "already there" argument especially compelling is that the corresponding formal logical or mathematical system appears to be "a free invention of the intellect" and therefore devoid of any irrelevancies unavoidable in the real world and – being a free creation – is already there in its complete form. Given the basic axioms of the system in question, what can be derived from them has to be already fully contained in the axioms, with no possible new additions being allowed by the very construction of the system by fiat of the intellect.

But, from the point of view developed in this article, information related to such formal systems is not fundamentally different from any other information. Any information is an ideal representation of the material world in some of its infinitely variable forms and aspects. In some cases such a representation is most immediate, in some other cases – rather intricately mediated. For any information actualized in the sphere of human practice (i.e. semantic, or "semantised," information), the mediative entity is the human practice itself. Formal systems created in the course of such practice and reflecting some essential forms of the practice and the real world, which is its subject, can be – by virtue of richness of the entities they reflect – highly nontrivial. Even when efforts are made to make such systems closed and entirely self-sufficient ("rigorous"), the ones that are sufficiently rich to be useful for the nature-changing practice successfully resist such attempts. The famous Gödel's theorems as well as M. D'Agostino and L. Floridi's recent uncovering [38] of virtual information in the simple propositional logic are two demonstrations of such resistance.

Moreover, even in nearly trivial formal systems – like the modified strictly analytical system discussed in [38] – where finding a derivation of any conclusion from the premises is relatively easy, there is no fundamental reason to worry about such deduction being completely devoid of informational content. Upon closer inspection, it becomes relatively clear that the foundations of the "scandal of deduction" paradox are of an "intuitive"[65] nature. One such argument is that the information in question is "already there" and hence there is nothing to discover. But this is true about all the information in the universe – it is already there, waiting to be actualized. Without too much exaggeration, it can be even claimed that the proverbial droplet of water contains – due to the fundamental unity in all the multitude – the essential information about the whole universe (most of it *in-itself*, or *in potentia*) to someone sufficiently intelligent to read it off. The second argument leading to a paradox is that – due to analyticity of the system – the information in possible conclusions of various deductions is in some sense "easy to obtain." A simple inspection of one's surroundings would however reveal that such ease of obtaining is enjoyed by a lot of other information instances about the real world – given that the agent obtaining and actualizing the corresponding information possesses the required level of intelligence. Thus, as we have already

[65]Not surprisingly, intuitive reasoning is widely used in all philosophy of information related literature. To give just one example, in one of the more insightful works [38] cited earlier in the article, the word "intuitive(ly)" is used ten times (and, in addition to that, there are two instances each for "intuition" and "counterintuitive"), with all instances of its usage carrying important for the narrative meaning. The reason for such extensive use of intuitively justified arguments is clearly the current lack of rational understanding of the nature of information.

stated, information obtained in the course of a derivation in a formal system is no fundamentally different from any other type of information. Figuratively speaking, paradoxes of information arise when one draws a line in the sand with a toy shovel (or a golf club) and forgets[66] that the sand on both sides of the line is the same.

To wrap up our discussion of probability paradoxes, let us revisit the one on the opposite side of the spectrum – the Bar-Hillell-Carnap (or Wiener) paradox. While the "scandal of deduction" arose from an observation of seemingly vanishing quantity of information in certain situations, the BHP paradox obtains as a consequence of apparently infinite amount of (abstract) information encountered in a logical contradiction. Indeed, if (the universal form of) the prior state of information assigned a zero probability to any state s_i ($q_i = 0$), then an occurrence of an event implying the state s_i (and thus setting the updated probability p_i of s_i to unity) would lead to the quantity of abstract information equal to

$$I(p, q) = p_i \log \frac{p_i}{q_i} = \log \frac{1}{0} = \infty. \tag{23}$$

If one uses *intuition* again, an infinite amount of any information is bound to be very informative, whatever the meaning of the latter is. But, on the other hand, equally *intuitively*, a contradiction is just a logical impossibility, a piece of nonsense, and, as such, should not be informative in the least.

Indeed, the reason the quantity (23) happens to be infinite is finding out that something which was previously deemed impossible happened. The obvious practically reasonable conclusion in such a situation would be simply to dismiss the prior beliefs as erroneous as they have been refuted by reality. Thus the infinite quantity in (23) would be assigned a purely subjective (in a bad sense) status, with no further consequences ensuing. Formally speaking, if we insist that information be truthful, such a resolution would also work in a theoretical framework as was indeed done in L. Floridi's concept of semantic information described in detail in [31]. We will have more to say about what role truthfulness plays in our information concept in the next section, but, as far as this paradox goes, there is another aspect to it that is worth a brief discussion here. Recall that, in Hegel's logical system, contradiction plays a special role. We have seen it already in this article how establishing a contradiction with its subsequent resolution leads to novel forms not present previously (before the resolution) in either side of the contradiction. According to Hegel, the logic of a contradiction and its

[66]Which is not al all difficult to do if one believes that a system that proclaims, for example, that "The facts in logical space are the world. The world divides into facts. Any one can either be the case or not be the case, and everything else remain the same." is directly related to philosophy, while Hegel, about a century prior, had already identified such views as belonging to the sphere of contemplation, the pre-cognition phase of the study of the world. We will say more about the regretful developments in philosophy in Appendix A.

resolution is valid in both ontological and gnoseological sense (for Hegel, their distinction is only relative).

The contradiction giving rise to the BHP paradox – like any contradiction – needs to be resolved. Depending on the nature of the contradiction, the resolution may take place into the *null* (in Hegel's language) or into something more interesting (in an innovation mode, in a more modern language). In the former case, we are talking about the standard dynamics of information where it gets updated and, under the circumstances being discussed, corrected. The infinite quantity of abstract information then indicates either a misinterpreted prior or indeed a radical change in circumstances which made possible what was previously impossible. In the latter case, the corresponding semantic information quantity could indeed be high. But, even in such a case, the previous information would be dismissed as no longer relevant. The more interesting case is where the contradiction can have a non-trivial resolution creating something entirely new that can't be described using the old set of states s_i providing "support" for the information universal form. In such case, both the prior q and posterior p universal forms are still valid, and the novel entity obtained as a resolution of the contradiction between q and p is at the same time in agreement with q and p and a negation of both of them.

In the history of science, there are numerous examples of resolved contradictions (although in a sporadic fashion, without a conscious realization of what exactly was done from a logical standpoint) as well as identified but still unresolved ones. Not surprisingly, the latter occasions were accompanied by delayed further progress. To give a couple of simple and well known examples of the former, consider the history of invention of Cartesian coordinates in space by their namesake, R. Descartes. The problem he was facing at the time was that of a quantitative characterization of positions in three-dimensional configuration space. The contradiction was that, while any quantity is necessarily simple and "one-dimensional" (being first negation of quality), there is an infinite multitude of various directions in space, and any distance (as a well defined quantity) is not sufficient for position characterization as it leaves the direction undetermined. Concisely put, one can say that there was a contradiction between the simplicity of quantity and the inherent "directional structure" of physical space. In order to put the two together, a coordinate system was invented that embodied both sides of the contradiction in one novel entity. Indeed, the position of any point in space is described by three quantities (Cartesian coordinates) such that each one of them is simple but together they capture the directional nature of physical space. The compromise, so to speak, is that the three quantities are not what is now called "scalar," i.e. they depend on the choice of coordinate system and change with the latter. The now indispensable *vector* quantities are also the result of a resolution of the same contradiction. Any vector, upon a closer look, reveals clear signs of that contradiction: the coordinate independence (or coordinate invariance) of any vector is achieved via explicit coordinate dependence of its components, the collection of which constitutes[67] the vector.

The second good example of a successful contradiction resolution in science history is related to the early days of statistical thermodynamics. The nature of heat energy was the main question. It became clear that mechanical motion could be converted to heat as well as the other way around. This implied that, in some fundamental way, they were the same. At the same time, it was clear that they were different: while mechanical motion takes place in space and has a definite direction and speed, heat appears to be just some amorphous non-directional mass of some mysterious substance. So a specific heat carrying substance – the *caloric*[68] – was hypothesized to exist and be able to flow in and out of physical bodies. How such substance could be same with directional mechanical motion was a mystery. That was the contradiction encountered: heat had to be the same and not the same with mechanical motion at the same time. L. Boltzmann was the one who expended a lot of energy[69] trying to resolve this contradiction and defending the corresponding views until they finally prevailed, primarily as a result of the study of Brownian motion. The contradiction resolution amounted to, as everybody knows, the realization that heat was just a consequence of *omnidirectional* chaotic *mechanical* motion of atoms or molecules constituting any physical body capable of accepting and releasing heat.

W. Ostwald's and E. Mach's *energetics*, banished from thermodynamics by the first decade of 20th century, did not stay outside of the building of physics for long. It promptly returned wearing a slightly different outfit. Having established the existence of atoms and molecules, physics was busy exploring the next level. The inner make-up of atoms, molecules, as well as the true nature of electromagnetism and light were on the agenda. Contradictions kept arising, but their proper resolutions proved to be more than the research community could handle at the time. Since a good size book can be written about that story,[70] we will mention just one of these contradictions. It is the famous *wave-particle duality* which

[67]Recall that the standard definition of an arbitrary vector is that of an object whose components transform under a rotation of a Cartesian coordinate system in the same way as components of a radius vector.

[68]As we have already discussed, this hypothesis was used by S. Carnot in the derivation of his famous expression for a heat engine efficiency.

[69]As is well known, his opponents were rather vocal and influential at the time. Two of the most prominent of them – W. Ostwald and E. Mach (the originator of Machist philosophy whose views influenced the early A. Einstein) – were promoting *energetics* – the general view in which energy was put forward as the primary "substance" of which matter was a kind of epiphenomenon: "Matter is therefore nothing but a group of various forms of energy coordinated in space, and all that we try to say of matter is really said of these energies." – as W. Ostwald proclaimed in [40].

[70]We recount some of it in Appendix B.

was found to be true for both light and massive “weighty matter constituent” particles like electrons, protons and neutrons. The contradiction was clear: the same objects could behave – depending on circumstances – as either a point particle or as a wave in some medium. The stage for a resolution of this contradiction – and thus for the uncovering of the *essence* (in Hegel’s sense) of such phenomena – appeared to be set. Unfortunately, it was not meant to be. Instead, as already mentioned, energetics showed up again and confused the physicists. In W. Ostwald’s words from [40]:

> Energetics offers us a means of fulfilling in its true sense the demand of Kirchhoff so oft misunderstood, namely, **the substitution of the description of phenomena for the so-called explanation of nature**.

Such “description of phenomena” from then on to a large extent took place of “the *so-called* explanation of nature,” just like W. Ostwald intended. So, in particular, instead of uncovering the essence of subatomic phenomena, physicists were growing increasingly content with their – albeit often ingenious and successful in the sense of agreeing with result of experimental measurements – descriptions. The wave-particle duality contradiction, in particular, got swept under the proverbial rug of N. Bohr’s *principle of complementarity*. The latter principle pronounced itself content with just the statement of the contradiction and proclaimed its resolutions unnecessary and, in fact, impossible.

Going back from the examples to our current main theme of the BHP paradox, we can summarize the preceding discussion by stating that this particular paradox turns out to be more interesting than could originally be anticipated. The formally infinite quantity of abstract information that is the paradox’s premise can indeed, under certain circumstances, give rise to a very high degree of informativeness, or, more precisely to a large quantity (or quasi-quantity) of semantic information. The circumstances in question are those that make possible a resolution of the corresponding contradiction in an innovation mode, i.e. not into the *null*, in Hegel’s language.

4.6 Philosophy of Information: where do we stand on its foundational questions?

Albeit still very young, the field of Philosophy of Information already has at least two interpretations: figuratively speaking, “small-p” and “big-p,” with the latter being stronger and subsuming the former. The “small-p” version seeks to use the traditional philosophical methodology to resolve fundamental questions concerning information, the first and the main of them being the *ti esti* one. The stronger version attempts to go further by using information as a fundamental notion to either revise or to expand upon the philosophical methodology. We are rather inclined to side with the "small-p" interpretation as it appears to be fairly clear that information as an entity (ontologically) and as a subject of study (gnoseologically) is sufficiently fundamental to warrant an explicitly philosophically centered and motivated study, i.e. a study with an explicit emphasis on the *unity in multitude*. On the other hand, we believe that one should carefully avoid narrowing down of philosophy itself, especially by borrowing methodologies, points of view etc. of particular sciences. The main function of philosophy per se is to help particular sciences maintain the general view of unity in any multitude and to avoid, figuratively speaking, inventing methodological bicycles that are clearly inferior, oftentimes belong to rather distant philosophical past, and are detrimental to scientific progress.[71]

Having stated our general position, let us discuss some of the 18 questions formulated by L. Floridi in the order they appear.

P.1: The elementary problem: What is information?

According to the founder of Philosophy of Information, L. Floridi, "This is the hardest and most central question in PI" [3]. We fully agree with this evaluation. At the risk of sounding repetitive, we are going to note that answering this very question is the main goal of the present article. At the risk of sounding overly pretentious, we are nevertheless going to state that the elementary problem of the fundamental nature of information as such has been largely solved here. We will briefly recount the main results in the next section, for the benefit of potential readers with limited time on their hands. Here we wish to only comment on the specificity of the problem, the methodology required for its proper solution, and on the main reasons for the previous attempts coming a bit short.

As was clear already to N. Wiener more than half a century ago, information is a fundamental entity at the scale of matter and energy. So the rational exposition of the true nature of information is a problem tailor-made for a *proper philosophical* treatment (in a more narrow sense). Having made such a statement, an explanation of what we mean by that is clearly in order. A more or less exhaustive explanation is a decently long story – requiring a historic excursion and much beyond the scope of this article – that we hope to be able to expound on in the future. In a nutshell, in the present state of scientific knowledge, the main function of philosophy as such (in the narrow sense[72]) is to provide particular sciences

[71]Indeed, the history of sciences is filled with instances of people inventing general "principles" on the basis of particular observations or even guesses, with *lègèreté extraordinaire* and youthful exuberance, absolutising these principles in short order and thereby applying both feet on the brake of the science vehicle. Many of the consequences of such philosophically ignorant behavior are still alive and well.

[72]In the current nomenclature of disciplines, philosophy is usually understood in a significantly wider sense

with ways (methodological tools, so to speak) of a *rational exposition of unity in multitude*.

Information, being the fundamental entity it is known to be, is naturally a unity in its rather pure form, but, at the same time, being a universal omnipresent entity, it shares its multitude of specific forms with literally the entire world – that includes phenomena from the natural, the mental, and ideas "sub-worlds" (in the sense that K. Popper was trying to assign to them). So finding unity in this multitude becomes the core of the problem at hand. This means that anything else (or less) than a proper philosophical treatment of this problem is unlikely to succeed. In particular, a still typical for particular sciences empiricist approach, that begins with various forms of information appearance on the surface and attempts to generalize on the basis of the preferred (i.e. more or less arbitrarily selected) type of "family resemblance," can be said – without much exaggeration – to be doomed from the beginning, as far as solving the *elementary problem* is concerned.

To see some examples of empiricist approaches that had to stop short due to their failure to do justice to the fundamentality level of the *elementary problem*, one can simply look at the page of [3] where the latter problem is described. To cite just a couple of examples (direct quotations below are all from [3]):

- "the communication theory approach (mathematical theory of codification and communication of data/signals, Shannon 1948; Shannon and Weaver 1949) defines information in terms of probability space distribution." As we now know, Shannon's (mathematical) communication theory takes advantage of managing (in a largely empirical fashion) to get hold of the *quantity of abstract information*, which is what happens to be important in communication problems. As far as the fundamental theory of information goes though, such approach can serve as a useful hint and a relief from doing extra work (since all Shannon's results are already available in a nice easily usable form) in the process of developing the said fundamental theory, but a suitable beginning for the latter it is not.

- "the probabilistic approach (Bar-Hillel and Carnap 1953; Bar-Hillel 1964; Dretske 1981) defines semantic information in terms of probability space and the inverse relation between information in p and probability of p." Same comments as above apply here as well, with the difference that this approach is somewhat more empirical and superficial than the communication theory based one. This approach is a classical example of the "quantity first" way of thinking made especially popular by the proponents of modern (20th century) theoretical physics. In this case, before anyone had any chance

than that. Vulgarizing a bit, one can say that philosophy in a wider sense often means "general overarching thoughts about any subject."

of understanding what information is, its quantity (i.e. the quantity of that mysterious something) is already presented. It is understandably difficult to move further from such a precarious position. Moreover, in order to define the mysterious information quantity, probability is used as a given premise. On the other hand, as we now know, probability distribution itself is just a (universal, or ideal) form of information, and an attempt to *define* information starting from probability constitutes a major reversal of the proper logical flow.

- "the modal approach defines information in terms of modal space and in/consistency (the information conveyed by p is the set of possible worlds excluded by p)." Besides empiricism, this approach suffers from a rather acute case of abstract formalism (we will say a bit more about this general tendency shortly). Without a serious attempt of coming to terms with the one and only world everything (including information) resides in, it takes off on afterburners into the stratosphere (or even mesosphere) of an infinite multitude of imaginary "worlds." After such a radical multiplication of entities that would have probably given William of Occam an immediate heart attack, any further progress in rational comprehension of the *unique* (if taken in its totality) information pertaining to the *unique* world of ours becomes an exercise in wishful thinking.

Before we turn to the status of the next problem, let us note in passing that the lack of a proper philosophical treatment we are discussing here hasn't been revealed by the problem of the true nature of information for the first time. Rather, it already has quite a respectable history. Details of this history being a good subject for a book, we can only point out that, at some point, philosophy lost its lead role among sciences which was fully understandable as far as the specific content of particular sciences was concerned. What was less understandable and hardly justifiable is that philosophy also relinquished its hold of the *logical* aspect of the particular sciences essentially letting their representatives develop the logical and rational components as they saw fit. Quickly, mathematics and fundamental physics came to the fore and started filling the logical void left by the overly shy philosophy that meanwhile veered off into "softer" subjects and concentrated on exploring the inner world of a stand-alone individual.

A quick expansion of sciences was accompanied by the ever-increasing fragmentation and specialization, so that experts in certain fields were having difficulties understanding the content of the work of even their close neighbors. So when physics and mathematics (and other natural sciences) faced new challenges (like, for example, understanding the true nature of light, electromagnetism and, a bit later, of atoms and subatomic particles, in the case of physics) that put higher demands on their logical components, philosophy wasn't there to help them. This left the more inquisitive – but poorly philosophically prepared –

scientists and mathematicians of the fast advancing narrow specialization era with the task of filling the logical and rational void to the best of their sometimes exceptional but almost universally woefully philosophically unprepared ability. The result of their collective efforts on the logical front – not very surprisingly – was a return to the Kantian, if not Humean, stage, but at a very different level of formalism (borrowed wholesale from mathematics) in the quest for "precision" and "rigor" of expression.

Physics, in its turn, struggling with the new challenges and left without an adequate logical help, resorted to what Hegel referred to – almost a century prior – as the *synthetic method* [1], p.725:

> If geometry, like algebra, quickly runs up against its limit with its abstract subject matter, suited as this is only to the understanding, it is evident from the start that the synthetic method is all the more insufficient for *other sciences*, and most insufficient of all for philosophy.

Specifically, physicists – primarily those of the theoretical specialization – began inventing *principles* and *postulates* on the basis of often limited and inconclusive experimental evidence and trying to derive other laws of nature from such principles in the style of Euclid's geometry, totally unsuitable to the task at hand. Hegel describes this phenomenon that reappeared a century later but still had the same content – not entirely unexpectedly due to the historic "roll-back" of logic mentioned above – in the following words [1], p.725:

> The *reflective determinations* of particular *forces*, or of otherwise inner and essential forms, which are the *results* of an analysis of experience and can be justified only as such *results*, must be *placed at the top*, in order to obtain from them a general *foundation* that can then be *applied to the singular* and be instantiated there. Since these general foundations have no hold of their own, we must *simply grant them* in the meantime; it is only in the derived *consequences* that we notice that the latter are in fact the ground of those *presuppositions*.

When philosophy returned to the natural science scene, it was either overwhelmed by the expansion of their scope, or too impressed by the advances in technology made – as it appeared – with the direct participation of the said sciences, or exceedingly awestruck by the developed "rigorous" and complicated looking formalism – it is difficult to point out the most compelling reason.[73] But the unfortunate result was that philosophy from then on seemed content to follow in the wake of the particular sciences and mathematics, interpreting

[73]We will say more about these matters in Appendix A and Appendix B.

and "generalizing" their findings and views. In the more extreme instances of this general trend, there were even – sometimes openly obscurantist and anti-philosophical – attempts of equating philosophy with the diligent study of the "language of science."[74] Thus, as it turned out, the collective particular sciences were unable to fill the place temporary vacated by philosophy, and philosophy itself got disoriented in the turmoil and – for some time – lost the sight of its main mission in the advancement of reason. The sooner it recovers the abandoned positions and moves forward again, the better it will be for all of us.

P.2: The I/O problem: What are the dynamics of information?

According to L. Floridi [3], "the question does not concern the nature of management processes (...); rather, it concerns information processes themselves, whatever goes on between the input and the output phase." A few lines down, it is added: "How is it possible for something to carry information about something else?" Taking the "input/output" language use here as a metaphor exploiting the current proliferation of computing devices and everyone's familiarity with their basic functions, we have to agree with the formulation of this question and its importance. We would only like to additionally emphasize the level of fundamentality of the information dynamics problem approached from the proper philosophical standpoint it demands.

Taken in its proper generality, the dynamics of information coincides with the dynamics of *the ideal* (the dialectical *other* of *the material*) as a whole. At the highest level of generality, the dynamics in question most likely can be rationally understood with the help of Hegel's famous (and much maligned and abused in the past) *triad*, i.e. the proverbial *double negation*. As we have already discussed earlier in this article, at the lower levels of matter organization (and forms of the universal motion), the ideal and the material are almost *indistinguishably one*. If one takes any (relatively) separate material entity, its material form carries multiple "imprints" of other entities. Taken as a whole though, the ideal is a permanent "shade" of the material, and, as far as we know at this time, in the forms of matter motion prior to the biological one, it (the ideal) plays no active role. The *first negation* of this "fused" state, is a *separation* of the ideal from the material, which begins with the advance of the biological form and – as far as we can tell at this time – reaches its fully developed form somewhere in the transitional stage from the biological to fully intelligent (i.e. around where we are now on the evolutional scale). At this stage, the ideal – and hence information – is active and can live "its own life" to a large extent. That relative independence of the ideal is ultimately

[74] And the science the language of which was supposed to hold keys to further advancement of philosophy was that same science that had been the result of the recent philosophical *la reculade* to mostly pre-Kantian positions. The fast proliferation of new experimental results only complicated matters as the obsolete methodological "equipment" was unable to adequately cope with it.

the main source of, for example, the subjective idealist trend in philosophy.

Logically speaking, the next step of the large scale evolution of the ideal is the *second negation* and thus *a kind of* a return to the original state of "fusion" between the ideal and the material. But this negation being a dialectical one, the return is only *a kind of* a return. This means that, at the resulting stage, the ideal and the material are again together, but not in the way they were together before the first negation. There, the ideal was just a "shade" of the material with no active role to play. On the other hand, upon the second negation, the active role of the ideal is still intact, but its indifference to the material and the relative independence it enjoyed after the first negation is gone. Figuratively speaking, one can say that the material becomes fully intelligent, and the ideal takes on a fully active – and indispensable – role. Before the second negation, the ideal as a whole, in spite of its relative independence of the material, is largely developing sporadically under the influence of consciously unrealized and uncontrolled "forces" of mostly material nature. As far as we can tell at this point, the second negation corresponds to the emergence of the fully intelligent form of the universal motion that can be called the (*homo sapience proper*). While it is probably true that we can now strive to achieve only a limited rational understanding of the logic of this second negation, it might very well be also true that we will *have to* somehow achieve a *sufficient* rational understanding of its logic to facilitate a relatively smooth transition to that form, and, quite possibly, to make sure it takes place. It is already fairly clear that this form is our only possible collective destination. Looked upon from this angle, therefore, the problem of understanding the information dynamics takes on somewhat unexpected proportions and import.

As to the more specific question of information dynamics ("How is it possible for something to carry information about something else?"), as far as its philosophical aspect is concerned, the answer to it – following from the developments presented in this article – appears to be rather straightforward. To quickly recap, the fundamental reason it becomes possible is the existence of the *universal bond* in all of matter, thanks to which all (relatively) separate material entities are related and hence carry "imprints" of each other which can be more or less "detailed." These imprints are simply some changes in the material form of the entities in question. To give a rough analogy, consider a key and a lump of clay. The key can be pressed against the clay to produce a physical imprint of the former in the latter. When the key is removed, what's left is the same lump of clay whose form now carries information about the key that is sufficient for its reproduction. At the same time, there is not even a modicum (disregarding the microscopic amount of the key metal left behind upon the physical imprint) of the key itself in the lump which now represents the key *ideally.* The information per se about the key is obtained – as we remember – by abstracting from the material form of the lump (its material, density, texture etc.), so that only the ideal form of the key is left. All other "imprints" of material entities in each other are similar to this key imprint in clay: the material form changes and these changes carry information which itself is indifferent to the particular material form (and thus information itself is a resolved contradiction).

The particular material details of various imprints are as multifarious as the forms of matter itself. The practical aspect of "reading off" the particular specific information from a particular material entity can be a very challenging problem. But such potentially complicated details do not concern the philosophical aspect of the question of the possibility of information carrying which, as we have stated above, becomes straightforward once the fundamental concept is obtained.

P.3: The UTI challenge: Is a grand unified theory of information possible?

It is stated in [3]: "The reductionist approach holds that we can extract what is essential to understanding the concept of information and its dynamics from the wide variety of models, theories, and explanations proposed. The nonreductionist argues that we are probably facing a network of logically interdependent but mutually irreducible concepts." W. Hofkirchner, however, argues in [41] that the correct approach to the unified theory of information is neither reductionist nor nonreductionist (which seems to deny the possibility of such unified theory altogether) but rather what he calls "integrative." The latter approach, according to W. Hofkirchner, is a *sublation* (in the sense of Hegel) of reductionism as well as projectivism and disjunctivism. In particular, W. Hofkirchner is a firm believer in the feasibility of a (grand) unified theory of information. We would have to agree to his evaluation in this regard and also with his foresight about the methodological aspect of developing such a unified theory.

The present article is, in a certain sense, a realization of W. Hofkirchner's plans of developing a unified theory of information at the level of fundamentality the subject requires. What we have here is far from a complete theory of all known manifestations of information in specific environments. At the same time, we are fairly certain that any such manifestation can be rationally understood and studied within the developed framework. Moreover, any significantly different overall framework would most likely lead to either an impossibility of extending it for the purpose of a rational understanding of a certain class of informational phenomena or to the need to resort – at some point – to some kind of intellectual discontinuous "leaps of faith" resulting in an invention of some ad hoc empirical "principles" or "postulates" and in standard logically circular arguments (as noted by Hegel) after that.

P.4: DGP, the data-grounding problem: How can data acquire their meaning?

The data-grounding problem – together with the immediately following problem of data alethization – is one of major beneficiaries of a proper philosophical treatment of information. The latter is relatively straightforward – as we have mentioned a few times already – due to extreme generality of the subject. To discuss the status of the data-grounding problem in the light of the developed fundamental concept of information, we need to say a few words about the nature of data. Given the standard usage of the term "data," it appears that the meaning that can be best assigned to it is that of *information in a particular material form*, or, figuratively speaking, "*undercooked information*," i.e. information that has not yet been "distilled" to its purely ideal self. It appears that the term "data" is used both in a narrow sense (where it means data produced with a direct participation of humans) and in a wider sense (where it means any "uninterpreted differences," to quote L. Floridi in [3]). Due to the nature of our overall subject, in the following, we will refer to data in that wider sense.

Since we are interested in *meaning* in this problem, we only have to concern ourselves with the information actualized in the realm of human practice (i.e. the totality of purposeful nature-changing activity) – what we have identified as semantic information (or, more precisely, information that has a semantic aspect to it). For any given instance of information of this kind, there is some data – understood in the wider sense as defined above – that plays the role of a "carrier" of this information. The meaning of these data is clearly the same as that of information it carries. How is that particular meaning acquired? The short – and rather obvious once we have made the problem clear – answer is that this *information (and data) acquires its meaning in the course of totality of all human practice* that is somehow – directly or otherwise – related to it. The human practice, being a rather developed form of the universal motion (even in its present transitional phase), goes through multiple transmutations from the material to the ideal and back. It is the totality of these numerous transitions in the course of practice that imports meaning to information (and the corresponding data). On the other hand, if one takes some *isolated finite* instance of data, it could be very difficult to point out (to make a list, so to speak) of instances of human practice (and the corresponding numerous material-ideal transmutations) that "have had a hand" in importing meaning to these particular data, for the obvious reason of vastness of the practice that has had taken place so far (up to the given data occurrence) and its universal interconnection.

The following quote from the article [42] of S. Harnad is given in [3]:

> How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads? How can the meanings of the **meaningless symbol tokens**, manipulated solely on the basis of their (arbitrary) shapes, be grounded in anything but *other meaningless*

symbols?

We can say that the worries of S. Harnad and L. Floridi about the "groundedness" of the meaning of various formal symbols in the variety of their uses are not at all ungrounded. We fully agree with their evaluation and find this occasion convenient for pointing out that the loss of meaning of symbols alluded to in the quoted passage is an everyday occurrence in the current practice in general and in the scientific practice in particular. The fundamental reason for such possible and actual loss of meaning is the high degree of relative independence of the ideal component of the human practice in its present state from the material one that we have mentioned most recently in the discussion of the problem *P.2*. This implies that the most clear-cut examples of this kind of meaning loss is likely to be supplied by the areas of endeavor that are most removed from the material component of the human practice.

Indeed, numerous such examples can be found – albeit not without going through a rather steep learning curve of the subject, its history, and philosophy – in the "loftiest" branches or theoretical physics such as string theory, supergravity, relativistic cosmology and the likes. Due to a rather severe lack of experimental data and the inadequacy of the logical/philosophical foundation, these fields have relied on symbols getting their meaning precisely from other symbols – as S. Harnad has warned in [42] – for a long time. Moreover, the symbols found in the beginning of such long chains of "inter-symbol meaning transfer" were often grounded in some shaky foundation – both in experimental and logical/philosophical aspects. Some examples of such meaning loss will be given in Appendix B.

P.5: The problem of alethization: How can meaningful data acquire their truth values?

As we have mentioned above – and as L. Floridi stated in [3] – this problem is closely related to the previous one. Therefore same comments largely apply to the present problem as well. Namely, just like the meaning of any data carrying semantic information has the totality of human practice as its source, same is true about the truth values of such meaningful data. Just like the case is for meaning, it is generally very difficult or impossible to point out the exact instance(s) of practice that makes the particular instance of data (or the corresponding information) true.

Moreover, fundamentally speaking, any information is always true. The reason is that it represents some entity, serves as its image or reflection of sorts. Put slightly differently, if the truth value is assigned *before the meaning*, then this true value is always positive, i.e. "true." Informally speaking, any deliberate lie contains the truth about the intentions of the liar. The problems resides in being able to recognize the real content of the information in question. If the data in question is already meaningful (i.e. has been given the meaning by the totality of practice that gave rise to it), then the subjective moment of information can indeed come to the forefront, especially given the (quasi-intelligent) nature of the present day human practice. The latter is the main source of various instances of "disinformation," "misinformation" etc., largely due to the vast variety of conflicting interests characteristic of the quasi-intelligent transitional phase of humanity (looked upon as a form of the universal motion) development.

It might appear rather obvious that scientific errors, for example, are as fundamentally unavoidable as any law of nature. Therefore, truth value acquisition by any data these days or any time in the future (regardless of the state of humanity development) will always continue being a valid problem. While this may well be the case, even this problem is going, in our opinion, to be significantly alleviated once the narrow particular interests are no longer a deciding factor in human purposeful activity. Speaking of science as a pinnacle of sorts (for the given stage of humanity development) of such activity, once it develops to its properly mature intelligent form, it is bound to rid itself of most of its present sources of possible fallacies, making the problem of data alethization a lot more straightforward than it might appear from the present perspective.

P.12: The informational circle: How can information be audited? If information cannot be transcended but can only be checked against further information – if it is information all the way up and all the way down – what does this tell us about our knowledge of the world?

L. Floridi makes the following comment in [3].

> The informational circle is reminiscent of the hermeneutical circle. It underpins the modern debate on the foundation of epistemology and the acceptability of some form of realism in the philosophy of science, according to which our information about the world captures something of the way the world is.

This problem, as L. Floridi notes, is closely related to the next two. Similarly to the situation with some of the problems considered earlier, these three are also made significantly easier by making use of the proper concept of information. Specifically, the key to the problem under consideration is simply knowing what information is, in the fundamental sense. Since – taken in its totality – information is the self-representation of (the totality of) matter in all its forms, it – figuratively speaking – has nothing else to do except representing matter (in all its forms) faithfully. Taken from a slightly different angle, information has no other source but (formed) matter itself. Any bit of information does not exist without the corresponding matter, just like matter cannot exist without accompanying information. Indeed, as we have already pointed out in the discussion of *P.5*, any information is always true, it is only the meaning that has to be determined correctly.

As far as the latter (meaning determination) is concerned, there are no fundamental obstacles in its path, only situational ones. Thus, even though it may be formally true that any (new) information – in any specific instance of human practice formally isolated by our consideration – can be checked against other information, the human practice itself, taken in its totality is the constant "back and forth" between the material and the ideal, the numerous iterations of this kind gradually "distilling" the correct meaning.

P.13: The continuum hypothesis: Should epistemology be based on a theory of information?

We have already discussed the status of knowledge relative to that of information, earlier in this article. One can quickly restate the main points of that discussion in relation to the questions posed in [3] associated with *P.13*, in the following way:

- "Can there be information states without epistemic states?" The answer to this question is positive since, as we have discussed, only a small fraction of information existing in the universe has so far made it into the sphere of human practice where semantic information, thought and knowledge reside.
- "What is knowledge from an information-based approach?" As we have already discussed, knowledge, taken in its totality, can be understood as a dynamic process that is a summary and result of the process of *thinking*, also taken in its totality. The latter process, in its turn, is the ideal moment of the purposeful human nature-changing activity (practice).
- "If knowledge does presuppose information, could this help to solve Gettier-type problems?" Again, as we have already established, Gettier-type problems arise when *finite* instances of knowledge of an isolated individual are analyzed. Since anything finite is inherently contradictory, it comes as no surprise that a contradiction can be also found in the "JTB" definition of a finite instance of knowledge. If solving is taken to mean finding a completely contradiction-free version of the "JTB" definition, then Gettier-type problems can not be solved. As was already mentioned earlier, this conclusion coincides with that arrived at by L. Floridi from a different perspective.

P.14: The semantic view of science: Is science reducible to information modeling?

Explaining the motivation for this problem, L. Floridi states in [3]:

> Theories do not make contact with phenomena directly; rather, higher models are brought into contact with other, lower models. These are themselves theoretical conceptualizations of empirical systems, which constitute an object being modeled as an object of scientific research.

The situation described in this quotation is indeed typical for scientific theories development at the present stage of the development of science itself. Namely, as we have already discussed, the ideal moment of human activity in theoretical science has largely separated from its material counterpart and taken on its own life, so to speak. The contact with the material aspect of the "real world" is indeed often of a limited nature, especially in some areas of physics, mentioned earlier. In such areas, models are built on the basis of other models, in the purest sense. If the original models are faulty (and they often are), further progress becomes problematic – there are many examples of this phenomenon in the past and present of science. The issue here is not only the limited experimental base, but also the logical foundations of theories themselves that often preclude proper incorporation of the available experimental evidence into the theory. It is indeed one of serious problems of the modern science that will have to be addressed in the future.

To wrap up the discussion of *P.14*, let us cite specific questions from [3] and comment on them.

- "How do we build the original model?" This is indeed a serious problem that Hegel anticipated two centuries ago [1], p.726:

  > One of the principal obstacles in the study of these sciences is thus *the way we enter into them*, which we can only do by *blindly taking* the presuppositions *for granted* and, without being able to form any further concept of them, often not even an exact representation,[75] at best by conjuring up in phantasy a confused picture of them, we right there impress in our memory the determinations of the forces and matters that we have assumed, their hypothetical shapes, their directions and rotations. If we are asked to produce the necessity and the concept of these assumptions in order to justify assuming their validity, we discover that we are incapable of making a step beyond the starting point.

  Hegel also proposed a sketch of a correct logical approach to science, in the last chapter

[75] Here, "representation" is a translation of the German *Vorstellung* which, according to the translator, is used in two distinct senses by Hegel. In this instance, a closer translation would be something like "mental image" or "figurative representation."

of [1] titled "Absolute Idea." The sketched proposed method is referred to as the *absolute*, or *dialectical* [1], p.741:

> This no less synthetic than analytic moment of the *judgement* through which the initial universal determines itself from within itself as the *other of itself* is to be called the *dialectical moment*.

From the current perspective, the proposed method seems to imply that *the whole of science* has to be built from ground up, in strict adherence to the principle of always seeing unity in multitude, with boundaries between different disciplines eventually disappearing. While such activity appears to be the task of the future, some aspects of such development can certainly be attempted even now.

- "Is information the (possibly nonlinguistic) content of these models?" Formally speaking, it is certainly true: any model as such is an ideal image of some real entity mediated by human practice. Therefore, taken in full abstraction from its specific form of expression, it is just an instance of information. At the same time, one should not forget that any viable model is an ideal moment (possibly very "concentrated") of some more or less extensive practice which has its material moment along with the ideal one and – in its wholeness (i.e. both material and ideal moments inseparably intertwined) – is a moment of human practice taken in its totality.

- "Is science a social (multi-agent), information-designing activity?" Just like the case is with models, science as a whole, taken from the angle of its static formal content (a kind of a "snapshot" of its current state) is an (much larger compared to that of a single model) instance of information. Science as dynamic activity though is a specific moment of the totality of human practice, the latter possessing both – material and ideal – moments. In some of its aspects and branches, science as activity may indeed *appear* to be dealing with information, producing new information from old, by means of pure "brain activity" of its representatives. As we have noted a couple of times, such outside appearance is a consequence of the relative self-subsistence of the sphere of the ideal at the given – transitional – stage of matter (or substance) development.

- "Is it possible to import, in (the philosophy of) science, modeling methodologies devised in information-system theory?" Depending of what we mean by importing, an answer to this question can be positive or otherwise. If importing means just taking advantage of some particular results obtained in information-system theory in some other branches of science, it certainly can be done in a meaningful way, simply because the different branches of science explore the unity that is the world from different aspects of the multitude that the unity appears to be on the surface. On the other hand, if importing the information-system methodologies into science is taken to mean using them as methodological foundation of the latter (as the mention of the philosophy of science implies), then the correct answer is almost surely negative. The main reason is simply the currently mostly narrow empirical character of these methodologies.

P.15: Wiener's problem: What is the ontological status of information?

N. Wiener's negative definition of information was the starting point of the discussion on the nature of information presented in this article, the whole content of which can be considered an answer to Wiener's question formulated in the above fashion. Therefore, here, we are going to repeat the points most directly related to the latter. As we remember, N. Wiener used the fundamental notions of matter and energy to contrast them with the (familiar but unknown) notion of information thus implying that the latter is likely to be as fundamental as the former two. As our analysis revealed, the three are closely related and have to be discussed together.

The only *principle* underlying our analysis is the one that lies at the heart of Hegel's dialectical logic expounded in his (by far) most important work and repeated a few times earlier in this article – that of *unity in multitude.* According to this principle, the totality of the objective reality – including people and all their creations – existing independently of anyone's individual consciousness is fundamentally a unity in spite of looking like a bewildering multitude on the surface. Moreover, its diversity is not just an illusion – it is indeed a multitude. It is unity and multitude at the same time – the unity exists via multitude and the multitude is a form of unity. The latter statement is a contradiction, and the whole existence of objective reality is a contradiction that's being constantly resolved only to appear again. The contradiction gets resolved via *dynamics* – the incessant transmutations of forms of the objective reality. The totality of these transmutations, changes of any kind is the *universal motion* which acts as a vehicle of *real abstraction* (Hegel's term also discussed in [41]) for the forms of objective reality. The meaning of this term is that the objective reality *itself* abstracts from its forms by means of the universal motion constantly transforming them into each other.

If we now reproduce the real abstraction of the objective reality in an ideal fashion, we can abstract it from all possible forms leaving us with a uniform formless continuity. This is the universal *matter*. We can thus state that **matter is all objective reality taken in full abstraction from its form**. One can say that the philosophical notion of matter captures the most abstract *static* moment *of unity* in multitude, a kind of a "momentary snapshot" of it. If we now turn our attention to the universal motion itself, we will see that the latter – being the motion of the objective reality that comes in a multitude of forms – has no choice but to come in a multitude of forms of its own. It should be noted here that, when we speak of forms of motion of matter, we actually mean *formed matter* (which in Hegel's logical system is called *content*) since the proper formless matter itself can't really undergo any changes.[76] The various forms of the universal motion undergo constant transmutations as well – more or less following those of the forms of matter itself. Thus the universal motion effects its own real abstraction in its own course. Reproducing this abstraction ideally, we again obtain a formless continuity which is historically known as **energy – the universal motion taken in full abstraction from its form**. Since energy by definition is devoid of any qualities, any finite instance of energy has (determinate) quantity as its only characteristic.[77] One can say that the notion of energy captures the most abstract *dynamic* moment *of unity* in multitude.

Due to unity of all (formed) matter, all its relatively separate finite instances are related. This relation is often referred to as the *universal bond*. In any finite instance of (formed) matter, it shows itself as "reflections" of various instances (material entities) in each other. These reflections are *ideal representations* of material entities by means of other such entities' material form. The latter form, while still being the specific unique form of the entity it belongs to, possesses some features that represent other entities the material content of which is completely absent from the given entity. Such representations are of an ideal (non-material) nature but they all come in some material form. Just like the material form that carries them, these representations are subject to constant change. The universal motion does not fail to perform a *real abstraction* act on them as well. Thus we could follow suit and repeat such an abstraction in our own ideal image of the world. The result is the **universal ideal self-representation of (formed) matter taken in full abstraction from its material form – information**. Information obtained this way is not yet a formless continuity like matter and energy (what Hegel would call *pure quantity*). Being abstracted from the material form of its carrier, it still possesses an ideal form[78] that is an embodiment of its content – material entities being ideally represented by it. But the universal motion never stops, and its inescapable real abstraction can't be avoided even by information. Thus the ideal form of (specific) information is also subject to abstraction and the result is simply **abstract information** that can be thought of the most abstract *ideal* moment *of unity* in multitude.

[76]Thus the phrase "a form of matter" is strictly speaking incorrect as matter is by definition is an abstraction that is indifferent to form and separate from it. It is still a convenient expression which is used frequently and causes no harm if its correct meaning is implied.

[77]As we have discussed in more detail earlier in this article, phrases like "kinetic energy" refer to (an instance of) energy taken together with some particular form – described by the category of *content* in Hegel's system.

[78]As we have seen earlier in this article, that ideal form is itself of a universal variety and is nothing else but a probability distribution.

We see that none of N. Wiener's triad of fundamental categories is ontologically independent from the other two. Indeed, they couldn't be if they are to be moments of a true ideal reflection of the world which is a unity. In particular, information which is our main focus is not an independent ontological category either. Neither is it reducible to any other category. Together with two of its ontological "peers" from N. Wiener's negative definition, it expresses, with the highest degree of abstraction, the moments of mere existence, universal motion, and universal mutual (ideal) reflection of the fundamental unity, respectively.

P.16: The problem of localization: Can information be naturalized?

L. Floridi introduces this problem in the following words [3]:

> It seems hard to deny that information is a natural phenomenon, so this is not what one should be asking here. Even elementary forms of life, such as sunflowers, survive only because they are capable of informational processes. The problem here is whether there is information in the world independently of forms of life capable of extracting it and if so, what kind of information is in question (an informational version of the teleological argument for the existence of God argues both that information is a natural phenomenon and that the occurrence of environmental information requires an intelligent source).

As we have just discussed in *P.15*, information is fundamental and a lot more basic than life and intelligence, so to speak. In fact, there is not a single bit of matter in the universe without some information attached to it. So it appears to be clear that the question about the existence of information independently of forms of life capable of extracting it should be answered in the affirmative. Such an unconditional "yes" though would have carried some *naïveté* (or, equivalently, it would have had some of what Hegel called "an understanding that abstracts and therefore separates, that remains fixed in its separations") with it. It is true as far as any *finite* instance of information is concerned: it is there regardless and independent of a presence of a suitable living or intelligent recipient for it. If such a recipient is not available, the finite information instance in question just misses its chance of actualization. Put slightly differently, it remains an instance of information, but this time around fails to acquire a semantic aspect to to it.

On the other hand though, if one takes the world as a totality, the mere fact that the world taken in such a way is a unity implies the universal self-representation of the formed matter (objective reality), the totality of which is the ideal which is *the other* (in Hegel's sense) of the material. The ideal which is originally (in the early stages of forms of matter evolution) one with the material is going (in the first negation cycle) to acquire relative independence from it which implies the emergence of life and, later, transitional forms of intelligence. Then (as we can foresee at this point of our knowledge development) the second negation of this grand cycle of substance evolution is going to give rise to a properly intelligent form. In this sense, the existence of information indeed implies life and intelligence which develop out of it (and moving formed matter) with absolute necessity.

Let us now cite some additional *P.16* related questions stated in [3] and give our comments.

- "Are cognitive processes continuous with processes in the environment?" The correct answer here would be that they are both: continuous and discontinuous, relative to processes at lower forms of the universal motion. Slightly more precisely, they have a moment of both continuity and discontinuity in them. They are continuous in that they are moments of the same unity, and in that the forms of the universal motion within which cognitive processes appear are a result of development of the same universal motion that goes through prior (lower) forms before producing the higher ones. There are no impenetrable barriers between environment (nature in the narrow sense) and cognition, no two separate worlds, no radical Cartesian dualism. At the same time, the higher forms of the universal motion – including those immediately responsible for cognition – cannot be *reduced* to the lower forms in any way. Thus cognition cannot be understood, for example, from a chemical or biochemical point of view. In particular, it cannot be rationally comprehended as any kind of model of the brain processes (like those of neural networks), no matter how complicated. To properly understand cognition, one needs to fathom the logic, genesis, and, to some extent, the future prospects of the human society as a whole. In general, the relation between the higher and lower forms of the universal motion is that of *sublation* (in Hegel's terminology), where the higher form does not appear from a gradual development of the lower form and, on the other hand, does not in any way abolish the lower form, but rather holds it inside itself in a subordinate status. A higher form, generally speaking, appears in an abrupt fashion – thus via a *break of continuity* – from a resolution of a contradiction *developed in the lower form itself.* This is the second – *innovation*, using the more modern language (or not into the *null*, for Hegel) – mode of contradiction resolution that Hegel describes in [1]. We see again that the transition to a higher form is continuous (since it develops within the lower form) and discontinuous (since it happens abruptly, and the higher form in what the lower form was not) at the same time.

- "Is semantic content (at least partly) external?" This is true: as we have discussed, any information acquires a semantic aspect when it gets actualized in the sphere of human practice. So its semantic content reflects on the corresponding aspect of the latter. Since human practice has to do with the material world, that particular aspect of it is directly related to its specific subject which is some material entity. This implies that the semantic content of any information always has a moment determined in a way external to any subjects of human practice. It is in this sense that any semantic content is partially external. One can also say – if the particular aspect of practice and semantic information expressed by the opposing pair (external/internal) of categories is of interest – that any semantic information is also partly internal (or, more precisely, has this moment in it). The reason is simply that human practice has an active (subjective) moment to it, and any objective reality that becomes an object of human practice is changed by the latter – so it is no longer quite what it was before being drawn into its sphere.

- "Does 'natural' or 'environmental' information pivot on natural signs or on nomic regularities?" As we have discussed in the beginning of this article and earlier in this section, environmental information (i.e. information originating outside the immediate sphere of human practice) pivots on the *universal bond* present in all objective reality. The notions of natural signs and nomic regularities both describe some particular aspects of the universal bond, so one can say that, in some cases, information pivots on them as well. But since our goal here is the fundamental concept of information as opposed to particular forms of its appearance in some specific situations, both of these notions are lacking in this regard. The notion of natural signs, for example, originated in (the philosophy of) pragmatism, i.e. a radical situational empiricism. The latter method of thinking may be useful in solving situational problems, but one would not have high hopes for it when fundamental questions need to be addressed. Indeed, according to the Wikipedia article about one of the founders of pragmatism, C.S. Peirce, "in recent years, Peirce's trichotomy of signs is exploited by a growing number of practitioners for marketing and design tasks." Similar comments can be made about the notion of nomic regularities (and the whole debate between "Regularists" and "Necessitarians"): these constructs take place largely at the empirical level, often with particular examples as starting points of general-type arguments, with generalizations developed directly from specific empirical observations. So, in particular, the debate between "Regularists" and "Necessitarians" can never be settled since any finite reality is contradictory, and any number of valid arguments can be found in favor of both positions for as long as one keeps insisting on their clear distinction and fundamental nature (which is absent from both).

- "Before the discovery of the Rosetta stone, was it legitimate to regard Egyptian hieroglyphics as information, even if their semantics was beyond the comprehension of any interpreter?" This is a very clear-cut case: they definitely were information even prior to the Rosetta stone discovery. They simply could not be actualized as such at the time. It was also clear that they had been actualized before and could definitely be actualized in the future as it happened a bit later when the Rosetta stone was discovered.

P.17: The "It from Bit" hypothesis (Wheeler 1990): Can nature be informationalized?

Here we have to confess right away to having a personal soft spot for intellectual constructs like the "It from Bit" hypothesis: they are quite charming in both the spontaneous *naïveté* of their content and the poetic qualities of their form. It is rather emblematic that the author of the hypothesis is a prominent specialist in one of the "flagship" branches of the "new theoretical physics" – General Relativity. One of the salient features of this flavor of "new physics" is – as was noted, among others, by F. Floridi in [3] and S. Harnad in [42], and already briefly discussed by us earlier in this section – that newer models are built almost entirely out of previous models, with mathematics being almost always the only tool of choice. Thus, if the original models are in some way inadequate, further progress becomes somewhat akin to paddling a boat upstream with golf clubs in place of proper paddles. As we have discussed earlier, theoretical physics in early 20th century, faced with challenging problems that placed high demands on the logical aspect of a theory, was found lacking in that regard, and started moving forward with just mathematical skills and common sense derived inventiveness (the main source of "crazy ideas") of its practitioners in place of a proper methodological foundation. The era of "freely invented laws of nature" has commenced.

For a "new" theoretical physicist – especially one working in the fields of General Relativity, Relativistic Cosmology, and, a bit later, Supergravity and String Theory – it is indeed not that difficult to believe that the universe can indeed be made of information in some fundamental sense. The reason is roughly twofold. On one hand, such physicists' everyday activity consists of transforming older models into newer ones by means of mathematical manipulation and projecting the results onto (sometimes imaginary) physical reality. It is not too surprising that, after a while, information really starts looking like a demiurge of reality. On the other hand, given the absence of logical/philosophical background that has achieved near perfect state in the second half of 20th century, theoretical physicists – when faced with problems of a general nature – often think nothing about proposing constructs that are philosophical analogues of dividing by zero. J.A. Wheeler, in particular, was a prominent physicist who, among other achievements, graduated a record number of Ph.D. students at Princeton, and was generally in high demand. This means that most likely he had absolutely no time to devote to a study of philosophy, and, in all likelihood, the results of his philosophical ventures were going to be of the naive variety. And this is indeed what we witness in the "It from bit" hypothesis.

On a more serious note, "It from bit" is an illusion that has roots in objectivity of information (the ideal moment of the substance) and its relation to its material counterpart. As we have discussed in the section on information appearance and actuality, the material and the ideal, taken as totalities, are one single substance. The universal motion is a fundamental attribute of this single substance, and the reciprocal causality that takes place between these two inseparable – and distinct at the same time – worlds is a direct result of the universal motion. Subjectively, both of these two worlds can appear to be original or derivative (posited) depending on the view, but both are indeed one – two distinct moments of a single substance. One should note that, gnoseologically (epistemologically), the view in which the material is considered primary and the ideal secondary is a more logical one. The reason is that, as we have already discussed, in the early stages of the (local) substance development, the ideal plays a passive role, acting as a "shade" of the material. It becomes active (get actualized) only – as far as we now know – with the advent of life. At the same time, the point of view absolutising the material side of reality (a kind of non-dialectical materialism) would be as one-sided as a radical subjective idealism in the style of Berkeley and Hume.

5 Summary: space, time, matter, mass, energy, and information

This section is mostly intended for anyone with not enough time and patience to read the whole article. Here we try to give a quick summary of the logical status of concepts listed in the section title in a way that hopefully still makes some sense in spite of its brevity.

Let us begin with space and time. The more detailed account is given in the second section of Appendix B where these notions indeed play a key role. Somewhat surprisingly, in spite of their almost "obvious" character, their logical status requires some philosophical background for its proper rational comprehension. Correspondingly, the lack of such background might easily result in a confusion as to what space and time can and cannot be or do. A famous example of such a confusion is provided by the history of physics where the difficulties encountered with understanding of the nature of electromagnetic and optical phenomena resulted in what can be called a philosophically incompetent (clearly without any realization of the amount of competence required) treatment of these basic notions, as explained in more detail in Appendix B. In short, both space and time are *universal abstractions*. Being such, they, in particular, as universal *abstractions*, cannot possess any dynamics of their own. On the other hand, by virtue of being *universal* abstractions, their measure[79] cannot be affected by any particular finite material object or process.

In order to arrive at the correct logical notions of space and time, one can begin, following the development of basic categories in "The Science of Logic," with the most abstract category of *pure being* which has inside itself – by virtue of being void of any determinations – its own negation in that of *pure nothing*. Their sublation leads then to the first concrete category of *becoming* which, in its turn, gives rise to *quality* and *determinate being*, or *existence*. Existence has opposite moments inside it which, upon sublation, give rise to a relatively self-subsistent *something*. The latter is the logical category corresponding to what empirically appears as any relatively stable, equal to self and at the same time constantly changing entity. All such entities, by virtue of being self-equal and, at the same time, in the state of constant transmutation, i.e. self-unequal, can be said, using the language of Hegel's objective logic, to possess the *moments* of self-equality and self-inequality that are inseparable. The former moment is *being-for-itself* and the latter is *being-for-other*.

Space and time can be understood as *universal abstractions* of these two moments, respectively. Thus **space as such is the universal (i.e. pertaining to all existents) abstraction of the being-in-itself (self-equality) moment**. This definition agrees well with the common empirical everyday practice derived notion of the perfect still, a "momentary snapshot" of sorts of all existent objects, *abstracted* from objects themselves. The mental image of Newtonian idealized "empty space" is also an adequate one, as far as mental images go. The emptiness of Newtonian space is an abstraction from all physical objects co-existing at any given moment. **Time is the opposite to space universal abstraction of the being-for-other (self-inequality) moment**. Thus time is, metaphorically speaking, pure change as such, abstracted completely from all changing objects. The important notion of Hegel's logical system still largely not understood by either scientists or philosophers is that of *pure quantity* that is different from *determinate quantity* and *measure*. Pure quantity[80] as such is, in Hegel's words, "a compact, infinite unity which continues itself into itself." Space and time are pure quantities, and as such have no determinations and cannot, in particular, expand or contract. In order to obtain a measure of time, a *determinate* quantity obtained by means of an external bounding (that creates a time interval) needs to be compared with

[79]Recall that, in Hegel's logic, measure is most immediately understood as a determinate quantity of certain quality. If one does not develop the category of measure further when it eventually passes over into essence, measure can be used as a synonym of determinate quantity assuming a certain quality is implied.

[80]In particular, pure quantity cannot be expressed as a number. Such a distinction belongs only to the determinate quantity (which can be thought of as an externally bounded pure quantity) once it is expressed in units of another determinate quantity.

another determinate quantity of time playing the role of measure unit. The latter has to be *chosen judiciously*,[81] so that it is not significantly affected by the material environment specific to the measuring process. Being sped up or slowed down depending on the *material* environment is a prerogative of *material* processes, but not of time which a universal *abstraction from all material* entities.[82] Same comments are valid for space.

Whenever space and time become the subject of a discussion, the question of absolute vs. relative invariably comes up. In the history of physics, in particular, at the critical junction caused by difficulties with a rational understanding of radiative forms of matter, Newton's notion of absolute space and time came under criticism which, due to the philosophical inadequacies we have just mentioned, was taken "much too far." The result of such uninhibited philosophical experimentation was the creation of a *finite absolute*, the original *material eidos* of the advancing mathematical neoplatonism (more details can be found in Appendix B). The absolute moment of space and time is directly connected to their status of *universal abstractions*. In this sense, space and time as pure quantities are indeed independent of any particular forms of matter, from the totality of which they are abstracted. When it comes to determinate quantities and measures, some specific material objects and processes have to be used as units of such measure. So any space or time measure is going to possess an unavoidable relative moment. In general, it could be a nontrivial task to choose the suitable material objects or processes for a particular act of measurement so that they are unaffected by the given environment to the required precision. But, due to the infinite multitude of material forms, such a choice is in principle always possible. While Newton correctly identified the presence of both absolute and relative aspects in space and time, his being unaware of the developments in classical German philosophy that took place after his lifetime caused his views to be semi-intuitive and open to justified criticism.

The most glaring such aspect of his views was the notion of the *true absolute space*, so that any particular mechanical motion with respect to that space would have been given the status of an *absolute motion*. While Newton admitted (in his Scholium to the Definitions in "Philosophiae Naturalis Principia Mathematica") that "absolute rest cannot be determined from the position of bodies in our regions," he still claimed physical reality of such absolute space. This claim later gave additional credence to the radical revision – accompanied by the

[81]An example of an unsatisfactory choice is provided, for instance, by a scuba diver's selection of a water permeable watch for underwater exploration.

[82]When physicists of early 20th century decided (although very reluctantly at first, when the classical tradition was still influential) to solve problems pertaining to material phenomena "at the expense" of the universal *abstractions from such phenomena*, a great deal of confusion resulted, the consequences of which are still in effect. Subjectively, such a decision was made possible by the lack of philosophical knowledge at the junction where such knowledge was needed.

introduction of the "miraculous" absolute speed – of his notions of space and time in special relativity. The notion of such real physical absolute space could have only made rational sense if the absolutely rigid immovable ether of Lorentz's theory of optical phenomena had existed. But such ether can only be rationally construed as an idealization used as an auxiliary means in a phenomenological description (like it was used by H. Lorentz), not as a real physical object. While little is known about the real ether still, one can be fairly certain that it is involved in mechanical motion at all scales: from subatomic to intergalactic. This means that no special universal (i.e. unique for the whole Universe) frame of reference – and thus no *real absolute* space – can exist. The latter observation, in particular, makes the *postulate of relativity* in its characteristically positivistic formulation (about impossibility of experimental detection of absolute motion from "inside" the corresponding lab) empty of content. Indeed, while one certainly *can* (as D.C. Miller conclusively showed in [43]) detect the state of motion of the given reference frame with respect to the *locally predominant* motion of ether at the corresponding scale, such motion is in no way absolute, and the *relativity of any specific mechanical motion* is left intact.

Let us now turn to matter and energy. Jumping ahead of ourselves a bit, we can say that matter and energy are "duals" of sorts of space and time, respectively. Namely, matter exists in space but not in time: matter as such is impermeable to change. Energy, on the other hand, taken in full abstraction, energy as *pure quantity*,[83] exists in time, but not in space.

While space and time are *abstracted away* from the totality of existent *somethings*, to arrive at the fundamental notions of matter and energy, one needs, on the contrary, to consider this totality in its incessant change and constant transmutations. In terms of the categories of Hegel's objective logic, this implies that one needs to move beyond the sphere of *being* (which was sufficient for the rational comprehension of space and time) and into the sphere of *essence*. In order to obtain the concept of matter, we concentrate on the existents themselves in their mutual transformations. Their dynamic negates any particular form. We can then do the objective logic exercise detailed in Section 3, going first through the categories of the sub-sphere of *shine* and *reflection* and then through that of *essentialities*, to arrive at that of *ground*. In Hegel's logical system, ground is understood as "substantiated essence": while the essence itself lives in dynamics, in constant negation of forms via mutual transformation, ground is the same essence taken firmly as a foundation for all the immediate forms (as opposed to being just a seemingly fleeting link between them). In Hegel's own

[83]As we are going to discuss shortly, in the existing terminology, energy as determinate quantity and as measure is also called energy. Matter, on the other hand, when taken as determinate quantity, gets a specific name: it is then called *mass*.

words, this point is expressed as follows: "Ground, on the contrary, is mediation that is real, since it contains reflection as sublated reflection; it is essence that *turns back into itself through its non-being and posits itself.*"

The relation of ground at first appears as *form and essence*, in which form and essence are the same: form is essence and essence is form. In the case of our subject being the totality of all existents, they represent both form and essence: they change constantly turning into other existents, never disappearing without any trace. Thus whatever is "behind" them and what they are – taken as totality – on the "surface" is themselves again. On the other hand, as Hegel says about form: "It posits itself as sublated; it therefore *pre*-supposes its identity; according to this moment, essence is the indeterminate to which form is an other. It is not the essence which is absolute reflection within, but essence determined as formless identity: it is *matter*." In other words, the unity that shows itself via all the transmutations, constant form change, even though it always exists in *some* form, is still objectively there, and thus can be logically considered as *opposite* to the totality of *its own* forms. It is the logical *matter* and also the universal physical matter that we are after. We see that, by definition, **matter is the totality of all existents (i.e. objective reality) taken in full abstraction of all form**. Clearly, matter defined this way is exempt from any change and thus no longer has any *being-for-other* moment. In other words, matter as such is *timeless.*

As we have already pointed out, the notion of matter is related to that of space. Namely, space is the universal abstraction of the being-in-itself (self-equality) moment of all existents. To obtain matter, we let the universal motion negate all form and take the resulting unity completely devoid of form. Such matter does not possess the self-inequality moment of change. Thus one can say that matter resides in space, but not in time. It is – as long as it is treated as matter, i.e. in full abstraction from all determinations of form – eternal and unchanging. Somewhat metaphorically speaking, i.e. at the level of representation or mental image, space is the abstraction of perfect still, abstracted, in particular, from all matter. Matter, on the other hand, is the abstraction from all form and thus also from change. These two abstractions – when they are kept at the level of pure quantity[84] – are thus very similar: space in the sphere of being is what matter is in the sphere of essence.

The next logical step in the relation of ground is the negation of form and matter, termed *form and content.* This content is understood as *formed matter*, i.e. the pure unity represented by matter is again endowed with form while still being kept distinct from form as such.[85] Such formed matter is no longer timeless. On the contrary, it is the subject of the

[84]When determinate quantity and measure are considered, space becomes length, area or volume, and matter turns into mass.

[85]The relation of form and content can be thought of as a return to the inseparability of form and essence,

universal motion. Most of the time when the notion of matter is used in either philosophy or physics, it is this *formed matter* that is implied.[86] The totality of formed matter, being the subject of the universal motion, is then the starting point for the discussion of the notion of energy.

The universal motion is the fundamental process of transmutations of the formed matter forms that, as far as we know, knows no exceptions. The universal motion, just like formed matter itself, comes in a variety of forms. Taking the universal motion in its totality as our subject of study, we can again go through the categories of the sphere of essence and arrive at the *ground* as *posited*, self-subsistent essence. At first, the relation of ground applied to the totality of the universal motion shows up as that of *form and essence* where the universal motion exists in the totality of its various forms, and all these forms are forms of the universal motion. Concentrating on the unity behind the multitude of the universal motion forms and noting that, by virtue of all the transmutations of these forms, the unity is objective (and not just some "thought economy" convention), one arrives at the *form and matter* relation of the ground. That matter in this case is the unity of the universal motion taken opposite to the totality of its forms. This formless matter is what is known as *energy* in one of the two meanings[87] of this word as it is used in physics and other natural sciences. Thus **energy is the universal motion taken in full abstraction from its form.** Energy thus defined, just like matter, is a *pure quantity*, a formless featureless continuity, motion divested of any form.

Matter or energy as pure quantities, when externally bounded, become determinate quantities. Then determinate quantities obtained thereby can be compared to some other determinate quantities arbitrarily chosen as units yielding the corresponding determinate quantities expressed as numbers. When such bounding is done with matter, the result is usually called *mass.* Thus **mass is the determinate quantity (or measure) of matter**. With energy, the terminological situation is a bit different: if energy as pure quantity is externally bounded and then expressed in units of other such determinate quantity, the resulting measure is also called *energy.* The main reason for such terminological discrepancy is the much older age of the concept of matter compared to that of energy which dates back (at least as a concept of physics) to only the beginning of 19th century. Thus matter being the longer studied

but at another level: while the unity in form and essence is implicit, in form and content, it is again one with the immediate multitude and fully articulated at the same time.

[86]Again, while the existing scientific terminology has developed enough to acknowledge the distinction between matter as such and matter as measure, it is still ambiguous between matter as pure quantity and formed matter.

[87]If one counts energy as determinate quantity taken at the logical level of *form and content* (see the discussion just below) separately, one can distinguish three distinct notions of energy.

concept, it had time, so to speak, to develop more, and, in particular, to work out the distinction between matter as pure quantity and matter as determinate quantity and measure. In case of energy, such distinction is implicitly realized and reflected in the language,[88] but, apparently, not yet to the extent of warranting a specific term. Information, as we will see shortly, finds itself in a similar position.

Going to the *form and content* phase of the relation of ground in application to the study of the universal motion, one arrives at energy in some specific form – paralleling the notion of *formed matter* which we discussed a bit earlier. At this level, the value of energy as measure can be expressed via the determinations of the particular form: one obtains all the energy expressions from physics. Terminologically speaking, it is interesting to note that physics has developed the corresponding language to some extent. Everyone heard about kinetic energy, potential energy, internal energy of a given volume of an ideal gas and so on, with the accompanying mathematical expressions for the energy determinate quantity as functions of the corresponding determinate quantities characterizing the specific form of the universal motion.

Before we address information, let us briefly comment on the gnoseological status of the concepts of matter and energy and their relations to those of space and time. As we have seen, the notion of matter is gnoseologically prior to that of energy. Simply put, before motion is considered, a subject of this motion has to be present. (This observation is not intended to mean that there can be matter without motion, of course.) As was already noted, matter as pure quantity is timeless and is closely related to the abstraction of space. Energy, on the other hand, being the universal motion abstracted from all forms, is closely related to the universal abstraction of time. In short, time is the "empty" abstraction of motion, obtained in the sphere of being, and energy (as pure quantity) is the more concrete abstraction of motion involving its subject – the formed matter.

While matter and energy are complete form abstractions of all existent objective reality (the formed matter[89] at the level of essence) and the universal motion, respectively, information, in a nutshell, is such an abstraction of self-representation of (formed) matter due to its

[88]For example, when physicists speak (somewhat imprecisely) about transformations of energy in the Universe, they mean energy in the first (pure quantity) sense. When they talk about the kinetic energy of the Earth moving on its orbits being equal to some specific value, they mean energy in the second (determinate quantity and measure) sense.

[89]The concept of matter is a bit special even among the members of N. Wiener's fundamental "triad" since it is gnoseologically the primary one. The formed matter is logically obtained later than just the abstract matter. So when we say that matter is the form abstraction of formed matter, we go logically backwards in a sense. With energy and information, this predicament does not arise since, when one begins the discussion of either energy or information, all logical determinations of matter are already available.

inherent attribute of the *universal bond*. Namely, as a consequence of constant transmutations of the (formed) matter forms that is the universal motion, different existent *somethings* possess form determinations that reflect those of other existents. If one considers, for definiteness, two such existents, then the second one might have among its form determinations those that reflect some features of the first. One can say then that the second existent represents the first one, or equivalently, that the first one is represented by the second. Such representation can take different material forms but still be the *same* representation of the same existent and its features. Moreover, in the course of the universal motion, such forms of the *same representation* constantly transform into each other. This constant motion of *negation* of any *particular form* of any specific representation (and thus of their totality) effects an *objective abstraction* from the (material) form of the representation in question. What is left is the representation itself abstracted from all details of its material form. This is what is known by the name of *information*. Information obtain by means of such an abstraction still carries form determinations of the *represented* material object (existent) – as opposed to those of the *representing* one(s) from which the abstraction has been taken. Thus it can be called *specific information*. It is not, in particular, pure quantity.

We have therefore found that **(specific) information is self-representation of (formed) matter taken in full abstraction from its material form**. The form determinations that specific information still possesses are purely *ideal*. As was detailed in Section 4, such ideal *universal form* of information in nothing else but the well-known *probability distribution*. At the level of *form and content*, one obtains information in some specific material form.

But the dynamics of specific information negate even its ideal form. Specifically, such negation takes place when specific information is either transmitted or accumulated somewhere before its actualization, i.e. an occurrence of its material effect. Such abstraction from any details of its ideal form produce the *abstract information* which can be classified as pure quantity. As such, it is the closest analogue of matter and energy as pure quantities.

We thereby find that **abstract information is specific information taken in full abstraction from its ideal form**. Taken as such, not yet bounded externally, it is another example of *pure quantity* (along with space, time, matter, and energy as pure quantities). When determinate quantity of abstract information is taken, its ideal (stemming from representation of material entities) nature presents a natural unit for measure: the elementary distinction, commonly known as *bit*. The existence of such natural unit gives rise to a universal form of any determinate (externally bounded) quantity of abstract information: an *incompressible string* of bits. The length of such string is equal to the *Kolmogorov complexity* of any compressible string equivalent to the given incompressible one. Thus the Kolmogorov complexity can be identified with a natural measure of abstract information. At the level of *form and content* of the relation of ground pertaining to the second abstraction (that of the ideal form), one obtains abstract information endowed with ideal form, i.e. in the form of a probability distribution (the universal form of specific information). The determinate quantity of abstract information then becomes what can be termed the *abstract quantity of specific information.* As was shown in Section 4, such abstract (determinate) quantity is given by the *Kullback-Liebler divergence* between the universal forms (probability distributions) before and after the reception of the specific information in question.

On the terminological side, as we have already mentioned, information is also lagging behind matter which enjoys having the established name for its measure (determinate quantity) in the form of *mass.* Information, as we see, comes in even greater variety compared to matter and energy. There is specific information obtained as form abstraction of (formed) matter self-representation. Then there is also abstract information obtained from specific one as an abstraction from its ideal form. For abstract information, just like matter and energy, one also has to distinguish abstract information as pure quantity and abstract information as measure. Moreover, abstract information may serve as measure of specific information. Thus, in the current terminology, the word information is used in several different senses. Often, it is clear from the context what kind of information is implied in every particular instance. On the other hand, such ambiguity of terminology reflects on the corresponding shortage of clear understanding. The lack in understanding of the basics, in turn, can lead to significant confusion with rather far reaching and enduring consequences. A famous example of such confusion is provided by the notion of “mass-energy equivalence”[90] still largely accepted in physics as a universal law of nature expressed quantitatively by the no less famous $E = mc^2$ relation.[91]

[90]At the level of pure quantities, this would read like “matter-energy equivalence,” clearly signaling a revival of W. Ostwald’s *energetics.*

[91]To do modern physics justice, this relation is hardly used in its original absolute form where the left hand side contains the *total* energy of the object, and the mass m in the right hand side is understood as the “relativistic” mass. One of the reasons is that this relation is false for “massless” particles (which is one of superficial descriptive concepts used by modern physics). The modern version reads $E^2 = p^2c^2 + m^2c^4$, where the mass m is interpreted as the more logically adequate “rest” mass, i.e. the standard mass of classical physics. Thus the expression $E = mc^2$ is now interpreted as the ultimate “internal” energy contained in any object of mass m – the consequence of the standard in modern physics universalisation and absolutisation of electromagnetic phenomenology. (In reality, such ultimate energy is almost certainly a lot larger than mc^2.)

A “Logical atomism” vs. rational dialectics: sublation or mere truncation?

Let us recall the quotation from Stanford Encyclopedia of Philosophy cited in the Introduction describing the still (apparently) widely spread view on Hegel’s philosophy that originated in the works of B. Russell and his collaborators and followers.

> In Britain, where philosophers such as T.H. Green and F.H. Bradley had developed metaphysical ideas which they related back to Hegel’s thought, Hegel came to be one of the main targets of attack by the founders of the emerging “analytic” movement, Bertrand Russell and G.E. Moore. For Russell, the revolutionary innovations in logic starting in the last decades of the nineteenth century with the work of Frege and Peano had destroyed Hegel’s metaphysics by overturning the Aristotelian logic on which, so Russell claimed, it was based, and in line with this dismissal, Hegel came to be seen within the analytic movement as a historical figure of little genuine philosophical interest.

We pronounced this view to be grossly misleading, without much explanation. What exactly was B. Russell’s view on Hegel’s logical system and to what extents was the latter really subsumed and made obsolete by the work on mathematical logic and B. Russell’s own philosophy? In this appendix, we provide brief answers to these questions.

A.1 B. Russell’s philosophical genesis

Before we explore B. Russell’s intellectual journey in the realm of philosophy – using his own excellent account [44] of it as well as his philosophical works – let us make some relevant preliminary observations based on personal experience. As is well known, a young person with some mathematical background (for example, an advanced undergraduate with science/engineering major) can understand the main ideas of modern mathematical logic and get a reasonable “head start” on it in one semester after taking a decent course. Then it would probably take one or two more years for such a young person to be able to read and understand current research papers and begin doing his/her own research and obtain meaningful results (a standard practice of today’s Ph.D. students). A course is about 50 contact hours plus about the same amount of independent study. A year dedicated to the study of the subject (besides other typical graduate student activity) is about 20 hours a week for a total of around $20 \cdot 52 \approx 1000$ hours so that the time spent on the introductory course is relatively negligible.

With Hegel's dialectical logic, things are qualitatively different. Here we can offer an interested reader a summary of personal experience. The author's first acquaintance with "The Science of Logic" happened some time ago, almost fresh from a Ph.D. in theoretical physics and a postdoctoral appointment in operations research during which he did some work on dynamic optimization and on queueing theory making use of methods of Information Theory. All that experience arguably amounted to a background exceeding that of a typical starting Ph.D. student. Having an interest in logical problematics, the author got hold of a copy of Hegel's main work and tried reading it (having relatively extensive prior experience in reading books and papers in string theory and algebraic geometry, not to mention Shannon's information theory and optimization). That first attempt had to be cut short after about a week or so, due the author's utter inability to make any sense of the content of the book. The second attempt took place almost a decade later, with the author having acquired some background in philosophy including – to cite one directly related example – I. Kant's "Critique of Pure Reason." Some extra resolve to make progress was also present at that time. Still, the initial impression was not that much different from that accompanying the first attempt. The author persevered though, especially when the additional motivation of resolving the puzzles of information presented itself a couple of years later. To cut the long story short, here is the quick summary of the corresponding learning curve timeline. Roughly, the author was able to spend an average of about two to three hours a day (assuming seven work days per week) for the study which mostly involved "The Science of Logic" itself, but also some other related sources. During the first about three years, it was still mostly incomprehensible, with little bits clearer than the rest (but still not really clear) here and there. The book appeared to be really that different from what a person with science/engineering background is used to. By the end of approximately fifth year, those clearer places started making good sense, while much of the rest of the content was still somewhat murky although not quite incomprehensible any more. And only by the end of seventh year the author of the present article could actually read "The Science of Logic" in a normal fashion – understanding most of what was written and being able to think about possible improvements and corrections. So, numbers-wise, this amounts to about $360 \cdot 7 \cdot 2.5 \approx 6000$ hours worth of time "investment" with some not insignificant science/engineering and also some philosophy background at the start of the study, accompanied with a great deal of frustration in the beginning stages and no "tangible" rewards – just a somewhat stubborn belief that the truth is hopefully getting closer.

Let us now get back to B. Russell's intellectual journey. According to [44] (Chapter VI titled "Excursion into Idealism"), in Cambridge where he began his studies in 1890, at the age of 18, his main subject was mathematics. But at the same time, he was interested in philosophy and "managed to get through a fair amount of philosophical reading and a large amount of philosophical arguing." He then had to interrupt his philosophical studies in order to concentrate more on passing some examinations in mathematics and resumed them around 1894. We read in [44] on p.38:

> All the influences that were brought to bear upon me were in the direction of German idealism, either Kantian or Hegelian, with one single exception... The two men that had most to do with teaching me were James Ward and G.F. Stout, the former a Kantian, the latter a Hegelian. Bradley's *Appearance and Reality* was published at this time and Stout said that this book accomplished as much as is humanly possible in ontology.

This last passage seems to imply that a good deal of what B. Russell learned about Hegel's philosophy was not by reading the originals but rather the works of later Hegelians and idealist philosophers such as F.H. Bradley. Unfortunately, we could not find in [44] or B. Russell's other writings a direct indication of the exact sources that were used to teach the young Bertrand – either by means of instruction of self-study – the philosophy of Hegel and which aspects of the latter philosophy received the most attention. However in his 1914 book "Our Knowledge of the External World as a Field for Scientific Method in Philosophy" [46], B. Russell writes (here what he refers to as the classical tradition includes Kant and Hegel):

> The nature of the philosophy embodied in the classical tradition may be made clearer by taking a particular exponent as an illustration. For this purpose, let us consider for a moment the doctrines of Mr. Bradley, who is probably the most distinguished British representative of this school.

After that, a discussion of Bradley's "Appearance and Reality" follows. One can take this as a (somewhat indirect) indication that he mostly learned the "idealist philosophy" from Bradley's (and possibly other British representatives of that school) books and assigned the findings to Hegel as the main source and inspirator of the whole movement.

"Appearance and Reality" [45] mentioned above is considered to be F.H. Bradley's main philosophical work. Content-wise it also happens to be the one most closely related to Hegel's most important creation – "The Science of Logic." Any detailed discussion of even the main ideas of this work is beyond the scope of this appendix, so we will just mention that while Bradley's book – just like Hegel's – addresses the main properly philosophical subject of unity in multitude, it does so in a very anti-dialectical manner – all unity to the total detriment of multitude.[92] The latter is relegated to the status of appearance and is

[92]Hegel himself never thought about appearance and reality as opposites, with the latter holding unques-

proclaimed to be unintelligible, inconsistent and unreal. The status of reality is thereby retained by only the Whole, i.e. the Absolute. For Bradley, "ultimate reality is such that it does not contradict itself; here is an absolute criterion." By contrast, in Hegel's system, "real" is often used as a synonym with "finite," i.e. being inherently contradictory does not imply being devoid of reality.[93] Such a theoretical stance adapted by Bradley in [45] gives rise to multiple assertions standing in sharp contrast with common sense and everyday experience. The following quotations, for example, are taken from Chapter V of [45] (pages 47 and 49, respectively) that discusses motion and change in general and concerns any change occurring in an arbitrary object A, i.e. something that happens every day in most people experience.

> On the other hand, if the change actually took place merely in one time, then it could be no change at all. A is to have a plurality in succession, and yet simultaneously. **This is surely a flat contradiction**. If there is no duration, and the time is simple, it is not time at all. And to speak of diversity, and of a succession of before and after, in this abstract point, is not possible when we think. Indeed, the best excuse for such a statement would be the plea that **it is meaningless**. But, if so, **change, upon any hypothesis, is impossible**. It can be no more than appearance.

> We have the dwelling, with emphasis and without principle, upon separate aspects, and the whole idea consists essentially in this oscillation. There is **total failure** to unite the differences by any consistent principle, and the one discoverable system is the systematic avoidance of consistency. The single fact is viewed alternately from either side, but the sides are not combined into an intelligible whole. And I trust the reader may agree that their **consistent union is impossible**. **The problem of change defies solution**, so long as change is not degraded to the rank of mere appearance.

The adjectives "meaningless," "unintelligible," "impossible" etc. are used by F H. Bradley to

tionably higher status, like Bradley does in his book. For Hegel, reality is actually rather abstract category from the sphere of being [1], p.119:

> In connection with the more concrete, it is however superfluous to repeat such earlier and more abstract categories as reality, and to use them for determinations more concrete than they are by themselves.

[93] Recall Hegel's definition of reality from [1] (p.85): "Quality, in the distinct value of *existent*, is *reality*; when affected by a negating, it is *negation* in general, still a quality but one that counts as a lack and is further determined as limit, restriction."

characterize anything less than the ultimate infinite unchanging Whole. It is not very difficult to imagine that such philosophy was not unlikely to trigger a "revolt against idealism" which indeed took place in B. Russell's mind and which we will soon discuss.

B. Russell meanwhile wrote his first philosophical work on the foundations of geometry that was – according to him – mainly Kantian. After that, he turned his attention to Hegel [44], p.40:

> However there was worse to follow. My theory of geometry was mainly Kantian, but after this I plunged into efforts at Hegelian dialectics. I wrote a paper "On the relations of Number and Quantity" which is unadulterated Hegel.

The first two paragraphs of said allegedly Hegelian paper are then given as those "containing the gist of the paper." From these paragraphs, it is fairly clear to anyone decently familiar with Hegel's dialectics that the paper in question has as much in common with the latter as the "London Bridge is Falling Down" song with Beethoven's 5th Symphony. What it seems to be instead is an attempt to describe the author's common sense derived views by means of a dialectics-sounding language, but the ordinary common sense content is still rather obvious. In particular, both the common sense and the author of the paper operate with notions of things and their properties. Thus, for instance, the author (young B. Russell) says: "We shall be forced to reject the view that quantity is an intrinsic property of quantities." The paper's view of contradictions, on the other hand, is more similar to that of Bradley than of Hegel. For example, we can read: "But a discussion of the kind of comparison involved in measure will bring back our previous difficulties in a new form; we shall find that the terms compared, though we no longer regard then as quantitative, are infected with contradictions." When the long quotation from his first Hegelian paper is over, the older B. Russell continues in [44]:

> Although Couturat described this article as "ce petit chef d'oevure de dialectique subtile," it seems to me now nothing but unmitigated rubbish.

Here we can note that, while it is hard to directly argue with the latter assessment as far as the content of the young B. Russell first attempt at dialectics goes, it is still true that, at the time, the future Nobel prize winner was at least trying to learn it – even though it was proving more difficult than he apparently had anticipated – instead of fully abandoning it in favor a somewhat formalized version of the ordinary common sense mixed with a good dose of the most naive Humean scepticism a couple of years later.

Having finished his book on the foundation of geometry, the young Hegelian turned to those of physics: "I was at this time a full-fledged Hegelian, and I aimed at constructing a complete dialectics of the sciences, which should end up with proof that **all reality is mental**." Here we see especially clearly in the last (highlighted) words of the quoted sentence that neither young not much older B. Russell managed to properly master the content of "The Science of Logic" and throughout all his life had no idea what modern dialectics is about (and what exactly the difference is between Berkeley, Hume, and Mach on one hand and Hegel on the other). This is an important observation we will need a bit later in this appendix. We read in few lines later in [44], on p.42:

> Two questions specially interested me in the philosophy of physics. The first of these was the question of absolute or relative motion. Newton had an argument to show that rotation should be absolute and not relative. But, although this argument worried people and they could not find an answer to it, the arguments for the contrary views, that all motion is relative seemed at least equally convincing. This puzzle remained unsolved until Einstein produced his Theory of Relativity. From the point of Hegelian dialectics it was a convenient source of antinomies: it was not necessary (so I supposed) to find a solution within physics, but acknowledge that **matter is an unreal abstraction** and that no science of matter can be logically satisfactory.

According to actual Hegel's dialectical logic (as opposed to F.H. Bradley's reinterpretation or B. Russell's own understanding of it), motion (in any form, not necessarily mechanical) has both[94] an absolute and a relative moments in it. Depending on the situation, one of the two moment can come to the forefront (become posited) while the other stays in the background (in itself). But the intended construction of no less than a complete dialectics of sciences was not to come to completion due to a radical change in B. Russell's philosophical convictions (described by him in Chapter I of [44] as a revolution) [44], p.43:

> Fortunately, before any of this work has reached a stage where I thought it fit for publication, I changed my whole philosophy and proceeded to forget all I had done during those two years. The notes I made at that time have however a possible historic interest, and although they now seem to me to be misguided I do not think they are any more than the writings of Hegel. Some of the more salient passages from the notes that I made in those years follow.

[94]In particular, Einstein's Theory of Relativity did not solve that puzzle – it just postulated the relative moment in an absolute fashion. One could say that it *absolutized relativity*, which is somewhat ironic: even if someone tries to abolish dialectics in a bout of a anti-dialectical (conscious or otherwise) ardor, it finds a way to laugh at the overzealous adept of external understanding. In this case, the ousted absolute moment of motion (along with that of space and time) came back in a guise of an "adjective" to its relative cousin, and, as we will discuss in Appendix B, got attached to the speed of unsuspecting light.

Upon reading said passages, any polite individual familiar with Hegel's dialectics would be well advised to tactfully remain silent on the directly preceding assessment of the quality of the young Bertrand's dialectical achievements. At the same time, one has to admire B. Russell's conviction of his own ability to produce work of historic significance even in its "misguided" components which are – according to him – are still no worse than anything Hegel had written. We are going to give a couple of examples from these misguided but historically significant notes, for the sake of illustration. In the note titled "Short statement on the antinomy of absolute motion" the pre-logical-atomism Bertrand writes:

> (a) No change of spatial relation can be measured.
>
> (b) No motion and therefore no matter and no force can be measured.
>
> (c) Dynamics is rendered dialectically untenable by the contradiction arising from the essential relativity of matter.
>
> (d) Matter and motion cannot form a self-subsistent world, and cannot constitute Reality.

Once again, while it is very difficult to discern the influence of Hegel on these writings, that of F.H. Bradley is hard to miss.

The next chapter (Chapter V) of [44] is titled "Revolt into Pluralism" (but could be more aptly called something along the lines of "Farewell to Reason"). The first two sentences of Chapter V read: "It was towards the end of 1898 that Moore and I rebelled against Kant and Hegel. Moore led the way but I followed closely in his footsteps." Then an important confession is made concerning, it appears, "the gist" of the two fearless revolutionaries' rebelion [44], p.54:

> I think that Moore was most concerned with the rejection of idealism, while I was most interested in the rejection of monism. The two were, however, closely connected. They were connected through the doctrine as to relations, which **Bradley has distilled out of philosophy of Hegel**. I called this "the doctrine of internal relations," and I called my view "the doctrine of external relations."

We can see here one more time, that, most likely, the young Bertrand was learning about Hegel's logical system mostly from F.H. Bradley's rendition. One could make a guess that the most probable reason for such a substitution was simply the overwhelming difficulty of Hegel's "Science of Logic" for any beginner. F.H. Bradley's main work [45] devoted to roughly the same issues is, on the other hand, a lot easier (orders of magnitude easier, speaking of the necessary time expenditure on the part of a conscientious reader) to read and understand. Indeed, nowhere in "The Science of Logic" does Hegel – unlike Bradley in his "Appearance and Reality" – speak about any "internal relations" between "terms" or "things." Then B. Russell – relieved in his having nailed down (with F.H. Bradley's help) Hegel's system main folly – goes on to bravely dispose of it in a paper read to the Aristotelian Society in 1907. The paper itself – at least the part of it quoted in [44] – is a good example of the proverbial tilting at windmills. For example, we read in that extended quotation:

> The difficulty is that "identity in difference" if impossible if we adhere to strict monism. For "identity in difference" involves many partial truths, which combine, by a kind of mutual give and take, into the one whole of truth. But the partial truths, in a strict monism, are not merely not quite true: they do not subsist at all.

As befits a true rebel against monism, B. Russell aptly invents (or borrows from F.H. Bradley's "distillate" of Hegel) a particularly unyielding "strict monism" that is completely alien to any semblance of dialectics and absolutely refuses to tolerate the presence of anything less than the Absolute itself. It is indeed hard to imagine any member of the Aristotelian Society – or any sensible individual for that matter – who would not side with any harsh criticism of so radically one-sided doctrine. Moreover, the "axiom of internal relations" that B. Russell so elegantly dismantles in the 1907 paper could not possibly have been proposed by Hegel in any form as the latter had always warned against using methods of mathematics (such as formulation of axioms) in philosophy, as we will review later in this appendix.

Thus B. Russell extracted himself fully from Hegelian (and Kantian) idealism, cleared his mind of philosophy with its prior achievements, and went into the full *tabula rasa* mode, plunging into "the doctrine of external relations" also known as "logical atomism" (which is nothing else but a formalized version of the ordinary common sense minus its spontaneous dialectics, as we will discuss a bit later). He describes the resulting feelings in the following words [44], p.61:

> But it was not only these rather dry logical doctrines that made me rejoice in the new philosophy. I felt it, in fact, as a great liberation, as if I had escaped from a hot-house onto a wind-swept headland.

In this regard, we can venture a guess that the liberation the young Bertrand felt could be more accurately described as that experienced by a somewhat inept musician who had been busy practicing some complicated classical pieces but, feeling overwhelmed, decided to give up after finding out that playing simple popular songs was a lot easier (and could even pay better). Indeed, studying Hegel's logic does sometimes hurt the brain, especially in the beginning. Going back to *easy* things could give a novice the feeling described in the passage above. It turned out though that such radical *simplification* of logic was somehow in demand. Philosophy – in its main (logical) aspect – was on its way of turning into an object of somewhat condescending dismissal on the part of philosophically aware representatives of particular sciences. We will have to say more about these matters in Appendix B, but one can recall, for example, S. Weinberg's "unreasonable ineffectiveness of philosophy" in physics from his popular book [47].

A.2 The subject matter of logic

We have so far sketched, following the older B. Russell's memoirs, the genesis of his mature philosophical convictions. It still remains for us to address the main content of his "logical atomism" and, most importantly for the main topic of this article, the relation the latter philosophical doctrine bears to Hegel's dialectical logic. More specifically, we want to find out whether the "logical atomism" (and its various later developments) can be considered to supersede Hegel's logical system in any way. Let us turn to one of B. Russell's mature philosophical works [46] written about 15 years after his and G.E. Moore's rebellion against idealism and monism. It has no less than "scientific method in philosophy" in its title and appears to be devoted to the exact topics we needed in the main body in this article.

First, one has to point out that even the mature B. Russell agrees with G.W.F. Hegel in at least one point: that logic is the most important aspect of philosophy as a whole. Hegel's extension of logic to include what previously was considered metaphysics is more than sufficient indication of such a position. B. Russell, on his part, states this explicitly in Chapter II (Lecture II) of [46] titled "Logic as the Essence of Philosophy":

> The topics we discussed in our first lecture, and the topics we shall discuss later, all reduce themselves, in so far as they are genuinely philosophical, to problems of logic. This is not due to any accident, but to the fact that every philosophical problem, when it is subjected to the necessary analysis and purification, is found either to be not really philosophical at all, or else to be, in the sense in which we are using the word, logical.

Also common between Hegel and Russell is the rather sceptical opinion on the previous state of logic. Thus we read on p.31 of [1]:

> As a matter of fact, the need for a reformation of logic has long been felt. In the

> form and content in which it is found in the textbooks, it must be said that **it has fallen into disrepute**. It is still being dragged along, more from a feeling that one cannot dispense with a logic altogether and the persisting traditional belief in its importance, than from any conviction that **such a commonplace content and the occupation with such empty forms are of any value or use**.

B. Russell agrees with that evaluation of the formal logic inherited almost intact from Aristotle [46], p.42:

> Logic, in the Middle Ages, and down to the present day in teaching, meant no more than a scholastic collection of technical terms and rules of syllogistic inference. Aristotle had spoken, and it was the part of humbler men merely to repeat the lesson after him. **The trivial nonsense embodied in this tradition** is still set in examinations, and defended by eminent authorities as an excellent "propædeutic," i.e. a training in those habits of solemn humbug which are so great a help in later life.

B. Russell notes however that some extensions of that "trivial nonsense"[95] have been made in more modern times. One of them is the method of induction [46], p.43:

> The first extension was the introduction of the inductive method by Bacon and Galileo – by the former in a theoretical and largely mistaken form, by the latter in actual use in establishing the foundations of modern physics and astronomy. This is probably the only extension of the old logic which has become familiar to the general educated public.

Now we come to the interesting part. Let us see what the former devout Hegelian, but now a rebel against idealism and monism, has to say about Hegel's approach to logic [46], p.47:

> Hegel and his followers widened the scope of logic in quite a different way – a way which I believe to be fallacious, but which requires discussion if only to show how their conception of logic **differs from the conception which I wish to advocate**. In their writings, logic is practically identical with metaphysics.

[95] We should note at this point that the Aristotelian formal logic – even if it can be called rather trivial – is hardly nonsense. As we see, Hegel calls is "commonplace" reflecting the observation that, by his time, the usage of it in most situations became sufficiently obvious to many people so that a dedicated study of it was not really necessary.

Remembering our original interest – that of finding out if the logical advances advocated by B. Russell make Hegel's system obsolete – we can point out right away that, according to B. Russell himself, his conception – rather than superseding that of Hegel – lies in a different plane, so to speak. B. Russell then continues to explain:

> Thus what he calls "logic" is an investigation of the nature of the universe, in so far as this can be inferred merely from the principle that the universe must be logically self-consistent. I do not myself believe that from this principle alone anything of importance can be inferred as regards the existing universe. But, however that may be, I should not regard Hegel's reasoning, even if it were valid, as **properly belonging to logic**: it would rather be an application of logic to the actual world. Logic itself would be concerned rather with such questions as what self-consistency is, which Hegel, so far as I know, does not discuss. And though he criticizes the traditional logic, and professes to replace it by an improved logic of his own, there is some sense in which the traditional logic, with all its faults, is uncritically and unconsciously assumed throughout his reasoning. It is not in the direction advocated by him, it seems to me, that the reform of logic is to be sought, but by a **more fundamental, more patient, and less ambitious investigation** into the presuppositions which his system shares with those of most other philosophers.

We can note here that what B. Russell proposes instead of Hegel's logic extension is easily (a lot) less ambitious, but not even remotely more fundamental. Also, Hegel never intended to *replace* the traditional (formal) logic by his own version,[96] but rather to quite radically *extend* the subject of logic by – indeed, as B. Russell states – including in it what had formerly been the domain of metaphysics. But – what is important to realize and what B. Russell apparently failed to do – is that Hegel does not substitute his new and improved metaphysics for the old and obsolete one, just calling it logic for the sake of novelty. Rather, he does away with metaphysics altogether and makes logic take care of the issues previously addressed by metaphysics. This is a very important point that B. Russell apparently totally misses. Let us now hear what Hegel himself has to say about the general subject of logic. The following quotation from [1] (p.24) concisely states Hegel's view on logic that, by all evidence we have, completely escaped B. Russell's comprehension:

> The concept of logic has hitherto rested on a separation, presupposed once and for all in ordinary consciousness, of the content of knowledge and its form, or of

[96]In particular, Hegel would never object, for example, to the assertion that from the propositions "All humans are mortal" and "Socrates is human" follows the proposition "Socrates is mortal."

> *truth* and *certainty.* Presupposed from the start is that the material of knowledge is present in and for itself as a ready-made world outside thinking; that thinking is by itself empty, that it comes to this material as a form from outside, fills itself with it, and only then gains a content, thereby becoming real knowledge.

Indeed, this statement by Hegel, taken literally at the face value with "thinking" understood as some subjective process taking place in somebody's head, sounds decidedly and unapologetically (subjective) idealistic, almost on par with the finest from Bishop Berkeley. The first reaction of anybody sympathetic to the notion of objectivity of science and philosophy could easily be the one of rigid opposition. But, as we have already mentioned earlier in this article, there is very little idealism – let alone subjective idealism – in Hegel's main work. It just takes significant time to properly understand its contents. Let us read "The Science of Logic" a bit further. On the next page (p.25) we find:

> These views on the relation of subject and object to each other express the determinations that constitute **the nature of our ordinary, phenomenal consciousness**. However, when these prejudices are carried over to reason, as if in reason the same relation obtained, as if this relation had any truth in and for itself, then they are errors, and the **refutation of them** in every part of the spiritual and natural universe **is what philosophy is**; or rather, since they block the entrance to philosophy, they are the errors that must be removed before one can enter it.

We see that, in Hegel's view, the ordinary "educated person common sense" views – still predominant now – that hold external objects given to us in our senses as completely independent of reason self-subsisting entities which thinking can learn about while being fully separate from them, are nothing but prejudices that need to be done away with *before any properly philosophical studies can be undertaken.* A sensible person is most likely still puzzled at this point since it certainly appears that the views called prejudices here are, on the contrary, perfectly correct objective views that all of science appears to be built on. Let us nevertheless wait a bit more before passing the final judgement and turn our attention to logical forms (i.e the formal aspect of logic) developed by Aristotle (and greatly refined and augmented by Boole, Frege, Peano, and many others in the modern times). It is these forms (at least in their original Aristotelian state), the emptiness, banality, and even nonsensical character of which (the latter according to Russell) was much lamented by the educated community as early as during Hegel times. In this regard, on p.27 of [1], we can read:

> More to the point is that the emptiness of the logical forms lies rather solely in the

> manner in which they are considered and dealt with. Scattered in fixed determinations and thus not held together in organic unity, they are dead forms and the spirit which is their vital concrete unity does not reside in them. Therefore they lack proper content – a matter that would in itself be substance. **The content which is missed in the logical forms** is nothing else than a fixed foundation and a concretion of these abstract determinations, and such a substantial being is usually sought for them outside them. But **logical reason is itself** the substantial or real factor which, within itself, **holds together all the abstract determinations** and constitutes their proper, absolutely concrete, unity.

We thus find that, according to Hegel, it is not the forms of logic themselves that are empty and trivial, but rather the failure of their prior users to recognize their proper content which – once it is acknowledged – makes all these previously seemingly empty forms a unity. Thus the properly understood logic has *its own inherent content* – contrary to the common sense "objective" views that such content can only be brought from the outside (relative to the thinking person's head where logic can only be found) world which, in its turn, is fully indifferent to logic. That content of logic is the reason itself, with all its determinations, the study of which is the main subject of Hegel's (by far) most important work.

Still, it sounds like the reason – even if it is the content of logic that unites all its otherwise empty forms – is something purely subjective residing in the heads of sufficiently wise individuals and acting as their personal advanced tool for comprehending reality existing in the outer world independently of that subjective reason. Put slightly differently, it might appear that in the overwhelming majority of possible locations of the physical objective universe, human beings – and hence the reason – are simply not present, while all kinds of physical objects (like stars) most certainly are. These objects have to be fully independent of any reason and thinking. Such reasoning sounds very plausible and objective – and this is roughly the view B. Russell maintains. But in Hegel's system, reason with all its contents – notably the concept and the idea – has *both the subjective and the objective moments.* Subjectively, it is the reason in the more usual sense. *Objectively, it is the universal* (or the unity) as it is present in the world. We read on p.29 of [1]:

> Pure science[97] thus presupposes the liberation from the opposition of consciousness [and its object]. It contains *thought in so far as this thought is equally the fact as it is in itself*; or the *fact in itself* in so far as this *is equally pure thought.* As *science*, truth is pure self-consciousness as it develops itself and has the shape

[97] Here, by pure science, Hegel means logic taken in its widest sense – the sense that, as he advocates in "The Science of Logic," should become standard.

> of the self, so that *that which exists in and for itself is the conscious concept and the concept as such is that which exists in and for itself.*
>
> This objective thinking is thus the *content* of pure science. Consequently, far from being formal, far from lacking the matter required for an actual and true cognition, it is its content which alone has absolute truth, or, if one still wanted to make use of the word "matter," which alone is the veritable matter – a matter for which the form is nothing external, because this matter is rather pure thought and hence the absolute form itself.

Clearly, the concept for Hegel has an objective moment which is just as important as the subjective one. In fact the English translation "concept" of the German "Begriff" does not convey its meaning very well as it has a decidedly subjective connotation – as a product of cognitive activity of a conscious individual. On the other hand, the German noun "Begriff" is directly related to the verb "begreifen" which has both subjective and objective connotations. Another noun directly related to the verb "begreifen" is "Inbegriff" which is translated into English as "epitome," "embodiment," "quintessence." In Hegel's writings, the word "Begriff" is often used in the sense very close to that of "Inbegriff" and thus has a mostly objective meaning. Thus, it would probably be a good idea to use the word combination "objective concept" or some equivalent in place of just "concept" in some instances of "Begriff" in "The Science of Logic" English translation. Same comment holds true about Hegel's "idea" which is defined – in a nutshell – as the unity of concept and reality. After all, Hegel is widely considered an *objective* idealist, so an emphasis on objectivity is to be expected in most of his writings. B. Russell – judging by his earlier "Hegelian" works – failed to take due notice of this very important point.

Indeed, on p.30 of [1], we find:

> *Thought* is an expression which attributes the determination contained in it primarily to consciousness. But inasmuch as it is said that *understanding, that reason, is in the objective world*, that spirit and nature have *universal laws* to which their life and their changes conform, then it is conceded just as much that **the determinations of thought have objective value and concrete existence**.

Thus thought, for Hegel, is not limited to the products of any individual's (or even the totality of all individuals) thinking head, but rather understood – in a more narrow sense – as *the other* of all human activity (whether or not it is fully adequately consciously reflected upon) and – in the widest sense – as *the universal* as such, regardless of it being part of past and current human activity. It is such views – as far as his main work is concerned – that made it regarded as falling within the scope of philosophical objective idealism. The following quotation from p.41 of [1] is a good summary, in Hegel's own words, of what he understood by thought and thinking:

> This objectifying deed,[98] **liberated from the opposition of consciousness**, is closer to what may be taken simply as **thinking as such**. But this deed should no longer be called consciousness; for consciousness holds within itself the opposition of the "I" and its intended object which is not to be found in that original deed. The name "consciousness" gives it more of a semblance of subjectivity than does the term "thought," which here, however, is to be taken in the absolute sense of infinite thought, **not as encumbered by the finitude of consciousness**; in short, **thought as such**.

As we have already mentioned, the notion of *concept* central to Hegel's logical system is understood both subjectively and objectively. In both cases, it is *the universal*, *the unity.* It exists in the objective world, even when there is nobody yet to form thoughts about it in the usual sense. It is not given directly in the senses, by virtue of existing "dynamically," through vanishing and emergence of various finite forms – various "things." It can be apprehended in human nature-transforming practice – and hence in *thought.* Then concept takes its subjective form – becomes concept in the usual sense – concept for itself, in Hegel's language [1], p.39:

> Thus it is the whole concept which we must consider, first as *existent concept*, and then *as concept*; in the one case it is concept only *implicitly, in itself*, the concept of reality or being; in the other, it is the concept as such, the *concept that exists for itself.* – Accordingly, the first division must be between the logic of the *concept as being* and of the concept *as concept*, or (if we want to avail ourselves of otherwise familiar, but very indeterminate and therefore very ambiguous expressions) in *objective* and *subjective* logic.

Thus logic, as we see, naturally divides itself into objective and subjective parts, even though, as Hegel likes to emphasize, the distinction between them should not be exaggerated and absolutised. The objective logic, according to Hegel, is dedicated to the study of "concept as being," or "concept in itself." This study begins with the immediate multitude given directly in the senses, but – unlike the adherents of B. Russell's "axiom of external relations" – does

[98] The "objectifying deed" here stands for human purposeful activity directed at the object in question.

not stop there. Instead, it proceeds to uncover the unity in the multitude. That unity is not separate from the multitude, but rather exists via its constant change and transmutations of its various forms. Thus it is never given directly in the senses (this fact brings a non-dialectical thinker's thought to a screeching halt and forces them to start inventing various metaphysical principles), but is discovered in the course of human practice and thus reflected in thought (in the usual "subjective" sense). In order to obtain a concept (that, roughly speaking, encompasses both the unity and the multitude) starting from the immediate (i.e. the sphere of *being*), thought has to go through the "intermediate" sphere of the unity as such. This is the sphere of *essence* [1], p.40:

> There results a sphere of *mediation*, the concept as a system of *reflected determinations*, that is, of being as it passes over into the in-itselfness of the concept – a concept which is in this way not yet posited for itself *as such* but is also fettered by an immediate being still external to it. This sphere is *the doctrine of essence* that stands between the doctrine of being and of the concept.

As we have mentioned earlier, the objective logic that B. Russell – having failed to understand it – considered "an application of logic to the actual world," is what replaced metaphysics from the earlier philosophical systems, like that of C. Wolff [1], p.42:

> The objective logic thus takes the place rather of the former *metaphysics* which was supposed to be the scientific edifice of the world as constructed by *thoughts* alone.

Metaphysics – which, by the way, B. Russell and his followers used to be quick in accusing someone (like Hegel, for example) of being guilty of – is, generally speaking, a system of ultimate laws that are formulated without proof and assumed to have very general – typically universal – applicability. Such laws are usually called principles and also, using mathematics as an example, axioms or postulates. Mathematics itself is explicitly metaphysical, but it is not considered a deficiency since it explores the world of – in Hegel's language – formal possibilities and formal necessities from the angle of abstract quantity. Mathematics, historically, was the most developed of all sciences, and, as Hegel puts it ([1], p.32), philosophy "looked with envy at the systematic edifice of mathematics." On the same page, he says:

> Spinoza, Wolff, and others, have let themselves be led astray into applying that method also to philosophy and in making the conceptually void external course of quantity, the course of the concept – a move contradictory in and for itself.

Indeed, the metaphysical method does not suit philosophy and other (with the exception of mathematics) sciences as their goal is to explore real possibilities and real necessities. The difference is that, in the case of formal possibilities, any system can be completely abstracted from everything else, and form a unity in its own right. This is indeed what is done in mathematics on a regular basis. Real possibilities and necessities, on the other hand, have to be studied in the context of the objective world which constitutes a single unity (that single unity which was absolutised by F.H. Bradley). It is a very difficult task. So the particular sciences begin with empirical observations and – where possible – designed experiments. Then they classify and organize the results and try go generalize them, i.e. find the underlying unity. At this point, they have no general method to follow, and resort to what essentially is trial-and-error. In the case of physics, such absence of a method was discussed by R.P. Feynman in his book "The Character of Physical Law" [48]. He writes on p.162:

> I want to discuss now the art of guessing nature's laws. It is an art. How is it done? One way you might suggest is to look at history to see how the other guys did it. So we look at history.

It is clear that no method of finding unity behind various physical phenomena was known to R.P. Feynman (and other physicists) at the time of writing (in 1964). The situation has hardly changed since that time. R.P. Feynman then discusses several prominent examples from physics history and hypothesizes about the possible ways the future general laws might be found. He says:

> Any schemes – such as "think of symmetry laws," or "put the information in mathematical form," or "guess equations" – are known to everybody now, and they are all tried all the time. When you are stuck, the answer cannot be one of these, because you will have tried these right away. There must be another way next time.

We see that – as far as generalizations and the search for unity go – physics (and other particular sciences) is still methodologically not far beyond a trial-and-error ad hoc stage of development. Once the subject matter of a science has been defined and sufficient amount of empirical material has been collected, the need for a theory arises. Any theory presupposes discovering the universal and the particular in the singular, and the process of such discovery is bound to have its own logic. How the universal is "contained" in the particular and in the singular. As Hegel repeatedly notes in [1], this is not given in the senses and has to be comprehended by means of thought. The universal in thought (subjective) and in reality (objective) thus has the same logic in how it is related with the singular (the immediate) given directly in the senses. This is the *content* of the thought (understood in the widest sense as explained earlier) and of the objective logic that replaces metaphysics of the earlier days of philosophy [1], p.42:

> Logic, however, considers these forms [pure forms of thought] free of those substrata [like the soul, the world, and god], which are the subjects *of figurative representation*, considers their nature and value in and for themselves. That metaphysics neglected to do this, and it therefore incurred the just reproach that it employed the pure forms of thought *uncritically*, without previously investigating whether and how they could be the determinations of the thing-in-itself, to use Kant's expression – or more precisely, of the rational. – The objective logic is therefore the true critique of such determinations – a critique that considers them, not according to the abstract form of the *a priori* as contrasted with the *a posteriori*, but in themselves according to their particular content.

One should especially note that the objective logic has nothing to do with the "*a priori*" type of reasoning (which, by the way, is a typical Kantian, not Hegelian, expression). The logical forms discussed in Hegel's objective logic are not in any way "inborn" in people, but are a result of the totality of human nature transforming practice, i.e. of experience. So one can say that they are themselves are a product of empirical based generalization, but empirical in a wider sense than usually understood by the likes of B. Russell – as a direct "transform" of some "piece" of "sense data" or a result of some very specific "decisive experiment" in the style of K. Popper. We see indeed that B. Russell genuinely believed that Hegel's objective logic was a result of some "a priori" reasoning that has an ontological character and expresses "self-consistency" (truly, it seems mathematics never released its monopolistic hold of B. Russell's brain) of the universe [46], p.47:

> Hegel believed that, by means of a priori reasoning, it could be shown that the world must have various important and interesting characteristics, since any world without these characteristics would be impossible and self-contradictory. Thus what he calls "logic" is an investigation of the nature of the universe, in so far as this can be inferred merely from the principle that the universe must be logically self-consistent.

Hegel admits that, even though the content of thought is universal in the sense of not depending in its main determinations on the subject matter of study, the purpose of logic is not itself but rather the rational comprehension of the objective world. This means that all sciences are instances of applied logic, and this is where it shows its full potential which remains somewhat “in itself” when logic is studied in its own right [1], p.37:

> Thus logic receives full appreciation of its value only when it comes as the result of the experience of the sciences; then it displays itself to spirit as the universal truth, not as a *particular* cognition *alongside* another material and other realities, but as the essence rather of this further content.

To summarize: logic, for B. Russell, had still the old purely subjective sense. It was, for him, that set of rules a conscious mind had to follow in order to not fall in a contradiction with itself. Such rules, by admission of both Hegel and B. Russell himself, had already become obvious and almost banal to all scientists and, in a wider sense, to most people doing any thinking on a regular basis. It was time for logic to step outside the circle of the banal and to go deeper than the surface of the immediate, to the *unity* of the world which would have to necessarily include the *thought* itself. The implication is that the latter would have to be also considered as a side (aspect, moment) of the unity and treated in the logic as such. The logic of this kind can then be called the *logic of reason*, as the latter came to be understood in the classical tradition. Hegel made the first concerted conscious attempt at developing such a logical system thereby – as it turned out – reaching the pinnacle of the classical tradition in philosophy. B. Russell, on the other hand, after an initial – inadequate for the task at hand[99] – effort at understanding Hegel's decisive advances, went back to the sphere of the banal looking for further improvements there as it was just easier. In the next section, we will see what he was able to find in that “wind-swept headland.”

A.3 Logical atomism: the original version

Now let us briefly explore, using B. Russell's own writings, what his “logical atomism” has to offer in place of Hegel's “metaphysics.” In B. Russell's own works, we see the genesis of that direction which took the form of a system a bit later, as we will review in the next section of this appendix.

After criticizing Hegel's extension of logic and denying it the status of such, as we have reviewed earlier in this appendix, B. Russell turns to the technical developments that took place in mathematical logic starting from the work of G. Boole in the middle of 19th century. But, as B. Russell notes, these original advances, before the work of Peano and Frege, were

[99]In particular, as we saw in this section, he kept thinking in terms of “things” and their “properties,” trying to understand Hegel's logic in terms of simple contemporary common sense – the undertaking doomed to failure from the outset.

largely limited to formalization of the old Aristotelian logic. What was the groundbreaking advance in logic effected by these works? In B. Russell's own words, [46], p.50:

> Traditional logic regarded the two propositions, "Socrates is mortal" and "All men are mortal," as being of the same form; Peano and Frege showed that they are utterly different in form.

In fact, in the second volume "The Science of Logic" devoted to the subjective logic (the concept), Hegel explores various previously known forms of judgment (proposition in the more modern language) and the syllogism to discover their inherent dialectics that up to his time had escaped the attention of philosophers. In particular, the proposition "Socrates is mortal" would be considered an example of the *singular* judgment (proposition) of reflection and the proposition "All men are mortal" – an example of the *universal* judgment of reflection or even (depending on the context) of the categorical judgment of necessity. So the form of these two proposition had been considered different long time before the works of Peano and Frege. In a footnote on p.50 of [46], B. Russell admits that "it was often recognized that there was *some* difference between them, but it was not recognized that the difference is fundamental, and of very great importance." We will see soon what kind of fundamental difference is to be found there, but one would probably suspect right away that the whole rather vast content of *mathematical* logic – and both Frege and Peano were mathematicians – would be a rather unlikely substitute for that of philosophy. B. Russell agrees with such suspicion [46], p.50:

> Mathematical logic, even in its most modern form, is not directly of philosophical importance except in its beginnings. After the beginnings, it belongs rather to mathematics than to philosophy. Of its beginnings, which are the only part of it that can properly be called *philosophical logic*, I shall speak shortly.

So what part of mathematical logic can be also classified as philosophical one (and thus serve as an alternative to Hegel's system), according to B. Russell? A couple of pages later, we find the answer [46], p.52:

> In every proposition and in every inference there is, besides the particular subject-matter concerned, a certain *form*, a way in which the constituents of the proposition or inference are put together...
>
> It is forms, in this sense, that are the proper object of philosophical logic.

Example are given to illustrate the point, and we find that, for example, the propositions "Socrates drank the hemlock" and "Coleridge ate opium" have the same form but altogether different constituents. The conclusion drawn from the stated observation of any sentence possessing both form and constituents is simply that one needs to have the knowledge of both such ingredients in order to understand the sentence in question [46], p.53:

> In order to **understand a sentence**, it is necessary to have knowledge both of the constituents and of the particular instance of the form. It is in this way that a sentence conveys information, since it tells us that certain known objects are related according to a certain known form. Thus some kind of knowledge of logical forms, though with most people it is not explicit, is involved in all understanding of discourse. It is the **business of philosophical logic to extract this knowledge** from its concrete integuments, and to **render it explicit and pure**.

Thus we learn of the main purpose of philosophical logic according to the reformed and liberated from the tenets of idealism and monism B. Russell: this purpose is to study the *possible forms of sentences of a language*. He continues on the same page:

> In all inference, form alone is essential: the particular subject-matter is irrelevant except as securing the truth of the premisses. This is one reason for the great importance of logical form.

We see the good old formal logic applied to sentences of a language. Apparently, thought (as a main subject of philosophy, the "laws" of which is the main interest of logic), in B. Russell's view, is nothing else but a collection of interrelated sentences produced by a thinking individual. We begin seeing the seeds of the philosophy of B. Russell's pupil which we will briefly discuss later. We also see the sharp distinction B. Russell's tries to make between subject matter of such sentences (that corresponds to "facts" to be discussed soon) and their form, i.e. simply a resurrection of the naive "separation, presupposed once and for all in ordinary consciousness, of the content of knowledge and its form, or of *truth* and *certainty*" which, according to Hegel, was to be left behind before a commencement of a properly philosophical study. In addition, "formal," to B. Russell, appears to a be a synonym for "rational" [46], p.54:

> In logic, it is a waste of time to deal with inferences concerning particular cases: we deal throughout with completely general and **purely formal** implications, leaving it to other sciences to discover when the hypotheses are verified and when they are not.

Again, subject matter of whatever happens to attract the current attention of a scientific philosopher is seen as some inert and alien to logic mass that has to be properly and carefully sorted out with the help of formal logic residing in the head of the said philosopher.

After that, the reader of [46] learns of one major fault of the classical philosophical tradition and simple propositions it made use of: "it believed that there was only one form of simple proposition, namely, the form which ascribes a predicate to a subject." It turns out, the classical tradition failed to realize the existence and importance of *relations* of the sort "this thing is bigger than that," and this failure doomed the classical philosophy as a viable instrument of science. Recalling that I. Kant started as what now would be considered a physicist and was the author of the famous *nebular hypothesis*, and Hegel was an expert in differential calculus[100] (cutting edge of mathematics at that time), the author of this article found himself in the state of disbelief upon reading that statement by B. Russell for the first time. Indeed, if the relations of the sort "x is greater than y" and "A is the father of B" (and "B is a son of A") had been deemed directly relevant to philosophy by these people, it is safe to assume that they would have studied them in some detail. Apparently, they had a reason to think otherwise. It would have been a good idea for a young student of philosophy (like the young B. Russell) to try to understand what that reason had been. Since the ("long") classical tradition is over two thousand years old, achieving such an understanding could require some serious effort for which B. Russell apparently did not have enough time or patience. But, as we will see next, he did not need any of those due to his enviable ability to quickly see through "integuments" of any sort.

It is well known that B. Russell was a man of many talents, being an accomplished mathematician, philosopher, writer, and a political activist. Fewer people are aware though of his talent as a psychologist and a mind reader, as the following passage shows [46], p.55:

> Belief in the unreality of the world of sense arises with irresistible force in certain moods – moods which, I imagine, have some simple physiological basis, but are none the less powerfully persuasive. The conviction born of these moods is the source of most mysticism and of most metaphysics.

With B. Russell's characteristic modesty, he interjects the words "I imagine" in the above incisive description of the source of the "mystical" brand of philosophy. A bit lower on the same page and on the next, the reader finds the names of the suspects and further rapierlike

[100]One could also remember Descartes – one of the founders of modern mathematics and a philosopher in the "long" classical tradition – from the Greeks to Hegel – at the same time. He obviously knew everything about relations of the form $x > y$ and all their variations, but talked about different matters in his philosophical works.

exposition of the inner sources of their erroneous philosophy that happen to lie in their disagreeable misanthropic personalities.

> It is in this way that logic has been pursued by those of the great philosophers who were mystics – notably Plato, Spinoza, and Hegel. But since they usually took for granted the supposed insight of the mystic emotion, their logical doctrines were presented with a certain dryness, and were believed by their disciples to be quite independent of the sudden illumination from which they sprang. Nevertheless their origin clung to them, and they remained to borrow a useful word from Mr. Santayana "malicious" in regard to the world of science and common sense...
>
> The logic of mysticism shows, as is natural, the defects which are inherent in anything malicious. While the mystic mood is dominant, the need of logic is not felt; as the mood fades, the impulse to logic reasserts itself, but with a desire to retain the vanishing insight, or at least to prove that it was insight, and that what seems to contradict it is illusion. The logic which thus arises is not quite disinterested or candid, and is inspired by a certain hatred of the daily world to which it is to be applied. Such an attitude naturally does not tend to the best results.

Indeed, one has to pity the poor Plato, Spinoza, and Hegel. If only they had been fortunate enough to have somebody like B. Russell as their counselor, perhaps they could have been cured of their hateful attitude towards the world, and we could all reap the corresponding philosophical benefits. Having duly disposed of the "malicious" science hater Hegel (along with many predecessors) and his complicated – but misanthropic and thus not worthy of serious study – philosophy, B. Russell clears the way for the *much* simpler – but very science friendly and totally free of mysticism – philosophy of his own. Let us see what "results" such an improved attitude "tends to."

Having rejected the whole of classical tradition of logic that culminated in Hegel's system, B. Russell had to propose something – hopefully equally substantial but orders of magnitude simpler – as a replacement. He decided to concentrate on relations that had escaped the attention of the classical tradition, especially the *asymmetric* ones [46], p.59:

> Asymmetrical relations are involved in all series – in space and time, greater and less, whole and part, and many others of the most important characteristics of the actual world. All these aspects, therefore, the logic which reduces everything to subjects and predicates is compelled to condemn as error and mere appearance. To those whose logic is not malicious, such a wholesale condemnation appears

> impossible. And in fact there is no reason except prejudice, so far as I can discover, for denying the reality of relations.

We can see one more time the clear traumatizing influence of F.H. Bradley (the reference to error and mere appearance in the quotation above stated in a categorical non-dialectical fashion) on B. Russell's ideas about dialectics.

Having made the resolution to make the study of forms of sentences the main goal of the new and improved scientific version of the philosophical logic, and having discovered that the classical tradition had not done any justice to relations, B. Russell duly noted that these sentences – if they are to be capable of describing scientific knowledge – have to reflect the objective reality which, for him, is nothing else but an enormous collection of "facts" understood as "things" taken with their properties and mutual relations [46], p.60:

> Thus such relations [between more than two terms] are by no means recondite or rare. But in order to explain exactly how they differ from relations of two terms, we must embark upon a **classification of the logical forms of facts**, which is the first business of logic, and the business in which the traditional logic has been most deficient.

The definition of a "fact" mentioned above follows next [46], p.60:

> When I speak of a "fact," I do not mean one of the simple things in the world; I mean that a certain thing has a certain quality, or that certain things have a certain relation.

Once again, we can already see the philosophy of B. Russell's once favorite pupil – which was going to take the teacher's[101] searches for truth purely in "external relations" to its logical conclusion – already in the making. Once such a direction is taken, what's going to follow is a rather simple matter to predict. Two independent worlds are coming – the world of facts registered and recorded by the senses and independent of thought, and the world of thought residing in the heads of scientists and scientific philosophers that records and organizes the facts, and makes inferences from them with the help of formal logic whose basic rules are self-evident [46], p.61:

> Given any fact, there is an assertion which expresses the fact. The fact itself is objective, and independent of our thought or opinion about it; but the assertion is something which involves thought, and may be either true or false.

[101] It is somewhat ironic that we have an example of an asymmetric relation ignored by the classical tradition – a pupil and a teacher – right here.

The subjective truth of propositions, the totality of which can in principle encompass the whole truth, depends entirely on how correctly the propositions record the objective facts. The propositions just expressing the facts and not relations between other propositions (i.e. the ones containing no conjunctions like "if," "and," "or," and so on) then are given the name of "atomic"[102] propositions (thus giving us a hint on how the "logical atomism" obtained its very scientifically sounding name). These "atomic" propositions' single goal is to faithfully record the facts [46], p.62:

> Whether an atomic proposition, such as "this is red," or "this is before that," is to be asserted or denied can only be known empirically. Perhaps one atomic fact may sometimes be capable of being inferred from another, though this seems very doubtful; but in any case it cannot be inferred from premisses no one of which is an atomic fact.

One more time still, we see a precursor of B. Russell's favorite pupil's philosophy with its *principle* of atomic facts independence (to be briefly discussed later in this appendix). The simple observation that, in most cases, atomic facts understood in this way can certainly be inferred from each other[103] (which is a consequence of the universal bond and the reason that any science can exist) does not stop the indomitable rebel against the malicious idealism from making such claims.

The two separate worlds now take a nice shape: one of them is of an entirely *a priori*[104] nature, and the other – separated from the first by an impenetrable barrier – is 100% empirical [46], p.63:

> Thus pure logic is independent of atomic facts; but conversely, they are, in a sense, independent of logic. Pure logic and atomic facts are the two poles, the wholly a priori and the wholly empirical. But between the two lies a vast intermediate region, which we must now briefly explore.

The vast intermediate region between the two poles consists, according to B. Russell, of the "molecular" and of *general* proposition of the sort "all men are mortal." B. Russell's rejection of the classical tradition that explored the unity in multitude makes itself known right way when he begins discussing these general propositions. He notes the following [46], p.65:

[102]As one would now expect, the proposition containing conjunctions are dubbed "molecular."

[103]To take an example of a more trivial nature, in the spirit of most of B. Russell's philosophy, one can note that if there is a red object on an apple tree (atomic fact #1) then there will be a green object in its immediate vicinity (atomic fact #2).

[104]Here, one could accuse B. Russell of having not yet overcome the Kantian way of thinking, but, in his case, such a shortcoming is a trifle not worth mentioning, as we will see soon.

> But all *empirical* evidence is of *particular* truths. Hence, if there is any knowledge of general truths at all, there must be *some* knowledge of general truths which is independent of empirical evidence, i.e. does not depend upon the data of sense.

So – without necessarily wanting to do so – he begins polemics with the likes of Hume, instead of Hegel. As will become clear from a look at the following chapters of [46], such a "reduction" of philosophical level renders itself inevitable once the "rebellion against idealism and monism" standpoint is adapted. On the same page, B. Russell then continues:

> We must therefore admit that there is general knowledge not derived from sense, and that some of this knowledge is not obtained by inference but is primitive.

So, for B. Russell, knowledge is either obtained from sense (with some help from formal logic – in the modern form with quantified variables and formalized predicates) or has to be of a "primitive" or "a priori" flavor. At this point, it is appropriate to recall that this is coming from the philosopher (or, rather, polymath) who loudly bemoaned the "mystical" origins of some representatives of the rejected (by him) classical tradition. The source of knowledge that escapes his attention time and time again is the *totality of human practice* and the fundamental unity (without exception) of the world.

But what is the source of the "primitive" knowledge in B. Russell's view. Indeed, even though some inexplicable (i.e. mystical) component of it is implied by what he says, he can't afford (being a scientific philosopher *par excellence*) to explicitly admit it. So what does he say? It is the following [46], p.66:

> Such general knowledge is to be found in logic. **Whether there is any such knowledge not derived from logic, I do not know**; but in logic, at any rate, we have such knowledge.

So the "primitive" a priori knowledge is to be found in the formal (new and improved by Peano and Frege) logic. Is it the kind of knowledge though that is sufficient to ascertain any general proposition as described by B. Russell? Clearly not, as argued by himself a couple of pages earlier. So some *other* "primitive" (not derived from senses) knowledge is needed. B. Russell, by his own admission we just cited, has no idea where to find it and whether it exists. But one has to realize that little setbacks of this sort are bound to take place if one tries sufficiently hard to become a self-made philosophical *tabula rasa* by rejecting the results of (at least) a couple of millennia worth of the classical tradition.

To wrap up his presentation of the newly reduced – and, we have to grant it to him, monumentally simplified by a banal truncation of its most challenging component – logic,

B. Russell draws another line by dividing the whole subject of formal logic into two parts, the first one largely belonging to the domain of philosophy, with the second being more of a concern for mathematicians [46], p.67:

> The first part [of logic], which **merely enumerates forms**, is the more difficult, and philosophically the more important; and it is the recent progress in this first part, more than anything else, that has rendered a truly scientific discussion of many philosophical problems possible.

The "truly scientific" qualification here refers to a discussion of *philosophical* problems with the help of *formal logic* and mathematical notation. It can be interesting to recall such attempts that took place in the earlier times, one of the more prominent ones having been made by G.W. Leibniz who (according to Hegel in [1], p.607) "subjected the syllogism to a combinatory calculus, thereby reckoning the number of possible positions of the syllogism" and "found that there are 2,048 such possible combinations, of which, after the exclusion of the useless figures, 24 useful ones remain." A comparison to the "mere form enumeration" of "the first part" of logic expounded by B. Russell is asking to be made. In fact, the founder of scientific philosophy was well aware of such attempts by Leibniz and – naturally – valued them highly [46], p.49:

> This kind of logic is mathematical in two different senses: it is itself a branch of mathematics, and it is the logic which is specially applicable to other more traditional branches of mathematics. Historically, it began as merely a branch of mathematics: its special applicability to other branches is a more recent development. In both respects, it is the fulfilment of a hope which Leibniz cherished throughout his life, and pursued with all the ardour of his amazing intellectual energy. Much of his work on this subject has been published recently, since his discoveries have been remade by others; but none was published by him, because his results persisted in contradicting certain points in the traditional doctrine of the syllogism.

That the developments in mathematical logic constitute significant advances in the science of mathematics is certainly true, and we agree (and Hegel would have likely done likewise) with B. Russell on this point. That they can form a basis of philosophy and facilitate the solution of philosophical problems is quite another matter. Since Hegel was aware of these attempts by Leibniz, let us see what he thought about their philosophical aspect. On p.607 of [1] we read:

> This Leibnizian application of combinatory calculus to the syllogism and to the combination of other concepts differs from the disreputable Art of Lully solely because it is more methodical on the *numerical* side, but for the rest it equals it in meaninglessness. – Connected with this was an idea dear to Leibniz, one which he conceived in his youth and, despite its immaturity and shallowness, never abandoned even in later life. This was the idea of a *characteristica universalis* of concepts – a standard language in which each concept is presented as a connection of other concepts or as connecting with others – **as if in a rational combination, which is essentially dialectical, a content would still retain the same determinations that it has when fixed in isolation**.

The true meaning of the highlighted phrase in the quotation above went right over the young Bertrand's head (assuming that he had gone as far as actually reading it as opposed to using F.H. Bradley as a translator from Hegelian), which in itself is not very surprising given the degree of difficulty of the material of the "The Science of Logic," his apparently impulsive nature, and the budding "young genius" attitude that he exhibited. What has to be classified as avoidable and therefore sad is that he – having failed to understand it at a tender age when his chances of success were objectively slim – went into a full-on denial mode and never made a second attempt.

Seemingly realizing deep in his mind that an introduction of quantified variables and a formalization of predicates does not amount to a radical transformative change capable of making the formal logic by itself a viable tool of reason, B. Russell begins looking for other advantages those advances bring about. He finds them in new possibilities afforded for the analysis of *individual beliefs* [46], p.68:

> Suppose I believe that Charles I died in his bed. There is no objective fact "Charles I's death in his bed" to which I can have a relation of apprehension. Charles I and death and his bed are objective, but they are not, except in my thought, put together as my false belief supposes. It is therefore necessary, in analysing a belief, to look for some other logical form than a two-term relation. Failure to realize this necessity has, in my opinion, vitiated almost everything that has hitherto been written on the theory of knowledge, making the problem of error insoluble and the difference between belief and perception inexplicable.

Here another characteristic feature of B. Russell's philosophy becomes evident. It is a somewhat exaggerated attention to an *isolated individual* and the corresponding beliefs, opinions etc. The root cause of such individualistic Robinsonade of a gnoseology has to be the renunciation of monism that started the young Bertrand's transformation from a staunch Hegelian into a truly scientific philosopher.

The next chapter (Lecture) of [46] is titled "On our knowledge of the external world." The world is really a unity, and not a collection of "externally related things," which also applies to B. Russell's philosophy. As we are going to see by surveying the contents of this chapter, the "reduction" of logic undertaken in the "scientific philosophy" had an immediate (and predictable) effect on the rest of the latter. Having erased – from his mind – the hard earned gains of the classical tradition, the idealistic hot-house escapee had to start from scratch and chose the "doubt as to the reality of the world of sense" as the *terminus a quo*. This move immediately caused a suitable substitution in the opposing idealistic team, and B. Russell found himself in contention with the likes of Bishop Berkeley instead of Hegel [46], p.71:

> **Berkeley's attack**, as reinforced by the physiology of the sense-organs and nerves and brain, is **very powerful**.

Indeed, at the philosophical level the logical "reduction" had brought about, G. Berkeley becomes a much better matched opponent. And, as we see from the above quotation, B. Russell indeed takes him very seriously. On the other hand, he finally feels himself – and this feeling is well justified – an adequate match for the idealistic team players on the field. Expertly parrying the attacks of Berkeley, Hume, and their later followers (like E. Mach, for example) he states [46], p.74:

> **Universal scepticism**, though logically irrefutable, **is practically barren**; it can only, therefore, give a certain flavour of hesitancy to our beliefs, and cannot be used to substitute other beliefs for them.

A glimpse of truth – and a hint at the connection of thinking to human practice taken in its totality – can be seen in the above quotation. Also recalling that for B. Russell logic is identical with formal logic, the statement he makes about the irrefutability of the universal scepticism has to be considered correct as well. On the other hand, this is clearly not so if the logic of the classical tradition (culminating in Hegel's system) is implied. The adapted "pluralistic" view however prevents B. Russell from realizing that, and he continues paying homage to the most extreme, crude version of subjective idealism [46], p.77:

> We naturally believe, for example, that tables and chairs, trees and mountains, are still there when we turn our backs upon them. I do not wish for a moment to maintain that this is certainly not the case, but I do maintain that the **question**

> **whether it is the case is not to be settled offhand** on any supposed ground of obviousness.

Indeed, the gnoseological position of an isolated passive observer one-on-one with the world and his/her senses does not allow even for a firm belief "that tables and chairs, trees and mountains are still there when we turn our backs upon them," even though, by B. Russell's admission, such a belief is "natural." It appears to be rather clear that he could have made some progress simply by asking himself about the reasons for such naturalness. It looks like though that the insistence on "formality" of any proof or argument belonging in a truly scientific philosophy precluded him from looking for such reasons. Thus "the sceptical hypothesis," for B. Russell, becomes an unsurmountable obstacle that he simply chooses to go around – and stay at the same general philosophical level [46], p.78:

> If we are to continue philosophizing, **we must make our bow to the sceptical hypothesis**, and, while admitting the elegant terseness of its philosophy, proceed to the consideration of other hypotheses which, though perhaps not certain, have at least as good a right to our respect as the hypothesis of the sceptic.

Having admitted the sceptical hypothesis' "elegant terseness," B. Russell proceeds to explore – from the same point of view of an isolated passive observer – a series of rather trivial examples of a sensual apprehension of an object. All his philosophizing from this point on sounds a lot like a dissertation defence in front of a committee consisting of Berkeley, Hume, and Mach.

In one example of such philosophizing discussed in the chapter under our review, B. Russell considers a table and an observer walking around the table and absorbing the changing views of it. Any reasonable person with a typical (in a rather wide range) life experience – B. Russell himself included – would be certain of seeing the same table from various angles. We can note in passing that, in this example, an active stance can be easily assumed by even such a refined gentleman – by coming closer to the table, changing its position, and even its shape and size if it happens to be of a folding variety. Not so for a scientific philosopher of the new generation: he is always on the guard against the possible deceit of the unreliable senses, and is not going to be fooled by them [46], p.85:

> What is really known is a correlation of muscular and other bodily sensations with changes in visual sensations.

So it is not a table – but just a correlation. One can almost see Berkeley and Hume nodding their heads in agreement.

Somewhat unexpectedly (at least for the author of this article on his first reading of [46]), the plot continues to thicken. Thus, on p.90, one can read B. Russell's account on the reality of other people. The main problem is – since he is building his philosophy from scratch – "we are not at liberty to accept testimony." So what results from such a lack of liberty on "our" part – by B. Russell's fiat – is the following [46], p.90:

> When we see our friend drop a weight upon his toe, and hear him say – what we should say in similar circumstances, the phenomena *can* no doubt be explained without assuming that he is anything but a series of shapes and noises seen and heard by us, but practically no man is so **infected with philosophy** as not to be quite certain that his friend has felt the same kind of pain as he himself would feel.

One has to admit – as it is widely known anyway – that B. Russell's wit can be truly unparalleled, as the highlighted word combination in the quotation above illustrates. Indeed, *the* philosophy he is trying to advance at the beginning of 20th century, about a whole century after Hegel's main work, can easily and justifiably be classified as an infectious disease.

To put a bit more substance into his philosophy desperately trying to deal with the dire consequences of the radical logic truncation, B. Russell injects a bit of projective geometry into it. To this effect, he takes an example of a penny located somewhere in the usual three-dimensional space (which is dabbed "perspective space" to distinguish it from a "private space" of sensations of a given – apparently severely restrained to be rendered passive – observer) and describes the situation thusly [46], p.98:

> For this purpose, let us again consider the penny which appears in many perspectives. We formed a straight line of perspectives in which the penny looked circular, and we agreed that those in which it looked larger were to be considered as nearer to the penny. We can form another straight line of perspectives in which the penny is seen end-on and looks like a straight line of a certain thickness. These two lines will meet in a certain place in perspective space, i.e. in a certain perspective, which may be defined as "the place (in perspective space) where the penny is."

This may or may not be related to philosophy, but at least it is easy to read and has a decent entertainment value.

The elaborate geometric construction just discussed – unlike some non-scientific philosophers might have thought – is still not sufficient to conclude that a penny is located somewhere on a table in a three-dimensional space. One has to remember that anything outside one's private world can be trusted no more than swamp lights for a beacon. B. Russell is not about to let his guard down [46], p.101:

> This brings us back to our original problem, as to the grounds for believing in the existence of anything outside my private world. What we have derived from our hypothetical construction is that there are no grounds against the truth of this belief, **but we have not derived any positive grounds in its favour**.

Prof. Berkeley in the committee can be seen gesticulating to end the defense and grant the candidate the degree without further questioning due to the latter's superior command of the material. Other members are in full agreement. But the candidate still needs to consider the problem of other people's (or some "phantasm's of our dreams" looking like people – but do we have a rigorous formal definition of people after all?) testimony as a source of information for a scientific philosopher. Do they have minds? They probably do, but one can never be sure, answers B. Russell [46], p.101:

> It must be conceded to begin with that the argument in favour of the existence of other people's minds cannot be conclusive.

On the next page, he continues:

> The obvious argument is, of course, derived from analogy. Other people's bodies behave as ours do when we have certain thoughts and feelings; hence, by analogy, it is natural to suppose that such behaviour is connected with thoughts and feelings like our own.

Again, if it is indeed "natural," why is it natural? But a gentleman's contemplative attitude prevails and we learn that (p.103):

> The hypothesis that other people have minds must, I think, be allowed to be not susceptible of any very strong support from the analogical argument. At the same time, it is a hypothesis which systematizes a vast body of facts and never leads to any consequences which there is reason to think false. There is therefore nothing to be said against its truth, and good reason to use it as a working hypothesis.

So it is still a hypothesis, but at least B. Russell is inclined to use it as a *working* hypothesis to build the rest of his philosophy upon. But would it be safer to wait a bit for a *formal* proof? What would the committee members think about such hastiness? But the candidate shows his strong adherence to the common sense this time around. After all, he set out to *combat* idealism, not maintain it [46], p.104:

> In actual fact, whatever we may try to think **as philosophers**, we cannot help believing in the minds of other people, so that the question whether our belief is justified has a merely speculative interest.

Implicitly, once again, B. Russell takes the totality of human practice derived point of view advocated (albeit in a somewhat convoluted way) in a reader's nightmare that is Hegel's "The Science of Logic." One can't help feeling a bit sad for B. Russell's unfulfilled philosophical – and thinking in general – potential.

In the next chapter, "The world of physics and the world of sense," B. Russell explains how his philosophy is to be used in physics. Since, as we already know, he began his mature phase as a philosopher by a radical truncation of the logic worked out by the classical tradition over more than two millennia worth of time, it would be a bit much for physics to hope to obtain some real help as far as the rational comprehension of its experimental results go. How the universal shows itself in the singular and the particular – any natural (and social) science needs a competent answer to this question, given in a way appropriate to its specific subject matter. Since formal logic is silent on these matters, it remains for the scientific philosophy to address some simpler issues. One if such issues is described in the chapter title. B. Russell formulates the problem at hand in the following way [46], p.106:

> Men of science, for the most part, are willing to condemn immediate data as "merely subjective," while yet maintaining the truth of the physics inferred from those data. But such an attitude, though it may be capable of justification, obviously stands in need of it; and the only justification possible must be one which **exhibits matter as a logical construction from sense-data** unless, indeed, there were some wholly a priori principle by which unknown entities could be inferred from such as are known.

As we have already mentioned, denying the objective universal (unity in the multitude) is likely to make one see the truth in the "sense-data" of an isolated individual (who is not really sure if other individuals exist provided he/she is sufficiently schooled in the scientific philosophy designed, as we have seen, under a decisive influence of maestros Berkeley and Hume). Therefore, as was shown on many occasions, since the modernized and adapted to physics version of Berkeley and Hume philosophy was provided by E. Mach, it would not be unreasonable to expect that what B. Russell has to say about physics would bear resemblance to – and be largely in agreement with – the philosophy of Mach, with his characteristic physical objects as "sense complexes," and the famous "economy of thought" principle making references to the no less famous "Occam's razor." Indeed, a few pages later, we find the following passage [46], p.110:

> Why should we suppose that, when ice melts, the water which replaces it is the same thing in a new form? Merely because this supposition enables us to state the phenomena in a way which is consonant with our prejudices. What we really know is that, under certain conditions of temperature, the appearance we call ice is replaced by the appearance we call water.

Anybody familiar with E. Mach's philosophy would agree that he himself couldn't have said it better. This passage is quite simply Machism at its finest – the spirit of the latter is expressed here in just one – but very characteristic – example in a truly virtuoso fashion. But what about "economy of thought" and "Occam's razor"? In another couple of pages we find it ready to be discovered.

First, we encounter a definition of sorts of a "thing" (to be stated explicitly shortly) which is almost verbatim Mach's physical objects as "sense complexes" – here they go under a more "objective" sounding name of "aspects" [46], p.112:

> More generally, a "thing" will be defined as a certain series of aspects, namely those which would commonly be said to be *of* the thing. To say that a certain aspect is an aspect *of* a certain thing will merely mean that it is one of those which, taken serially, *are* the thing.

One might want to inquire as to the justification for such "sense-centered" definition of a "thing." The answer is simply the "economy of thought" in the form of "Occam's razor" (on the same page):

> The above extrusion of permanent things affords an example of **the maxim which inspires all scientific philosophizing**, namely "Occam's razor": Entities are not to be multiplied without necessity. In other words, in dealing with any subject-matter, find out what entities are undeniably involved, and state everything in terms of these entities. Very often the resulting statement is more complicated and difficult than one which, like common sense and most philosophy, assumes hypothetical entities whose existence there is no good reason to

> believe in. We find it easier to imagine a wall-paper with changing colours than to think merely of the series of colours; but it is a mistake to suppose that what is easy and natural in thought is what is most free from unwarrantable assumptions, as the case of "things" very aptly illustrates.

Indeed a changing thing which is equal to itself (since it is the same thing) and not equal to itself (since it is changing) is impossible to rationally comprehend without dialectics which B. Russell rejected in a wholesale fashion after failing to put enough time and effort into its study (using the original source as opposed to any "distillate"). As a result, he found himself siding with Mach (and thus Berkeley and Hume) – so much for the "revolt against idealism."

The formal definition of a "thing" just hinted at comes in due order [46], p.115:

> Thus we may lay down the following definition: *Things are those series of aspects which obey the laws of physics.* That such series exist is an empirical fact, which constitutes the verifiability of physics.

A moment of note here is an idealistic definition ("... which obey the laws...") of the sort that would become commonplace in theoretical physics in a rather short time. Physics at that time was struggling to adequately assimilate and rationally comprehend new experimental results. A proper (dialectical) philosophy was desperately needed. Unfortunately, philosophers could not rise to the occasion, and the consequences are still felt as anybody familiar with the state of the modern theoretical physics (especially its most "fundamental" branches) could confirm.

The last chapter of the book [46] is devoted to the notion of cause and contains a summary of the new proposed philosophical method. It is the latter which is of direct interest to us. First, we learn that there is no general method to speak of [46], p.240:

> What has been said on philosophical method in the foregoing lectures has been rather by means of illustrations in particular cases than by means of general precepts. **Nothing of any value can be said on method except through examples**; but now, at the end of our course, we may collect certain general maxims which may possibly be a help in acquiring a philosophical habit of mind and a guide in looking for solutions of philosophic problems.

At this point it is appropriate to contrast this B. Russell's admission on the absence of any general method with Hegel's main work *all of which* is devoted to an exposition of just such a general method. The monism that B. Russell made a resolution to rebel against and fight with comes back with a riposte: *no logic except formal implies no philosophical method*, no matter how many times one pronounces any parts of formal logic philosophical.

For the lack of a method, let us at least consider the maxims: indeed it would certainly be desirable to learn of something that can provide guidance for solutions of philosophic problems. The first such maxim reads (on the same page):

> In order to become a scientific philosopher, a certain peculiar mental discipline is required. There must be present, first of all, the desire to know philosophical truth, and this desire must be sufficiently strong to survive through years when there seems no hope of its finding any satisfaction.

We have to admit that this maxim – as maxims go – is a very good one. It would have been even better if B. Russell could have followed that maxim himself when he still considered himself a Hegelian. This is especially true for the maxim's second part – about surviving through years without any positive incentives except the desire to know the truth. Let us now turn to the second maxim. It reads [46], p.242:

> The naive beliefs which we find in ourselves when we first begin the process of philosophic reflection may turn out, in the end, to be almost all capable of a true interpretation; but they ought all, before being admitted into philosophy, to undergo the ordeal of sceptical criticism.

Just like the first one, the second maxim seems to make sense, with one exception: the criticism better be *rational* rather than sceptical. One would only wish for B. Russell to have shaken himself free of the shade of his sceptical compatriot. On the other hand, even I. Kant could not quite do it – so it must be a fairly difficult task. But the founder of the classical German philosophy at least had a valid excuse: the modern dialectical logic was still to be formulated at the time he fought with the sceptical obscurantism. B. Russell, on the other hand, cannot be granted a parole on similar grounds.

While the first two maxims were more of a psychological variety – to be motivated by the truth, to stay indifferent to worldly success, and to avoid using the ordinary common sense uncritically – the third one reads more like an admission of the lack of a general method [46], p.243:

> At the same time, and as an essential aid to the direct perception of the truth, it is necessary to acquire **fertility in imagining** abstract hypotheses. This is, I think, what has most of all been lacking hitherto in philosophy.

Let us slightly rephrase: since there is no general method, one should just go with (abstract) *imagination*. Which, incidentally, would have made perfect sense if the world had not been a unity in multitude, but just an ad hoc collection of random "things" which, in turn, had been nothing more than a series of "aspects" comprised of "sense-data." And, granted, that *was* lacking in the classical philosophy. The early – staunch and vocal Machist – A. Einstein with his "free invention" of laws of nature comes to mind as soon as one begins reading the third maxim.

But – one might be inclined to ask – what about generalization which is implied by any *law* of nature? Well, the third maxim already contains – somewhat implicitly – B. Russell's answer to this question, in which mystical overtones can clearly be heard [46], p.245:

> When everything has been done that can be done by method, a stage is reached where only **direct philosophic vision** can carry matters further. Here only genius will avail.

Of course: if imagination fertility is the main tool of advance, a "direct vision" of a genius is needed. In practice, it meant that theories continued to be concocted in an ad hoc fashion, by taking *some* experimental results and making use of an "abstract hypothesis imagining fertility" to come up with some *principle* that would hopefully lead to a mathematical scheme capable of reproducing *these* experimental results – often ignoring others. Once some principle was zeroed in on – which could happen for a variety of reasons, including its "beauty" and "elegance" – further experimentation was often conducted within the newly established paradigm, with the principle and the corresponding scheme used as a basis for the experimental design. Not very surprisingly, further confirmations of the principle itself kept being found. The following passage of Hegel from [1] (p.726) reads like a text written by somebody intimately familiar with the history of theoretical physics in the 20th century:

> The so-called *explanation*, and the proof of the concrete brought into theorems, turn out to be partly a tautology, partly an obfuscation of the true relation, and partly also an obfuscation that serves to hide the deception of cognition. For cognition has collected experiences tendentiously, only so that it could attain its simple definitions and principles; and it has preempted the possibility of empirical refutation by taking experiences and accepting them as valid, not in their concrete totality but selectively, as examples that can then be used on behalf of its hypotheses and theories. In this subordination of concrete experience to presupposed determinations, the foundation of the theory is obscured and is only indicated according to the side that suits the theory; and, quite in general, the

> unprejudiced examination of concrete perceptions for their own sake is thereby much impeded.

B. Russell nevertheless insisted that the newly found absence of a logical method was going to be the starting point for a previously unheard of explosion in philosophical achievements [46], p.246:

> The one and only condition, I believe, which is necessary in order to secure for philosophy in the near future an achievement surpassing all that has hitherto been accomplished by philosophers, is the **creation of a school of men** with scientific training and philosophical interests, **unhampered by the traditions of the past**, and not misled by the literary methods of those who copy the ancients in all except their merits.

B. Russell's favorite pupil fit the highlighted description to the dot. We will discuss his further contributions to the "unhampered philosophy" in the next section of this appendix.

To wrap up our brief review of the content of B. Russell's logical atomism, we can note that, oftentimes, new happens to be just a slightly disguised old. This everyday experience derived rather banal observation appears to fully apply to the new philosophy put forward by the rebel against idealism. As we have just witnessed, the logical method proposed by him boils down to the usage of the old – made more formal by the introduction of quantified variables and enhanced use of mathematical notation in general – formal logic, which is supposed to be applied to the sense data expressed in clear-cut relations and properties of things (that are really nothing more than series of aspects). Not surprisingly, the outcome is the complete absence of any general method, with generalizations being relegated to abstract hypotheses created – somehow, in an inexplicable "mystical" fashion – by geniuses. Such absence of a method is partly compensated by psychological and pedagogical recommendations. This resembles something that was happening a century earlier and described by Hegel as follows [1], p.24:

> A large part of these psychological, pedagogical, or physiological observations, of these laws and rules, whether they occur in logic or anywhere else, must appear in and for themselves to be quite shallow and trivial. The rule, for instance, that one should think through and personally test what one reads in books or hears by word of mouth; or, if one has poor sight, that one should aid the eyes with spectacles – rules which were offered for the attainment of truth in the textbooks of so-called applied logic, and even pompously set out in paragraphs – these must

> immediately strike everyone as superfluous – apart from the writer or the teacher who is in the **embarrassing position of having to pad with extra material the otherwise too short and lifeless content of logic**.

Indeed, if the unity of the world giving rise to its own inherent logic that is objective and subjective at the same time is "taken out of the equation," the little of what's left is lifeless, trivial, and shallow.

To conclude this section on a higher note, let us recall that B. Russell was also famous for his witty remarks, in true spirit of a British gentleman of the highest calibre. One of his well-known philosophy related jokes was given in his article "On denoting" [49], where he considered an example of a non-existent person, the present (in 1905) King of France, and started looking for paradoxes in his favorite formal logic (the only logic he was aware of, as we have seen). The question he proposed to settle was whether the King of France was bold or not. According to formal logic, the King of France had to be either bold or not. B. Russell, however, notes:

> Yet if we enumerated the things that are bald, and then the things that are not bald, we should not find the present King of France in either list. Hegelians, who love a synthesis, will probably conclude that he wears a wig.

The last sentence of this quotation contains the famous joke of the kind the British gentleman *par excellence* was known for. An extended discussion of such a witty person could only benefit from one more philosophical joke. To this effect, one could be justified in saying that the kind of philosophy B. Russell proposed in place of Hegel's impenetrable metaphysics was really a quintessential *gentleman's philosophy*. Indeed, it is sufficiently simple to be discussed in a club between the results of horse races and likely future trends in stock prices. It is also sufficiently rigorous to be able draw a hard and fast line between the money a gentleman owes and the money that is owed to him. (No silly unities of opposites are allowed here.) Lastly, it tries to appear forward looking and progress loving on the surface, but is conservative at its core: gentlemen like the existing *status quo* and are not really keen on changing it. Respectively, the logic truncation undertaken in the gentleman's philosophy is bound to keep changes at bay by restraining the reason that might bring unwanted surprises if given too much leeway.

A.4 L. Wittgenstein: logical atomism as a system

As we have seen, B. Russell – along with G.E. Moore – was what could be called a pioneer of the logical atomism as a distinct direction within philosophy. However, by his own admission, there was no general method to speak of – only assurances that a proper application of a sceptical analysis by means of the newly revised formal logic aided by the emancipation from the "metaphysical" classical tradition would propel philosophy to the new heights. The mission of making the logical atomism into a system fell to B. Russell's favorite pupil L. Wittgenstein. That system was expounded in the latter's book "Tractatus Logico-Philosophicus" [50]. The book is – as expected – rather small in volume and written in a somewhat peculiar style, with individual paragraphs and sometimes even sentences numbered. The latter feature, on the other hand, makes the task of quoting and finding quotations easier than usual. The edition we used has the original German text and two English translations: an earlier one by Ogden/Ramsey and one made at a later date by Pears/McGuinness. In the following, we use both of them for direct quotation. One obvious difference between these two translations is that the German "Sachverhalt" is translated as "atomic fact" in Ogden/Ramsey and as "state of affairs" in Pears/McGuinness. "Sachlage," on the other hand, is "state of affairs" in Ogden/Ramsey but "situation" in Pears/McGuinness. To avoid confusion, we always use the Ogden/Ramsey translation of these terms. Also, the German "Zeichensprache," seemingly central for the system presented in [50] is translated as "symbolism" in Ogden/Ramsey but as "sign-language" in Pears/McGuinness. We use the former version as it seems to agree with what B. Russell uses in his introduction to [50].

In the preface, the main goal of the book is stated: to deal with the problems of philosophy, no less:

> The book deals with the problems of philosophy, and shows, I believe, that the reason why these problems are **posed** is that the logic of our language is misunderstood.

To any half-serious student of philosophy, the second part of the sentence given in the quotation above sounds a bit surprising, and, if taken seriously, somewhat discouraging. Indeed, what is implied here is that the "problems of philosophy" are even *posed* for a wrong reason, meaning there is nothing really to study (and all the efforts have been wasted). On a second thought though, it occurs that such a radical claim is very unlikely to be true, and therefore should not be taken fully seriously. Let us continue reading the preface. The very next paragraph proclaims:

> Thus the aim of the book is to draw a **limit to thought**, or rather – not to

> thought, but to the expression of thoughts: for in order to be able to draw a limit to thought, we should have to find both sides of the limit thinkable (i.e. we should have to be able to think what cannot be thought).
>
> It will therefore only be in language that the limit can be drawn, and what lies on the other side of the limit will simply be nonsense.

Since the nature and content of thought and thinking is indeed one of the main problems of philosophy, drawing a limit thereby could indeed have an effect of rendering philosophy a "subject without matter" of sorts – provided the said limit is a sufficiently severe one. The clarification that follows the radical statement of a (universal or personal?) limit to thought sounds mildly encouraging: the limit is to be drawn only to the *expression* of thoughts (whose?) and, moreover, there is even an admission by the author to being able "to think what cannot be thought" (seemingly implying that it can be thought after all, perhaps with a special permission). The encouragement does not seem to last long though since the limit is to be drawn in language (which by itself does not sound very terminal as one is aware of any language's potential of further development), but, at the same time, whatever is left on the other side of the limit is relegated to the status of "nonsense," meaning, apparently, that what we were still hoping to be able to think of with a permission is not worth thinking about. Again, history seems to suggest that such unfortunate situation may be one of a temporary variety, and what we cannot yet think about now (due to the lack of any practical experience with it, for example) might become quite thinkable – and even commonplace – later. But this appears to be not what the author of [50] has in mind. To him, the limits to thought are more fundamental than just a situational lack of knowledge. The final paragraph of the preface makes quite a resounding announcement:

> On the other hand, the truth of the thoughts that are here communicated seems to me **unassailable and definitive**. I therefore believe myself to have found, on all essential points, **the final solution** of the problems. And if I am not mistaken in this belief, then the second thing in which the value of this work consists is that it shows **how little is achieved** when these problems are solved.

Assuming the author of [50] is not joking, he literally means that he has closed the door on philosophy, and it is kind of permanent. Recall that "the problems" from the quotation above are those of philosophy, and "the final solutions" to these problems are claimed to have been found. Moreover, "little was achieved" by doing so, i.e. the problems were almost trivial all the while multiple generations of philosophers were doing their best to address them.

Moreover, the author claims to have solved the problems of philosophy in an "unassailable and definitive" manner *without consulting the work of philosophers.* Indeed, no other works are referenced in [50], and, according to the author, the reason for such lack of references is that he feels indifferent to "whether the thoughts that I have had have been anticipated by someone else." But the main concern here is not the possible anticipation of the author's thoughts by somebody else (as we will discuss in the next section of this appendix, it is very possible), but rather that a thorough study of the contents of prior philosophical works could have prevented such thoughts altogether and perhaps given rise to thoughts of a different kind. But let us continue out brief review of logical atomism as a system and turn from the preface to the main content of [50].

Right away, a reader learns of what the world is [50], 1.1: "The world is the totality of facts, not of things." A natural question the reader might have is what a fact is. The answer is given a few sentences later [50], 2, 2.1: "What is the case, the fact, is the existence of atomic facts," and "An atomic fact is a combination of objects (entities, things)." After such an ontological overture, the reader – if in possession of any philosophy background – begins feeling confirmed in his/her initial suspicions (raised by the preface) as to the presence of such background on the author's part. Indeed, the beginning sounds a lot like a slightly formalized statement of the mental imagery (representation) characteristic of the ordinary common sense, a sort of naive realism that has been left behind by the mainstream ("long" classical) philosophy tradition at least a few centuries ago. For comparison sake, one could recall that, for example, in Hegel's "The Science of Logic" devoted to very similar problems, the notion of a "thing" along with its "properties" appears more than a hundred thousand words after the beginning.

Let us continue reading. Paragraphs 2.011, 2.012, and 2.0121 contain what looks like an exposition of the universal bond (or, the "internal relations" rejected by B. Russell) in the author's hyper-laconic style:

> It is essential to a thing that it can be a constituent part of an atomic fact. In logic nothing is accidental: if a thing *can* occur in an atomic fact the possibility of that atomic fact must already be prejudged in the thing. It would, so to speak, appear as an accident, when to a thing that could exist alone on its own account, subsequently a state of affairs could be made to fit. If things can occur in atomic facts, this possibility must already lie in them. Just as we cannot think of spatial objects at all apart from space, or temporal objects apart from time, so we cannot think of any object apart from the possibility of its connection with other things. If I can think of an object in the context of an atomic fact, I cannot think of it apart from the *possibility* of this context.

In other words, to know something fully, one needs to explore all its ties to the rest of the world which is hard to argue against. So this part of [50] begins looking like a – somewhat abridged – version of first volume of "The Science of Logic." Indeed, just a few lines later the notion of *substance* makes its appearance [50], 2.02, 2.0201, 2.021:

> Objects are simple. Every statement about complexes can be resolved into a statement about their constituents and into the propositions that describe the complexes completely. Objects make up the substance of the world. That is why they cannot be composite.

So, according to the author of [50], substance is just a collection of objects (!) which have to be simple (what does it mean?). For comparison, in Hegel's system, the notion of substance appears only towards the end of the first volume of [1], taking several hundred pages of quite dense text to develop. Let us see what this substance is about. Clearly, it has to be something simple and easy to explain (which is, by the way, a decisive advantage [50] enjoys, especially over "The Science of Logic"). These expectations are indeed fulfilled as we learn the following [50], 2.024 to 2.03:

> The substance is what subsists independently of what is the case. It is form and content. Space, time, colour (being coloured) are forms of objects. There must be objects, if the world is to have unalterable form. Objects, the unalterable, and the subsistent are one and the same. Objects are what is unalterable and subsistent; their configuration is what is changing and unstable. The configuration of objects produces atomic facts. In an atomic fact objects fit into one another like the links of a chain.

So, the substance is just a collection of unalterable objects that change their (spatial?) configuration thereby creating different atomic facts. This sounds like a version of a naive atomism ontology, with objects playing the role of atoms. On the other hand, we have learned a bit earlier that "we cannot think of any object apart from the possibility of its connection with other things" and also ([50], 2.01231) that "If I am to know an object, though I need not know its external properties, I must know all its internal properties." This seems to imply that objects, although unalterable, possess "internal properties" and cannot be known taken in isolation. Thus what we see here is not a naive atomistic ontology, but rather an ontology maximally "adapted" for the subsequent analysis with the help of formal logic. As we have already mentioned, [50] expounds logical atomism as a system, and, apparently, to make it possible, a kind of ontological atomism is required.

The presence of the universal bond in the substance appears to be staunchly denied in that system, just like in B. Russell's teachings (recall his rejection of "internal relations") as we find the following categorical statement [50], 2.061, 2.062:

> Atomic facts are independent of one another. From the existence or non-existence of one atomic fact it is impossible to infer the existence or non-existence of another.

The whole of reality, in all its manifestations, being a refutation of such a claim – regardless of how one might want to define an atomic fact – does not seem to stop the undaunted system developer steadfastly bound on – as we have seen already and will see again – overthrowing the whole of the classical tradition of philosophy.

Now that we are done with the ontological curtain-raiser, we are ready for the gnoseological main event. We already know that the world is an enormous collection of mutually independent atomic facts. How do we learn about this world? Obviously, we just "picture facts to ourselves" ([50], 2.1). Nobody would also be much surprised to learn that "a picture is a model of reality" ([50], 2.12), and that "in a picture the elements of the picture are the representatives of objects" ([50], 2.131). What we have here is rather clearly a case of what Hegel calls "Vorstellung" – representation, or mental imagery – and constantly emphasizes its preliminary – compared to concept – nature, as far as gnoseology is concerned. Such a picture might be true or false by either agreeing or disagreeing with reality [50], 2.21 to 2.223:

> A picture agrees with reality or fails to agree; it is correct or incorrect, true or false. What a picture represents it represents independently of its truth or falsity, by means of its pictorial form. What a picture represents is its sense. The agreement or disagreement of its sense with reality constitutes its truth or falsity. In order to tell whether a picture is true or false we must compare it with reality.

A picture, as we see, has an inherent "pictorial form" that represents its "sense." As we will see shortly, that "sense" appears to play an important role in the system of [50].

Now that pictures have been introduced and their sense hinted at, the reader is prepared to learn what thought is [50], 3, 3.001, 3.01:

> The logical picture of the facts is the thought. "An atomic fact is thinkable" – means: we can imagine it. The totality of true thoughts is a picture of the world.

Thus thought is rather unequivocally identified with just a mental picture of observable facts, even though that picture has to be "logical" – we will see later what this implies. No trace of thought in the sense Hegel associated with it – as the universal present in the singular and the particular that has both objective and subjective moments – can be seen here yet. Let us see what follows from such a "clear" notion of thought. Turns out that, in order to make thought "tangible," it can be made into a proposition that simply depicts the "state of affairs" [50], 3.1, 3.11:

> In a proposition a thought finds an expression that can be perceived by the senses. We use the perceptible sign of a proposition (spoken or written, etc.) as a projection of a possible state of affairs.

Not surprisingly, in such a proposition, every object of the thought is depicted with a corresponding sign. Recalling that in the preceding ontology objects were declared to be simple (like the atoms of the ancient Greeks), they are depicted by like signs which can only be named (but not further "dissected") [50], 3.2, 3.201, 3.202:

> In a proposition a thought can be expressed in such a way that elements of the propositional sign correspond to the objects of the thought. I call such elements "simple signs," and such a proposition "completely analysed." The simple signs employed in propositions are called names.

The possibility of the existence of such "simple signs" appears to be of a fundamental importance to the system under consideration – it is going to be directly related to the clarity, or determinateness, of sense of the corresponding propositions – so much so that anything lacking such clarity is going to be proclaimed to be devoid of sense, a pseudoproblem etc. [50], 3.21 to 3.23:

> To the configuration of the simple signs in the propositional sign corresponds the configuration of the objects in the state of affairs. In the proposition the name represents the object. Objects I can only *name*. Signs represent them. I can only speak of them. I cannot *assert* them. A proposition can only say *how* a thing is, not *what* it is. The postulate of the possibility of the simple signs is the postulate of the determinateness of the sense.

We see that the possibility of simple signs is even made into a postulate.

Now we are moving closer to what the author of [50] considered – judging by the verbiage used – his groundbreaking (and almost philosophy ending) contribution: the discovery of the main reason why philosophy had been so inefficient solving its problems before. Turns out, it can be traced to the typical use of everyday language which was, supposedly, uncritically adapted by philosophy [50], 3.323:

> In everyday language it very frequently happens that the same word has different modes of signification – and so belongs to different symbols – or that two words that have different modes of signification are employed in propositions in what is superficially the same way.

As we have mentioned, philosophy – according to [50] – was found to be far from immune to such sloppy word usage. So the recipe to the correct philosophy – and thinking in general – appears to be clear: one has to simply avoid using same signs for different symbols (that are understood to be one-to-one reflections of objects, their properties, and (external) relations between them) and vice versa [50], 3.324, 3.325:

> In this way the most fundamental confusions are easily produced (the whole of philosophy is full of them). In order to avoid such errors we must make use of a symbolism that excludes them by not using the same sign for different symbols and by not using in a superficially similar way signs that have different modes of signification: that is to say, a symbolism that is governed by logical grammar – by logical syntax. (The logical symbolism of Frege and Russell is such a language, which, however does still not exclude all errors.)

Buoyed by this discovery (of the main fallacy of all previous philosophy, no less) and by his youthful enthusiasm (he was not yet 30 when he finished it), the author of [50] sets on the path of making sure that such woeful and fateful mistakes cannot be repeated any more. His recipe? Nothing new actually: just the maximal formalization (to the extent of automatization) of logic, and thus the process of thinking, which should be doable without reference to meaning as soon as the latter has been established as the outset [50], 3.33:

> In logical syntax the meaning of a sign should never play a role. It must be possible to establish logical syntax without mentioning the meaning of a sign: only the description of expressions may be presupposed.

Thus, as we see, a logical "syntax" has to be developed that would take care of (logical) thinking leaving no room for errors. According to L. Wittgenstein, his teacher was not sufficiently determined in eliminating meaning from the process of thinking [50], 3.331:

> From this observation we turn to Russell's "theory of types." It can be seen that **Russell must be wrong**, because he had to mention the meaning of signs when establishing the rules for them.

If we wanted to just explain the main point of philosophy expounded in [50] and to point out the main reason for why such an approach could not possibly lead to any advancement of the level of philosophy achieved by early 20th century, we could end our brief review of the content of [50] at this point. Indeed, it is already clear why the proposed approach was going to fall short of being a philosophical one in the proper sense. In a nutshell, the main reason for its deficiency is the complete neglect of the unity that is present in the observable multitude of "objects" and "facts." Once B. Russell's "doctrine of external relations" is adapted in any form, all possibility for progress in philosophy (in the narrow sense[105] of philosophical logic as the investigation of the true nature of thought) is immediately taken away. The purely descriptive ontology that begins with facts understood as simple objects "hanging together" in external relations unavoidably leads a "proposition centered" gnoseology whose focus shifts to clarity and correctness of the respective (subjective) descriptions of the said facts, leaving no room to what Hegel considered the subject matter of philosophy as such. The most instructive point though – and this is where the contribution of [50] to philosophy really lies – is to follow the logic of [50] further to see what conclusions such a theoretical stance is going to lead to. L. Wittgenstein made a system out of B. Russell's still somewhat fuzzy "doctrine of external relations" and, in the process, rather clearly demonstrated its logical and philosophical consequences.

At the beginning of the next "chapter," [50] reiterates its notion of thought 4, 4.001:

> A thought is a proposition with a sense. The totality of propositions is language.

So apparently thought, according to [50], is not much different from a sort of silent speech that takes place in the head of a thinking individual. Such suspicion is further confirmed by the next statement (4.002): "Everyday language is a part of the human organism and is no less complicated than it." It makes it clear that thought is attributed to an individual human organism, and not to humanity as the subject of the totality of the nature transforming practice. The next paragraph (4.003) is a verdict concerning the "most of" (not all!) philosophical work that had taken place prior to the creation of [50]:

> **Most propositions** and questions that have been written **about philosophical matters are** not false but **senseless**. We cannot, therefore, answer questions of this kind at all, but only state their senselessness. Most questions and propositions of the philosophers result from the fact that we do not understand the

[105] Given the common meaning of the word "philosophy" as it is used these days, it appears to be necessary to distinguish philosophy in that narrow sense and in the wider sense as a certain subfield of humanities understood as a collection of sufficiently "general" thoughts and opinions on humanities related topics.

> logic of our language. They are of the same kind as the question whether the Good is more or less identical than the Beautiful. And it is not surprising that the **deepest problems are** in fact **not problems at all**.

Quite a disparaging remark, one has to admit! Makes one really doubt intellectual ability and dedication of philosophers who wrote their books prior to the appearance of [50]. The situation seems to be at its most hopeless for the "deepest problems" that turn out to be so inane as to be "not problems at all." One can recognize the influence of the author's teacher with his "cleaning the metaphysical lumber," but, as we will se shortly, L. Wittgenstein, like a proper good student, surpasses his teacher, especially in the nihilistic attitude towards and annihilating critique of the philosophical predecessors.

Next comes a radical (one is quickly getting used to dramatic statements while reading [50]) redefinition of the very subject matter of philosophy, at least in comparison with the classical tradition [50], 4.0031:

> All philosophy is a 'critique of language.' It was Russell who performed the service of showing that the apparent logical form of a proposition need not be its real one.

Recall that, in the classical tradition, philosophy gradually distilled itself – after giving rise to and separating from particular sciences – to the study of the nature of thought understood as an attribute of the universal substance. Since for L. Wittgenstein, as we know, thought is identical with language, philosophy naturally becomes a (critical) study of language whose main goal – as we have seen and will see again – is a "cleansing" of the language (and therefore thought) from "senseless" words and expressions.

It has to feel good to be able to uncover the futility of many centuries worth of previous work, as L. Wittgenstein continues redefining – and monumentally curtailing – the subject matter of philosophy [50], 4.111, 4.112:

> The object of philosophy is the logical clarification of thoughts. **Philosophy is not a theory** but an activity. A philosophical work consists essentially of elucidations. The result of philosophy is not a number of "philosophical propositions," but to make propositions clear. Philosophy should **make clear and delimit sharply** the thoughts which otherwise are, as it were, opaque and blurred.

L. Wittgenstein is an honest person – you have to give him that. *The kind of philosophy* he is trying to develop is definitely not a theory in any proper sense. One could also recall that

B. Russell himself came to the conclusion that his "doctrine of external relations" leaves him with no logical method whatsoever – leaving the "scientific philosopher" with the task of just clarification and general freestyle "critical thinking." In his view, the goal of effecting further progress (which implies further generalization) is fully relegated to the somewhat mystical activity of a genius capable of "direct philosophical vision." We see very similar motives in the system of [50], with the main methodological hope residing in drawing "hard and fast lines" whenever possible (thus building a wall between the thinker who might choose to follow these guidelines and the reason). At this point, it is worth noting that such simple minded "critical thinking" has its place in human activity, at least at the latter's current development stage. Namely, as a tool against the widely spread arbitrary ratiocination, it could play an useful negative role, in a way similar to the role D. Hume's scepticism played its own negative role during its time. One simply should avoid thinking that one could make progress in philosophy at this level.

Now that the whole of philosophy has been reduced to clarification and elucidation, the rest is – very clearly and lucidly – rather predictable. Like a bicycle sans wheels, philosophy sans universality and the objective content of thought becomes a limiting device rather than an enabler. So we expect edicts to this effect: what the rational reason cannot accomplish due to its timeless limited nature – somewhat along Kantian lines, but simpler and more categorical (due to large extent to the author's tender age and level of philosophical maturity) [50], 4.113-4.116:

> Philosophy sets limits to the much disputed sphere of natural science. **It must set limits to what can be thought**; and, in doing so, to what cannot be thought. It must set limits to what cannot be thought by working outwards through what can be thought. It will signify what cannot be said, by presenting **clearly** what can be said. Everything that can be thought at all can be thought **clearly**. Everything that can be put into words can be put **clearly**.

It is not a difficult task to anticipate – given the proposed "fact and object" ("grade school") ontology – what is going to come next. These atomic objects are going to be given letter names *à la* mathematics and be made into variables, then statement about these variables and their relations are going to be pronounced "clear," with the rest (including the unity in the multitude in all its manifestations) being relegated to what cannot be said and therefore thought. The details are not very important, but let us see what exact conclusions a system based on "external relations" making clarity of expression its main guiding principle is able to draw.

The author of [50], in spite of his youthful exuberance, probably felt that a system *that* simple cannot fully capture the truth, and that, besides external relation between unchangeable objects, there has to be something else. His belief in the power of fully formalizable clearly stated propositions and the existence of logical "syntax" that can express the truth without any reference to the meaning of the corresponding signs could not be shaken, but he found that a possibility of something "hidden," "internal" that is compatible with full propositional clarity of expression is hiding in the *form* of propositions themselves [50], 4.12:

> Propositions can represent the whole reality, but they cannot represent what they must have in common with reality in order to be able to represent it – the logical form. To be able **to represent the logical form**, we should have to be able to **put ourselves with the propositions outside logic**, that is outside the world. Propositions cannot represent the logical form: this mirrors itself in the propositions.

Indeed, if one wants to see the form of, say, a house, one has to step *outside* the house. It has to be very similar with logic, no doubt. The power of mental imagery (representation) and the all-conquering method of (arbitrary) analogy are displayed here in their full strength (recall the author's age again). If that logical form cannot be expressed logically, how can we get at it? It turns out that, even though we can't put it in words, we can *see* it [50], 4.1212, 4.1213:

> What *can* be shown *cannot* be said. Now we understand our feeling that we are in possession of the right logical conception, if only all is right in our symbolism.

That draw of mathematical clarity can indeed be quite strong, as we see here. Also somewhat noteworthy is yet another "hard and fast line" drawn by the author with the same categorical resolve: *can* be shown, but *cannot* be said. That same implication of thought as an attribute of an isolated thinking gentleman (i.e. a purely contemplative "office" thinker) keeps hurting L. Wittgenstein's own thinking process. This appears to be far from unavoidable since the notion of thought as *the other* of all totality of human practice had been known long before the author of [50] was born. So, in reality, there cannot be any hard line between "shown" and "said," and anything that can be shown can be said as well.

So the idea of an "internal property" as a property of form or structure that defy being put into words (or other signs) gets exploited in [50], 4.122:

> We can speak in a certain sense of formal properties of objects and atomic facts, or of properties of the structure of facts, and in the same sense of formal relations and relations of structures. (Instead of property of the structure I also say "internal

> property"; instead of relation of structures "internal relation." I introduce these expressions in order to show the reason for the confusion, very widespread among philosophers, between internal relations and **proper (external) relations**.) The holding of such internal properties and relations cannot, however, be asserted by propositions, but it shows itself in the propositions, which present the facts and treat of the objects in question.

Note that B. Russell's external relations are still considered "proper," and the internal ones maintain their mystical unspoken character. One more philosophical problem (previously considered difficult) is solved along the way in a few sentences [50], 4.125, 4.1251:

> The existence of an internal relation between possible states of affairs expresses itself in language by an internal relation between the propositions presenting them. Now **this settles the disputed question** "whether all relations are internal or external."

Next in order is the *concept* – the pinnacle of philosophy according to Hegel. Besides finding out that proper concepts can be represented by functions (so wonderfully easy!), we learn of the existence of *formal concepts* that are expressed by just variables [50], 4.126:

> In the sense in which we speak of formal properties we can now speak also of formal concepts. That anything falls under a formal concept as an object belonging to it, cannot be expressed by a proposition. But it is shown in the symbol for the object itself. Formal concepts cannot, in fact, be represented by means of a function, as concepts proper can. For their characteristics, the formal properties are not expressed by means of functions. The expression of a formal property is a feature of certain symbols. So the sign for the characteristics of a formal concept is a distinctive feature of all symbols whose meanings fall under the concept. So the expression for a formal concept is a propositional variable in which this distinctive feature alone is constant.

The clarity of expression is indeed going to make tremendous gains if one just replaces the whole process of concept development by just a single letter that has to from now on stand for this concept. Take information as an example. In the system of [50], it would have to fall under the notion of a formal concept since it cannot be expressed as a proposition – as a picture of a fact. So it would have been enough to reserve a variable, say I, for information and use that variable for information only. Then one could have assigned the known properties of information to I such as additivity, storability, etc. Then one could have tried "quantifying" it in various senses, and, after some time and hard work, come up with more or less sophisticated quantitative schemes which could have even been useful in some practical applications (assuming the empirical ad hoc generalization that went into the schemes just mentioned had been sufficiently inventive). The only problem still present would have been two-fold: we would have had absolutely no clue what information was and the empirical schemes mentioned above would have worked just as well without our imagined theory.

Next in order in [50] is a study of propositions. Beginning from the simplest kind – pictures of atomic facts [50], 4.21, 4.211:

> The simplest kind of proposition, an elementary proposition, asserts the existence of an atomic fact. It is a sign of a proposition's being elementary that there can be no elementary proposition contradicting it.

Such elementary propositions as pictures of different atomic facts can't *formally* contradict each other. Does it mean that there is no connection – and therefore interdependence – between "atomic facts"? The negative answer to this questions is seemingly implied by the very existence of (any) laws of nature. Let's not get ahead of the text though and wait to see L. Wittgenstein's answer. And his answer proceeds as follows [50], 4.27:

> With regard to the existence of n atomic facts there are $K_n = \sum_{\nu=0}^{n} \binom{n}{\nu}$ possibilities. **It is possible for all combinations of atomic facts to exist, and the others not to exist**.

You have to give it to the author of [50] – he is pretty consistent. If there is no logic in the world besides the formal logic of propositions (and the corresponding atomic facts), everything formally possible has to be really possible. But what about laws of nature and science? We will find out a bit later. As a side remark, one could note that the above expression for K_n can be simplified to just $K_n = 2^n$ which is immediately obvious given that possibility of existence of *all* combinations of n atomic facts.

What propositions are possible besides the elementary ones? According to [50], the answer is functions of elementary propositions. Since – being propositions – these functions have to be either true or false, they have to be *truth functions*, i.e. functions whose value takes one of these two symbols [50], 4.42:

> For n elementary propositions there are $\sum_{\kappa=0}^{K_n} \binom{K_n}{\kappa} = L_n$ ways in which a proposition can agree and disagree with their truth possibilities.

One can again note that the expression for L_n given above can be written simply as $L_n = 2^{2^n}$ which is obvious since there are 2^n possible values of the argument of a truth function of n elementary propositions. This classification of truth functions and their table representation constitute a contribution of [50] to the field of mathematical logic. In particular, for $n = 2$, there are 16 different truth functions ranging from the tautology ("true" for 4 possible values of the argument) to the contradiction ("false" for all values) and including the well known logical conjunction, disjunction, implication (in both directions) and some others. Recalling that elementary propositions are pictures of atomic facts, it is easy to conclude that general propositions (truth function of elementary ones) are pictures of more general facts (and their relations), except for tautologies and contradictions [50], 4.462:

> Tautologies and contradictions are not pictures of reality. They do not represent any possible situations. For the former admit *all* possible situations, and latter *none*.

The next fifth "chapter" of [50] is devoted mainly to relations between propositions and to logical inference, i.e. to what traditionally has been known as formal logic as such. It begins with a restatement of the relation between elementary and other propositions [50], 5, 5.01:

> A proposition is a truth-function of elementary propositions. Elementary propositions are the truth-arguments of propositions.

Formal logic – somewhat surprisingly since L. Wittgenstein knows of no other kind of logic – is not held in high regard in [50]. In particular, it states [50], 5.13:

> When the truth of one proposition follows from the truth of others, we can see this from the structure of the propositions.

This implies that logical inference is seen as a trivial affair. The next paragraph confirms this point of view [50], 5.132:

> If p follows from q, I can conclude from q to p; infer p from q. The method of inference is to be understood from the two propositions alone. Only they themselves can justify the inference. **Laws of inference**, which – as in Frege and Russell – are to justify the conclusions, **are senseless** and would be superfluous.

So what L. Wittgenstein's teachers considered a core of reason – laws of inference – is actually senseless. But the biggest surprise – even for the jaded veteran of logic B. Russell – is coming next [50], beginning at 5.133:

> All deductions are made *a priori*. One elementary proposition cannot be deduced from another. There is no possible way of making an inference from the existence of one state of affairs to the existence of another, entirely different state of affairs. **There is no causal nexus to justify such an inference. We *cannot* infer the events of the future from those of the present. Belief in the causal nexus is** *superstition.*

Recall that B. Russell himself believed in the mutual independence of atomic facts *all taken at the same time* (so that a cubic Moon and a tetrahedral Sun are still in principle possible), but maintained a form of Laplacian determinism: given all atomic facts at one time moment, it is in principle possible to deduce them at any later time moment – by the use of... *the very causal nexus* his favorite pupil has rejected in such a cavalier fashion thereby eliminating the possibility of not just science but any purposeful activity whatsoever (since the latter assumes "inferring the event of the future from those of the present"). If the highlighted phrase in the quotation above had been true, even a stone axe "manufacturing" would have been impossible. It is in fact quite entertaining to read what B. Russell has to say about this little issue in his introduction to [50]:

> The fact that nothing can be deduced from an atomic proposition has interesting applications, for example, to causality. There cannot, in Wittgenstein's logic, be any such thing as a causal nexus. "The events of the future," he says, "*cannot* be inferred from those of the present. Superstition is the belief in the causal nexus." That the sun will rise to-morrow is a hypothesis. We do not in fact know whether it will rise, since there is no compulsion according to which one thing must happen because another happens.
>
> Let us now take up another subject – that of names.

As we see, B. Russell just states the existence of the "interesting applications" making no further comment and immediately switching to a different (more innocuous) subject of names.

The rest of the fifth "chapter" of [50] is somewhat less exciting for a typical reader. Relation of propositions to each other is discussed and it is claimed that different propositions can be obtained by applying operation of mathematical logic (such as negation, conjunction and disjunction) to the already existing (accounted for) propositions [50], 5.2, 5.21:

> The structures of propositions stand in internal relations to one another. In order to give prominence to these internal relations we can adopt the following mode

> of expression: we can represent a proposition as the result of an operation that produces it out of other propositions (which are the bases of the operation).

The natural starting point for such a process is elementary propositions that cannot be obtained from other ones being pictures of simple (atomic) facts [50], 5.3:

> All propositions are results of truth operations on elementary propositions. A truth-operation is the way in which a truth-function is produced out of elementary propositions.

The rather obvious conclusion is that any proposition (since all of them are truth functions of the elementary ones) can be obtained by means of such operations [50], 5.32:

> All truth-functions are results of successive applications to elementary propositions of a finite number of truth-operations.

Since all possible propositions can be obtained in a mechanical fashion from the elementary ones, it is easy to see that they cannot really say more than what is already present in the elementary propositions [50], 5.43:

> But the propositions of logic say the same thing. That is, **nothing**.

And the reason for this impotence of the formal logic, as has been already indicated is the following [50], 5.442:

> If a proposition is given to us then the results of all truth-operations which have it as their basis are given *with* it.

The sixth "chapter" of [50] is the last one where conclusions are made and the contributions of the book to the general subject of logic (and philosophy) – as seen by the author – are stated. It begins with an emphasis of the gnoseological status of the formal logic (held in high regard by B. Russell) [50], 6.1, 6.11:

> The propositions of logic are tautologies. The propositions of logic therefore say nothing. (They are the analytical propositions.)

Thus the emptiness of the formal logic is stated with abundant clarity. So, with no logic left for the purpose of generalization, the conclusion is somewhat pessimistic from the point of view of any particular science [50], 6.1231:

> To be general means no more than to be **accidentally** valid for all things. An ungeneralized proposition can be tautological just as well as a generalized one.

But since the very possibility of any science (and any purposeful activity to boot) has been already refuted in the previous "chapter" of the book, this accidentality of anything general is easily taken in stride. But, on the other hand, since the objective logic (in Hegel's terms) does not even exist and the formal logic is empty and "senseless," what is left for the subject matter of logic at all? There is none, says L. Wittgenstein [50], 6.124:

> The propositions of logic describe the scaffolding of the world, or rather they represent it. **They have no 'subject-matter.'** They presuppose that names have meaning and elementary propositions sense; and that is their connexion with the world. It is clear that something about the world must be indicated by the fact that certain combinations of symbols – whose essence involves the possession of a determinate character – are tautologies. This contains the decisive point. We have said that some things are arbitrary in the symbols that we use and that some things are not. In logic it is only the latter that express: but that means that logic is not a field in which *we* express what we wish with the help of signs, but rather one in which the nature of the natural and inevitable signs speaks for itself. If we know the logical syntax of any sign-language, then we have already been given all the propositions of logic.

Thus, even though logic does not have its own subject matter, it represents the "scaffolding" of the world by expressing it via "the nature of the natural and inevitable signs." A logician's (i.e. a philosopher's) task seems to be reduced to that of a "sign police" of sorts: that of someone whose mission is to guard against meaningless names and senseless (nonsensical) propositions. We will see (and we have already seen a hint of that in the preface) that this is indeed one of the main results of [50].

As we have already seen, any proof in logic is mechanical and, in particular, can be done in a purely formal fashion, with no concern about meaning [50], 6.1262, 6.1263:

> Proof in logic is merely a mechanical expedient to facilitate the recognition of tautologies in complicated cases. Indeed, it would be altogether too remarkable if a proposition that had sense could be proved *logically* from others, and *so too* could a logical proposition. It is clear from the start that a logical proof of a proposition that has sense and a proof *in* logic must be two entirely different things.

What's interesting in the quotation above is a opposition of a logical proof of a meaningful proposition and a proof *in* logic (a purely formal manipulation). The point is – since all elementary proposition are already known to be mutually independent and the world is just an arbitrary mosaic – a logical proof of any meaningful proposition is simply impossible. As we have been already informed, the only function of logic is guarding against anything "nonsensical." But what about *laws* of any kind? Do they exist? Here is our answer from [50] (6.3, 6.31):

> The exploration of logic means the exploration of *everything that is subject to law*. And **outside logic everything is accidental**. The so-called law of induction cannot possibly be a law of logic, since it is obviously a proposition with sense. – Nor, therefore, can it be an *a priori* law.

So, to summarize, the (formal – the only kind known to L. Wittgenstein) logic is empty, but anything that is subject to law belongs to logic. The conclusion is there are no laws. Even the good old induction is not much use. On the other hand, it is very hard to believe that a former engineering student would seriously try to develop a system that leaves no space whatsoever for laws of nature. There simply has to be some provision for the latter. Indeed such a provision is found a few lines later. It begins with an example of black spots on a white surface [50], 6.341:

> Let us imagine a white surface with irregular black spots on it. We then say that whatever kind of picture these make, I can always approximate as closely as I wish to the description of it by covering the surface with a sufficiently fine square mesh, and then saying of every square whether it is black or white.

After some musings about the possibility of a description of the same black spots with a hexagonal or triangular mesh instead of the square one, L. Wittgenstein says:

> The different nets correspond to different systems for describing the world. Mechanics determines one form of description of the world by saying that **all propositions used in the description of the world must be obtained in a given way from a given set of propositions** – the axioms of mechanics. It thus supplies the bricks for building the edifice of science and it says, "Any building that you want to erect, whatever it may be, must somehow be constructed with these bricks, and with these alone."

So here it is: the logical atomism view on the laws of nature. Even though all elementary propositions are mutually independent and can't be derived from each other, it could be possible to obtain a description of the world by constructing all propositions from some given (smaller) set, i.e. to "compress" the original "raw" description obtained by simply listing all true elementary propositions. Is does not take a lot of insight to notice that we see here a version of Machism with its notion of the laws of nature as concise descriptions of the otherwise chaotic reality – the laws of nature that are "free inventions of the intellect" (according to A. Einstein, whose views we will consider in more detail in Appendix B.).

L. Wittgenstein continues trying to save laws of nature from his own philosophy using his main epistemological tool of mental imagery combined with analogy [50], 6.35, 6.36, 6.361:

> Although the spots in our picture are geometrical figures, nevertheless geometry can obviously say nothing at all about their actual form and position. The network, however, is *purely* geometrical; all its properties can be given *a priori*. Laws like the principle of sufficient reason, etc. are about the net and not about what the net describes. If there were a law of causality, it might be put in the following way: There are laws of nature. But of course that cannot be said: it makes itself manifest. One might say, using Hertz's terminology, that only connexions that are *subject to law are thinkable*.

So the imaginary black spots have a totally random shape, but can be *described* by means of a regular network (so no law in the spots, but regularity – and hence law – in their description). Are black spots sufficiently analogous to the nature as a whole? To L. Wittgenstein, they certainly are. Thus natural phenomena are like black spots and our logic is like that square (or triangular, depending on the taste) net. But – we are warned again – one should refrain from trying to say anything about it, just try different types of "bricks" and hope the propositions expressing natural phenomena will fit the resulting description. There is no explicit mention of a genius "bricklayer," like in B. Russell's description of his method requiring a "direct philosophical vision" of a mystical nature on the part of a supranormally gifted individual, but the implication seems to be the same. But is there anything in the proposed logical method that could lend a helping hand to the future genius "bricklayers"? What about, for instance, induction as an already widely used source of hints? We read the following [50], 6.363-6.36311:

> The procedure of induction consists in accepting as true the simplest law that can be reconciled with our experiences. This procedure, however, has no logical justification but only a psychological one. It is clear that there are no grounds for believing that the simplest eventuality will in fact be realized. It is a hypothesis that the sun will rise tomorrow: and this means that we do not *know* whether it will rise.

What is interesting here is that the author of [50] is actually correct in being cautions towards both induction and simplicity as the main criterion of truth. The last sentence however (mentioned by B. Russell in the introduction to [50] as we remember) sounds remarkable indeed clearly placing the author in the same camp with Berkeley and Hume. Recall that the teacher B. Russell had to bow down to the wisdom of Hume conceding that scepticism was irrefutable. The pupil, on the other hand, in spite of holding very similar views, proves to be less reverential to the great sceptic [50], 6.51:

> Scepticism is *not* irrefutable, but obviously nonsensical, **when it tries to raise doubts where no questions can be asked**.

Thus scepticism – along with a lot of other philosophical work of the predecessors (including a lot more serious that those of Hume) – receives the "nonsensical" label. The latter is no longer a great surprise to an attentive reader able to get that far in [50]. What is a bit more interesting (although the attentive reader would most likely expect that as well) is that sceptism is being criticized here not for underestimating reason, but rather for overestimating it in a sense. It turns out that D. Hume was already exhibiting some reckless gnoseological behavior and reaching too far by asking questions that he should not have.

Let us briefly summarize: what logical atomism as a system has to offer scientists (and engineers) as far as a method goes. After seeing the famous sceptic being scolded for not being sufficiently sceptical, one could begin suspecting the proposed method of possessing a very distinct "negative" flavor in its recommendations. Indeed, towards the end of the book, we find the following admission [50], 6.52:

> We feel that even when *all possible* scientific questions have been answered, the problems of life remain completely untouched. Of course **there are then no questions left**, and this itself is the answer.

Slightly rephrasing the above passage, once inorganic matter, due to its relative "uniformity" has been adequately described by a "curve fitting" of sorts to the observed empirical data, we lose the ability of not just searching for rational comprehension of more complicated forms (such as life), but even of asking any questions to this effect. If we do, those questions are doomed to be just a lot of hooey. This means that life – and any social matters – will for ever defy any attempt at a rational comprehension and explanation. Does this observation imply their mystical nature. It surely does [50], 6.522:

> There are, indeed, things that cannot be put into words. They make themselves manifest. They are what is **mystical**.

As we have mentioned before, the main contribution of L. Wittgenstein to philosophy is a clear demonstration of all the gnoseological consequences of the "doctrine of external relations" based on wholesale denial of the objective universal which is the proper content of thought.

So B. Russell admitted that logical atomism has no method – just a few general rules of a largely psychological nature combined with a yearning for a "direct philosophical vision" on the part of a genius – and his favorite pupil went to the pains of developing a corresponding system. A system implies a method of some kind (the way to make use of the said system). So what is the correct method after all? Here is a clear answer [50], 6.53:

> The correct method in philosophy would really be the following: to say nothing except what can be said, i.e. propositions of natural science – i.e. something that has nothing to do with philosophy – and then, whenever someone else wanted to say something metaphysical, to demonstrate to him that he had failed to give a meaning to certain signs in his propositions. Although it would not be satisfying to the other person – he would not have the feeling that we were teaching him philosophy – *this* method would be the only strictly correct one.

To this, we can only add that the imaginary person suspected of "saying something metaphysical" in the quotation above would have probably also felt a bit grateful for being spared a philosophy lesson by experts of such qualification. But one has to acknowledge L. Wittgenstein's powerful intuition that – even though unable to fully compensate for his lack of proper philosophical background – turned out to be sufficient for making this astute observation about the feelings of the imaginary object of philosophy teachings (supposedly a scientist of some kind) about this kind of philosophical help: "it would not be satisfying to the other person." It most likely would not be since the only reason for "the other person" of this type looking for logical and philosophical help would be to receive some constructive advice on developing a theory on the basis of the specific empirical data (and prior generalizations) and not to hear proscriptions on what can be said. L. Wittgenstein probably suspected that the "strict correctness" of such a nihilistic method would have offered only a mild consolation to the imaginary scientist in search for a method of theoretical advancement.

Philosophy annihilators, like L. Wittgenstein, apparently were known before and during Hegel's times as well. The reason for their philosophical nihilism had always been virtually the same: impatience and lack of proper education that makes it possible to actually *understand* philosophical questions, and, respectively, think *rationally* about possible answers. One of such general type questions that often presented a stumbling block for the impatient types prone to rushing to quick (and of course simple) conclusions was the following

([1], p.122): "*How does the infinite go forth out of itself and come to finitude?*" Hegel then makes the comment which would have done the young L. Wittgenstein a world of good, had he been able to read it and take it seriously at an opportune moment:

> It is above all on the answer to this question that *whether there is a philosophy* is taken to depend, and people believe, while still professing willingness to let the matter rest on it, that they also possess in the question itself a sort of puzzle, an invincible talisman, that firmly secures them against the answer, and consequently against philosophy and the attainment of it. In order to *understand questions*, **a certain education is required** also in other subject matters, and **this is all the more the case for things philosophical** if more of an answer is to be had than that the question is an idle one.

To wrap up, let us make an observation of a somewhat entertaining nature. As we recall, B. Russell had tried to master Hegel's logical system (quite possibly mostly in F.H. Bradley's renditions), but could not do so and ended up with its wholesale rejection. L. Wittgenstein, to the best of our knowledge, had never made a concerted attempt to get an intellectual hold of its content. But dialectics is there regardless of any particular individual's conscious awareness of its presence. Let us see an example of dialectics in action in L. Wittgenstein's own "nonsensical propositions" [50], 6.54:

> My propositions serve as elucidations in the following way: anyone who understands me eventually recognizes them as nonsensical, when he has used them – as steps – to climb up beyond them. (He must, so to speak, throw away the ladder after he has climbed up it.) He must transcend these propositions, and then he will see the world aright.

Indeed, his claim is that philosophy has no theory – it is just an (theory-free, i.e. mindless) "activity." On the other hand, he wrote a whole book on philosophy. So there is a theory. We have a clear-cut contradiction: philosophy has a theory and does not have a theory at the same time and in the same sense. Contradictions in Hegel's system, as we know, get resolved. So what happens with this contradiction in L. Wittgenstein's view? *It gets resolved.* The resolution L. Wittgenstein proposes is described in the same paragraph quoted above: the imagined conscientious and attentive reader ("anyone who understands me") is going to use the propositions of [50] as a ladder (so there is a theory or otherwise there would be nothing to climb on), but promptly discard them (so there is no theory) as nonsensical upon finishing the climb. The result of this resolution is not the *null*, but rather the newly acquired ability of the imaginary subject of the philosophical enlightenment to "see the world aright" – the most welcome change indeed. We see that, in this example, the author of [50] acts just like Mr. Jourdain from Molière's "*Le Bourgeois gentilhomme*," who had been speaking prose all his life without knowing it.

A.5 Summary: the paradox of anti-philosophical philosophy

Having reviewed the main content of B. Russell's "logical atomism," we can now get back to the quotation from Stanford Encyclopedia that was the original motivation for this appendix. Recall that the main claim of the said quotation announces that, according to B. Russell, "the revolutionary innovations in logic starting in the last decades of the nineteenth century with the work of Frege and Peano had destroyed Hegel's metaphysics." Let us recall the main points of our review of B. Russell's own philosophy (developed into a system by L. Wittgenstein) and see to what extent the above claim corresponds to reality.

First, let us point out that "The Science of Logic" does not contain any metaphysics as it does not *postulate* any fundamental *a priori* law of nature. As Hegel himself notes, his objective logic takes place of metaphysics of prior systems (such as the one of C. Wolff) in that it considers the universal content of reason invariant with respect to specific subject matter. This content expresses the possible forms of logical comprehension of *unity in multitude* in the objective world. It is also important to note that the division of logic into its objective (the doctrines of being and essence) and subjective (the doctrine of concept) parts is – in Hegel's view – by no means categorical and was introduced to a large extent as a concession to the existing views, to make the material more accessible to a reader used to such views. Speaking of metaphysics, we will see soon where it had gone following the philosophy (in its logical component) revision undertaken by B. Russell and his followers.

In short, that revision largely took the form of a simple truncation: the contents of all three parts – the doctrines of being, essence, and concept, respectively – of Hegel's logical system were simply discarded, and the *whole* of logic was reduced to just the *formal* logic – in its modernized and extended form. It is that extension which was the subject of work of Frege and Peano. As B. Russell himself admitted, not all of mathematical logic – that was developed by Frege and Peano – is directly relevant to philosophy, but only its basics, the part that "enumerates the different kinds of atomic propositions, of molecular propositions, of general propositions, and so on" ([46], p.67). The remaining part – the technique of manipulating the propositions "which assert the truth of all propositions of certain forms" – belongs more to the realm of mathematics, according to B. Russell. Thus, in order to see what was discarded and what left in the subject matter of logic following B. Russell's truncation of the latter, it would be helpful to state clearly what the status is of formal logic in the context of the (much) more general system of “The Science of Logic.”

Hegel does not explicitly discuss this status, but it can be easily extracted from the text of [1]. In the Introduction, he makes a couple of derisive comments about the “old logic” calling it, for instance, (on p.31) “a commonplace content” and the corresponding teachings in the Aristotelian spirit “the occupation with empty forms” which can hardly be “of any value or use.” (We can also recall that this general sentiment is mostly shared by B. Russell.) Hegel then proceeds to state that the particular sciences – and even the ordinary common sense – of the period had already absorbed the little of the formal logic that was indispensable in their functioning making it self-evident and not really worthy of any further discussion and development [1], p.37:

> The other sciences have on the whole discarded the well-regulated method of proceeding by way of definitions, axioms, theorems and their proofs, and so on; so-called **natural logic** has become their accepted norm and thus manages to do its work without any specialized knowledge of thought itself.

So formal logic becomes natural logic and is taken for granted in particular sciences. But what is formal logic, i.e. if it is not – according to Hegel – the logic of the objective world or thought, what exactly is it a logic of? To find Hegel's answer to this question, let us turn to his discussion of *understanding* (Verstand) in the second volume of [1] (p.538):

> Here we have the circumstance that explains why the understanding is nowadays held in such a low repute and is so much discredited when measured against reason; it is the *fixity* which it imparts to determinacies and consequently to anything finite. This fixity consists in the form of the abstract universality just considered that makes them *unalterable*.

Let us note in passing Hegel's mention of the low repute in which understanding (Verstand) was held at the time (in the period between Kant and Hegel, mostly as a result of writings of Schelling and his followers). The “fixity” of the understanding determinacies would be elevated to a lofty status again after B. Russell's “revolt” and the subsequent logic “reduction.” But Hegel himself did not quite share Schelling's disparaging views on the understanding. On the same page of [1], we can read:

> But further, we must pay due respect to the infinite force of the understanding in splitting the concrete into abstract determinacies and plumbing the depth of the difference – this force which alone is at the same time the mighty power causing

> the transition of the determinacies. The concrete of *intuition*[106] is a *totality*, but a *sensuous totality*, a real material that subsists in space and time, *part outside part*, each indifferent to the other; surely this lack of unity in a manifold that makes it the content of intuition ought not to be credited as privileging it over the universal of the understanding.

So **formal logic is the logic of these fixed abstract determinacies** and their relations, and – in case one wants to think according to reason – should be used as such, without forgetting its limitations. It would be interesting at this point to recall L. Wittgenstein's view on the subject [50], 6.124:

> It is clear that something about the world must be indicated by the fact that certain combinations of symbols – whose essence involves the possession of a determinate character – are tautologies. This contains the decisive point. We have said that some things are arbitrary in the symbols that we use and that some things are not. In logic it is only the latter that express: but that means that logic is not a field in which *we* express what we wish with the help of signs, but rather one in which **the nature of the natural and inevitable signs speaks for itself**.

As we can see, for L. Wittgenstein, formal logic expresses somewhat mysterious "nature of the natural signs." Also, for him, this is the end of the story as far as logic is concerned and the great divide beyond which the mystical abides. For Hegel, it is just the very beginning of logic – not the logic itself yet but just a necessary preparatory step [1], p.539:

> Consequently, since the understanding exhibits the infinite force that determines the universal, or conversely, since it is the understanding that through the form of universality imparts stable subsistence to the otherwise inherent instability of determinateness, then **it is not the fault of the understanding if there is no further advance**. It is a subjective *impotence of reason* that allows these determinacies to remain so dispersed, and is unable to **bring them back to their unity through the dialectical force opposed to that abstract universality**, that is to say, through the determinacies' own nature which is their concept.

Thus only when the determinacies previously extracted from the concrete of the senses and separated by the understanding are brought back to their unity, the reason proper – and

[106] Here, the German "Anschauung" would be arguably better translated as "contemplation" instead of "intuition."

philosophy in the narrow (logical) sense – begins. This is the inherent *thought content* that B. Russell failed to comprehend and somewhat angrily (recall his characterization of Plato, Spinoza, and Hegel as malicious) discarded, leaving himself – and the scientists that believed him and his followers – armed with just the understanding and its corresponding (formal) logic against the difficult problems nature was presenting them with. That thought content completely overlooked by B. Russell is concisely described by Hegel as follows [1], p.18:

> The inadequacy of this way of regarding thought which leaves truth on one side can only be remedied by including in our consideration of thought **not merely what is customarily credited to external form**, but the **content** as well. It is soon evident that what in ordinary reflection is, as content, at first separated from the form cannot in fact be in itself formless, devoid of determination (in that case it would be a vacuity, the abstraction of the thing-in-itself).

That "external form" from the quotation above refers to propositions subject to formal logic. So formal logic – even though it has become commonplace and obvious in most instances of its application – is still relevant and should be adhered to if one wants to keep thoughts coherent and consistent. The point that needs to be understood – and this can be not very easy as, for example B. Russell, failed to do so – is that *consistency of thought expression is by no means sufficient to capture truth.* The *content* of the thought proper (i.e. the content invariant with respect to its particular subject matter) needs to be addressed.

As we have seen, B. Russell and his followers including L. Wittgenstein, *having nothing but formal logic* in place of thought content (which in reality is just its external form, as we know) made a *proposition* the main (and only) carrier of truth and thus the main object of their logical study. B. Russell, in particular, had high hopes for propositions of the type that had been – so he thought – overlooked by the philosophers of the classical tradition, namely, those expressing "asymmetric relations" of the sort "x is older than y" or "A is the father of B." Hegel as a representative of the classical tradition, by the way, would call such propositions "sentences" and reserve the term "judgment" for the propositions relating a singular (or a particular) to a universal, i.e. propositions carrying a nontrivial philosophical content, as opposed to sentences used for the description of "facts" belonging to the sphere of determinate being (German "Dasein" sometimes translated as simply "existence"). Such simple relation expressing sentences were not explicitly discussed at any length in the classical tradition – and in "The Science of Logic" in particular – due to their not being directly relevant to properly philosophical problems.

L. Wittgenstein – as a logical atomism system builder – is very clear about the role of propositions in logic (and philosophy) [50], 4.26:

> If all true elementary propositions are given, the result is a complete description of the world. The world is completely described by giving all elementary propositions, and adding which of them are true and which false.

Also, for him, a *description* is as far as rational cognition can go, and the "essence[107] of the world" is thus reduced to simply the propositional form – nice and clean indeed [50], 5.471, 5.4711:

> The general propositional form is the essence of a proposition. To give the essence of a proposition means to give **the essence of all description, and thus the essence of the world**.

But, of course there was nothing new in this kind of reductionist cavalier attitude to matters as serious and deserving of a lot more respect as the essence of the world. Hegel was explicitly warning about it a century prior [1], p.525:

> For example, the form of the positive judgment is accepted as something perfectly correct in itself, and **whether the judgment is true is made to depend solely on the content**. No thought is given to investigating whether this form of judgment is a form of truth *in and for itself*; whether the proposition it enunciates, "the individual is a universal," is not inherently dialectical.

A few lines later, he gives a concise characterization of such attempts:

> This rather is then where the *impossible* and the *absurd* lie, in the attempt to grasp the truth in such forms as are the positive judgment or a judgment in general.

Slightly more specifically, as I. Kant (re)discovered, it is inevitable that *opposite* determinations (predicates) can be assigned to the same subject upon sufficiently careful scrutiny (analysis) of the latter.[108] Kant, however, considered such unavoidable dialectics an *illusion* inherent to pure reason as such, so that a thinker's duty was to be aware of such illusion and not fall victim of it when exercising the capacity of reason. He then classified the possible dialectical applications of reason and concluded about the existence of exactly three different kinds of it: the transcendental paralogism, the pure reason antinomies, and the pure reason

[107] It should be noted here that he would have called the very notion of essence "nonsensical" – recall his characterization of his whole system as a ladder to be climbed on and discarded upon the climb completion, in the previous section of this appendix.

[108] Readers familiar with physics can quickly recall the famous "corpuscular wave dualism" as an example.

ideal. He found that only the second type led to logical contradictions, and formulated four instances in which contradictions – which he called cosmological antinomies – appeared. It was Hegel's major contribution to notice that, first of all, antinomies can arise not only in these four "cosmological" applications of reason, but in all of them, and, second and most importantly, the resulting contradictions are not a subjective illusion but rather a reflection – in and by the reason – of the true nature of objective reality [1], p.157:

> I remark, to begin with, that Kant wanted to give a semblance of completeness to his four antinomies by means of a principle of division which he took from his schema of the categories. However, a more profound insight into the antinomial or, more accurately, into the dialectical nature of reason reveals that *every* concept is a unity of opposite moments to which, therefore, the form of antinomial assertions could be given.

Thus these contradictions are not a sign of the reason trying to reach beyond the sphere of its applicability, not a fundamental limitation of reason, as Kant believed, but rather a sign of the reason reaching – as it should – beyond understanding (Verstand) and functioning according to its true nature [1], p.26:

> The reflection already mentioned consists in *transcending* the concrete immediate, in *determining* and *parting* it. But this reflection must *equally transcend* its *separating* determinations and above all *connect* them. The conflict of determinations breaks out precisely at the point of connection. This reflective activity of connection belongs in itself to reason, and to rise above the determinations and attain insight into their discord is the great negative step on the way to the true concept of reason. But, when not carried through, this insight runs into the misconception that reason is the one that contradicts itself; it fails to see that the **contradiction is in fact the elevation of reason above the restrictions of the understanding** and the dissolution of them.

It is not even worth repeating that, in B. Russell's "logical atomism," a contradiction is understood entirely in terms and at the level of formal logic – as something that can correspond to nothing in reality and can only point to either an objective impossibility or a subjective error.

What also deserves a separate mention is the tendency – that appeared together with logical atomism and is still alive now – to the drastically increased usage of formal "mathematical style" notation outside of the specific realm of mathematical logic in philosophical literature. Expressions of the sort aRb meaning that "a stands in relation R to b" were brought into wide circulation in philosophy by B. Russell and his followers. The purpose of such mathematical style formalization was clearly to simplify formal manipulation with various propositions that, according to L. Wittgenstein, constitute "the essence of all description, and thus the essence of the world." Obviously, the inspiration for such developments was coming from mathematics and its successes. The only problem with such program is that proper philosophical concepts and relations between them have very little in common with their mathematical counterparts expressing external relations between abstract quantities that have no qualitative determinations. In fact, such attempts were not entirely new, and had been already taken note of and characterized by Hegel [1], p.544:

> The great Euler, infinitely fertile and sharp of mind in detecting and arranging the deep relations of algebraic quantities, the dry, prosaic Lambert in particular, and others, have attempted to construct a *notation* for this class of relations between determinations of the concept based on lines, figures, and the like, the general intention being to elevate – or in fact rather to debase – the logical modes of relation to the status of a *calculus*. One need only compare the nature of a sign with what the sign ought to indicate immediately to see that even the project of a logical notation is unworkable.

Note that the use of the word "logical" in the quote above is decidedly different from "formal logical." What formal notation explicitly enforces – and this was one of the central points of L. Wittgenstein's "logical atomism" system – is the one-to-one correspondence between objects, relations, "formal concepts," and the corresponding signs (letters, arrows etc.) that stay unchanged in the course of all formal manipulations. This feature of formal notation also happens to be exactly what makes it unsuitable to be used to represent the proper philosophical concepts as Hegel had known long time before [1], p.544:

> It is characteristic of objects of this kind [algebraic letters, lines and their connections, magnitudes], as contrasted with the determinations of the concept, that they are mutually *external*, that they have a *fixed* determination. Now **when concepts are made to conform to such signs, they cease to be concepts**. Their determinations are not inert things, like numbers and lines whose connections lie outside them; they are living movements; the distinguished determinateness of the one side is immediately also internal to the other side; **what would be a complete contradiction for numbers and lines is essential to the nature of the concept**.

This is exactly what happens: the logical machinery left by B. Russell in logic after his truncation of the latter (that can be compared to pruning a tree from one small branch) and the ensuing enhancement of the latter by the advances in mathematical logic (which is not unlike embellishing the remaining branch with the help of Christmas decorations) is completely unable of even getting hold of concept in the sense of the classical tradition, let alone of developing it further to any degree.

Recall that B. Russell, among his many talents, had a gift of an insightful psychologist and a mind reader. His exposing of the malicious intents of Plato, Spinoza, and Hegel was truly a sight to behold. Encouraged and inspired by his example, we are going to feel sufficiently bold for a short period of time and do a little of mind reading of our own using the maestro himself and his favorite pupil as subjects. More seriously though, using the information presented in this appendix, we would like to try to make a reasonable guess as to the – both subjective and objective – reasons for the "logical atomism" coming-to-be and its subsequent acceptance by the philosophical and scientific community of the period.

As we remember from the a prior discussion in this appendix, B. Russell started as a student of mathematics, and began the study of philosophy several years later without leaving the field of mathematics. Mathematics was also his favorite subject when he was still a schoolboy, and it became for him a standard and a reference point not just for intellectual rigour, but also for intelligence in its highest sense [44], p.36:

> I hoped sooner or later to arrive at a perfected mathematics which should leave no room for doubts, and bit by bit extend the sphere of certainty from mathematics to other sciences.

Trying to extend the sphere of certainty from mathematics to other sciences using mathematics as an etalon of sorts is a very dangerous proposition as Hegel, for example, noted multiple times in "The Science of Logic." The reason for his special attention to this subject is easily explained by the historic fact of the repeated occurrence of such attempts in the past, motivated in a way similar to that B. Russell most likely had in mind. Namely, the relative simplicity of the subject matter of mathematics (external relations between abstract quantities) resulting in its historically earlier development makes the hope of extending its successes to other fields without a drastic change in the general method an enticing proposition.

So when B. Russell began his philosophical studies, he already had a certain mind set with a strong preference for clear-cut unambiguous definitions and formal proofs (as we have seen before in this appendix, in his writings the word "formal" is often used in place of the term "rational"). In addition, it is very clear from his own account of his development, that he had a very active restless personality, with a fast developing "young genius" kind of attitude and the corresponding "*veni vidi vici*" type of approach even to problems not in the least conducive to it. One of the subjects of this sort that the young Bertrand attacked in his flamboyant style expecting to see quick and maybe even novel results was precisely that of Hegel's logical system which to this day remains notoriously difficult for comprehension. Not very unexpectedly – at least for us – his cavalry charge did not bring the anticipated success. The material was simply proving to be on a different level of difficulty compared to anything in the field of mathematical logic. What could aggravate Bertrand's struggles was his insufficient mastery of German (we do not have the corresponding information). If that was the case, he was likely forced to read English translations, but English language is known to not be the best suited for expression of "speculative content" (using Hegel's terminology). At any rate, failing to properly understand the original, the young B. Russell apparently turned to F.H. Bradley's works instead, the latter having the reputation of a leading idealist and Hegelian of the period. F.H. Bradley's main book on the subject [45] is indeed a lot easier to read and understand compared to "The Science of Logic." Unfortunately, it is also a lot shallower, and is missing the main point of Hegel's system – its dialectics. The young Bertrand, apparently, was able to master the content of [45] decently well which did not take him any closer to getting in touch with Hegel's logic. What he acquired though was a misleading notion about dialectical logic that he was never able to overcome in his later life. Growing (understandably) unhappy with F.H. Bradley's putting down anything finite as "not real" and "unintelligible," B. Russell found no better way out than to "revolt" against idealism and monism, thereby essentially abandoning the properly philosophical way of thinking without making any advancement in that direction. What he produced after said revolt under the label of logic and philosophy was regrettably nothing but a formalized and elaborated point of view of the ordinary common sense of the period (often minus some of its spontaneous dialectics).

We cannot claim any familiarity with the science of psychology, but, in this case, it would be safe to say that the young Bertrand's personality and general attitude was in a sense opposite to what would have been required for getting a firm intellectual grasp of something as difficult, unfinished (as in just beginning to see logic as thought content and the universal form of the unity of the world at the same time) and forward looking (as in being significantly ahead of its time) as Hegel's logic. Thus in [44] (p.41) we can read:

> I had when I was younger – perhaps I still have – an almost unbelievable optimism as to the finality of my own theories.

Indeed, as we saw in one of the previous sections of this appendix, the 20-something year old

B. Russell, without any understanding of what Hegel's logic was about, wrote a paper having nothing in common with the latter and, many decades later, was still claiming that paper being "as good as anything Hegel wrote." What is remarkable and ironic in this regard is that later in his life the "post revolt" B. Russell was preaching for "a more fundamental, more patient, and less ambitious investigation" (as we have reviewed earlier) of logic – compared to what Hegel was proposing. If we consider the "more fundamental" part here a figure of speech, then his plea of being "more patient and less ambitious" would have had been much more useful in the self-addressed quality at the time he had been busy studying Hegel's logic several years prior. This is exactly what had been required *of him* at that time – to be patient, to take his time studying, to hide his ambitions for a while and refrain from trying to make advances of his own by producing "original" papers filled with simplistic raw immature opinions at the time when just a conscientious careful study of *what had been done before him* was called for.

As a side remark, one could note that sometimes it can be hard to fail noticing that "understanding that abstracts and therefore separates, that remains fixed in its separations" (using Hegel's expression) seems to hold some mystical sway over British thinkers. F.H. Bradley himself readily acknowledged this deficiency of English philosophy when he wrote in the Preface to [45]: "The chief need of English philosophy is, I think, a sceptical[109] study of first principles, and I do not know of any work which seems to meet this need sufficiently." Here we have a curious example of two opposite absolutisations of one side of the whole by F.H. Bradley and B. Russell, respectively.

Specifically, the former British philosopher absolutised the unity to the detriment of the multitude, relegating the latter to "mere appearance" and hence something "unintelligible," using his own favorite adjective. B. Russell, on the other hand, having gotten frustrated with Hegel's dialectics (mostly in F.H. Bradley rendition), took offence on the part of the consistently denigrated (by F.H. Bradley) immediate "sense data," and retaliated in the most decisive fashion by rejecting the unity altogether – and hence absolutising the multitude immediately given in the senses. Let us give a very simple example to illustrate this comparison. As all schoolchildren know these days, ice, water and vapor are just different forms of the same chemical substance H_2O. This also happens to be the point of view of Hegel's dialectics that by now gradually has made its way into the common sense. Ice, water and vapor, in Hegel's view, would belong to the realm of immediate being, and H_2O would be identified with their essence (at the level of ground) – what remains constant in being transmutations. Once the essence is discovered, the being can be "promoted" to the rank

[109] Take a note of the word "sceptical" in this sentence. Curiously, it does look like D. Hume's shadow was blocking the light of reason from his compatriots in a more drastic fashion than could otherwise be expected.

of (concrete) existence and appearance. The essence appears in the latter and it is (the appearance) by no means not real or unintelligible (or second rate in any other sense). When our H_2O appears in the form of, for instance, water, *all* of H_2O is present there – there no other H_2O left "behind the scene."

F.H. Bradley would have probably relegated all the particular forms of H_2O along with H_2O itself to the rank of unintelligible mere appearance since only the absolute is real. B. Russell, on the other hand... Fortunately, we do not have to guess in this instance, as B. Russell himself has already spoken loudly and clearly. We have already given this quotation earlier in the present article, but it is truly worth showing one more time. So here it is again, in all its unadulterated brilliance [46], p.110:

> Why should we suppose that, **when ice melts, the water which replaces it is the same thing in a new form**? Merely because this supposition enables us to state the phenomena in a way which is consonant with our **prejudices**. What we really know is that, under certain conditions of temperature, the appearance we call ice is replaced by the appearance we call water.

Thus, in case anybody did not know, considering ice and water just different forms (aka aggregate states) of the same (chemical) substance is nothing but prejudice. We can also note in passing that L. Wittgenstein, if solicited a philosophical lesson on the same matter, would most likely have pronounced the whole issue "nonsensical" and pointed out that the "mystical" melting of ice "makes itself manifest," and the student (the receiver of the philosophy lesson) should be silent about it.

Speaking of the pupil of the famous teacher, he indeed went farther than the latter, as a good student should thereby justifying B. Russell's characterization of him cited in [51]: "I love him & feel he will solve the problems I am too old to solve ... He *is* the young man one hopes for." And the problems he did solve, as we know, the most important of which was really making a system of his teacher's logical atomism thereby exposing it in plain view for the benefit of anyone caring to take a look. As we already mentioned in the previous section of this appendix, the resulting logical atomism ontology takes just a couple of pages to fully develop whereas, for example, it takes Hegel in [1] about two orders of magnitude words more to arrive at a comparable point. For L. Wittgenstein it is really (as in not meant to be a joke) as simple as, for instance, "objects hanging one in another, like the links of a chain." ([50], 2.03). Platitudes of this sort are found in numbers (as we have seen already) in a full-fledged philosophical book, not even a popular exposition of the latter, a century after the subject matter of philosophy (in its logical aspect, at least) had been already defined as the objective thought content and it was clearly stated that [1], p.29:

> To get at least some inkling of this [the thought content], one must put aside the notion that truth must be something tangible.

The problem with L. Wittgenstein was really that, in order to heed such warnings, – and, more generally, to make real progress in philosophy – one would need to *study the philosophical work of predecessors* carefully and sometimes painstakingly, allowing as much time for such study as needed, and not as much as one feels like allocating. And this is exactly what L. Wittgenstein did not do. As one of his close acquaintances recalls (based on the corresponding Wikipedia article), at the age as young as 23, when he just began a study of history of philosophy, "he expressed the most naive surprise that all the philosophers he once worshipped in ignorance are after all stupid and dishonest and make disgusting mistakes!" A rather telling admission indeed. We have a kid in his early twenties who has had no chance whatsoever yet to understand anything about philosophy (such a state of mind is usually called "ignorance" as he admitted, but the problem is this particular – philosophical – kind of ignorance takes a long time and considerable effort to go away) passing categorical judgment about philosophers of the past on the basis of his rather juvenile and simplistic (as we now know from the contents of [50], and it could hardly have been otherwise at his age and prior experience) mental images of the world.

On a slightly personal note, when the author of this article was reading "Tractatus Logico-Philosophicus" after having reasonably thoroughly studied "The Science of Logic" and some other works belonging to the classical tradition, the immediate impression – that grew only stronger as the reading progressed – was that of being acquainted with a typical views of an undergraduate student with an interest in physics and mathematics but – very understandably for even a smart undergraduate – no philosophical background whatsoever. If that imaginary student had been given a course project to come up – from "scratch" or "first principles" as he/she understood them – with a general philosophical system, the result could have been very similar to the "Tractatus" in content. As a matter of fact, many beginners in natural science and math fields have their own "philosophy" similar to that expounded in [50], and can often express disdain towards philosophy proper that tends to discuss "trivial" matters related, for instance, to "pure being" and "pure nothing," or muse at length about "pure and determinate quantity" whereas every physics student already knows everything about quantity and is always ready to "calculate" something serious and significant for science like, for example, the moduli space of vacua of a supersymmetric gauge theory. The difference is that most of them either lose all interest in philosophy due to being too busy with their professional activity or (the minority) manage to find time and learn some real philosophy enough to understand its problematics thereby adjusting their early disdainful attitude. So neither of these two types end up producing any philosophical work extolling their early views. Had they done so we would have been able to compare several "Tractati" to each other and debate their relative virtues.

As we have pointed out earlier, both B. Russell and L. Wittgenstein admitted that their philosophy had no method to speak of, i.e. was essentially content free as such. Recall that B. Russell himself conceded ([46], p.240) that "nothing of any value can be said on method except through examples." It is indeed true and it is true simply because there is no method (i.e. no thought content apart from its subject matter) in the truncation of philosophy that he proposed. For B. Russell, thought as such is empty and therefore is only capable of copying and manipulating the immediate material provided by the senses. The whole totality of human practice leaves – according to B. Russell – no trace on thought other than possibly a tedious account of its prior accomplishments, which – if properly cleared from all "metaphysical lumber" – is, in its turn, just a very long list of descriptions of various "sense data." Philosophy itself for him is nothing but an exercise in parting, separating and cataloguing that very same immediate sense data [44], p.133:

> It seems to me that philosophical investigation, as far as I have experience of it, starts from that curious and unsatisfactory state of mind, in which one feels complete certainty without being able to say what one is certain of. The process that results from prolonged attention is just like that of watching an object approaching through a thick fog: at first it is only a vague darkness, but as it approaches articulations appear and one discovers that it is a man or a woman, a horse or a cow or what not. It seems to me that those who object to analysis would wish us to be content with the initial dark blur. Belief in the above process is my strongest and most unshakable prejudice as regards the methods of philosophical investigation.

It appears that what he could not understand is that "those who object to analysis" (at least some of them that do not believe that all study of the prior work has to be easy) do not object to analysis as a necessary component of rational thinking, but rather to analysis as the ultimate expression of it, its alpha and omega (they tend to think that it is more akin to just alpha). Also emblematic in the quotation above is B. Russell's admission that philosophical investigation (the adjective "philosophical" appears to be misplaced here anyway as there is very little philosophy in just analysis) starts from a mystical sounding state of "feeling complete certainty." Indeed, when the method summarizing at least two millennia worth of rational thought development is simply tossed aside, what's left is to rely on "feel," "intuition," "genius direct vision," and other miracles.

The pupil of the great polymath teacher is in agreement with his mentor, as we have seen him admit. If philosophy is identical with just analysis (a pre-philosophical phase of cognition to Hegel as we can recall) for the teacher, it is just "an activity" for the pupil. That activity's goal is to question and pronounce "nonsensical" anything not directly related to the same good old B. Russell's favorite "sense data." For the young man whose mission was to solve the problems his teacher was too old to solve (the verb "to solve" here appears to be used as a synonym of the verb "to deny"), the whole subject of philosophy was no more than a result of inability of philosophers of the past to clearly express their thoughts – just a figment of their imagination rooted in stupidity.[110] The statements of this sort were able to make even K. Popper – the person who was never suspected of being a classical tradition proponent and who produced a lot more simple ideological content than philosophy – feel obliged to defend the existence of proper philosophical problems against his colleague's (quite ridiculous – there is no hiding this "atomic fact") insinuations. Besides the wholesale denial of philosophy on the basis of non-existence of its subject matter – which gets thereby relegated to the status of a linguistic police of sorts – L. Wittgenstein surprised the world with a number of other groundbreaking "philosophy canceling" discoveries. Let us mention just one of them – for its entertainment value if nothing else [50], 4.128:

> Logical forms are without number. Hence there are no pre-eminent numbers in logic, and hence there is no possibility of philosophical monism or dualism, etc.

A brief reminder: his teacher had revolted from that very same impossible *monism*[111] no more than a decade before the discovery stated above was made. This means... you have guessed it: the said revolt *had no sense*, plain and simple. But one could also note, that, in the name of clarity and logical consistency, it has to be noted that L. Wittgenstein's denial of *philosophical* monism (along with dualism, pluralism etc.) makes that additional discovery redundant: no philosophy automatically implies no "properties" pertaining to philosophy.

As we have already remarked, L. Wittgenstein's main achievement was really to make a system of his teacher's logical atomism and thereby rather clearly demonstrate that – devoid of proper (pure) thought content coinciding with objective forms of universality – logic unavoidably get reduced to a sort of "language games."[112] The latter, by the way, is a truly

[110] We keep thinking that anyone – especially anyone in possession of some philosophical background – who denies feeling disbelief upon the first reading of [50] is not being completely honest.

[111] Recall, that according to B. Russell himself, he was revolting mostly against monism while his fellow revolutionary G.E. Moore had a particular grudge against idealism.

[112] That particular name was introduced in L. Wittgenstein's later work titled "Philosophical Investigations." What appears to be most remarkable about him is that, in spite of the obvious dedication to his studies and utter indifference to any selfish considerations (such as career, fame, any "monetary" gains), he just plain refused to study the works of his predecessors insisting on extraction of all necessary wisdom from the depths of his own self and seemingly refusing to admit that no self can be *that* deep.

brilliant name for what remains of logic (as its formal part – according to L. Wittgenstein – is trivial) upon an "amputation" of pure (i.e. its specific subject matter invariant) thought content that Hegel explored in the most thorough fashion so far.

Given all the obvious glaring deficiencies of logical atomism – in either its original or systematized form – the no less obvious question is literally shouting to be asked. Namely, how could it happen that such a blatant truncation of almost all prior achievements in logic got adapted – and praised – by the larger community instead of just being properly corrected on the spot by sending the authors back to school (and not to the drawing board yet)? Let us try to rationalize a bit about possible objective and subjective reasons for such a puzzling – at the first glance – phenomenon.

Let us begin with the seemingly easier subjective part. One of the subjective reasons is almost impossible to fail to notice. It is simply the difficulty of the pinnacle of the classical tradition development as far as its logical component is concerned – Hegel's "The Science of Logic." As we have already mentioned, it is considered very difficult to understand now, and even though it is possible that the general philosophical culture was at a higher level at some times and some locations in the past, Cambridge – and more generally Britain – at the beginning of 20th century was likely not one of these locations. Also – in spite of the quite possible decline of the interest in philosophy and its impact in the general scientific community – a significant increase in empirical evidence on various transmutations of forms of matter in science, industry, and even everyday life has taken place since then. Objectively, such accustomation to the constant flow of forms makes dialectics somewhat easier to grasp. This implies that, at the time of logical atomism occurrence, a community of people possessing a thorough understanding of logic at or around Hegel's level simply did not exist anywhere in the world, let alone in Britain and Cambridge. Suffices it to say that, at that time, F.H. Bradley who had a very vague – to the point of being plain wrong – idea of Hegel's dialectics was considered a leading authority on the latter. What B. Russell and his followers proposed in the field of logic had one undisputable advantage over Hegel's system: it was multiple orders of magnitude simpler to understand – simply because *all* difficult parts of Hegel's logic were just thrown away and just formal logic of fixed abstract determinations – that Hegel does not even specifically discuss in his book – was put in the place of all logic. The result, as we know, was an empty space in place of a general method that, as we have seen, was filled with polemics with the likes of Berkeley and Hume in which multiple concessions to the anti-reason point of view of the latter were made.

A quick glance at the history of science and philosophy in the beginning of 20th century reveals that the advent of logical atomism (and closely related logical positivism largely originated by the group known as the Vienna Circle) received acceptance and support from the "new (nonclassical/postclassical) science" community (of primarily theoretical physicists and mathematicians) and the (professional) philosophical community itself. It has to be remembered that, at that time, the current near disconnect between philosophy and natural sciences was just in its beginning stage, and their interaction was a lot more active, with pure physicists like W. Heisenberg writing books on philosophy as late as the second half of 20th century. Thus, when B. Russell was revolting against idealism and monism, physicists were already struggling with a number of difficult problems centering around the nature of radiative matter. These problems were sufficiently difficult so that the standard methods based on mental imagery (visual representation) did not work as before, and the need for something more advanced – as far as methodology was concerned – started being acutely felt. The dialectical logic – at least in its first iteration – was already available, but, due to the difficulty level of its own, almost entirely absent from physicists' methodological "toolbox" (just like in our times). Besides that, there was really little: formal logic which was already natural and obvious to them, and the method of building directly visualizable (mechanical at their core and based on the well understood forms of mechanical motion) models.

When such models did not yield a consistent explanation of radiative phenomena, physicists found themselves at a loss, and, having realized that some form of new logic is needed, some of them (such as H. Poincaré and E. Mach) began philosophical investigation of their own. Having little background in philosophy (and equally little time to acquire it due to being busy with their main professional duties[113]), they took to emulating L. Wittgenstein (or, rather, L. Wittgenstein could be said to have been emulating them as their work appeared earlier) in devising their philosophy "from scratch." Since "scratch" in this case is a synonym of "nothing," the corresponding philosophy ended up being designed on a nonexistent foundation, and – expectedly – was very simple. The history of philosophy indicates that the simplest kind of the latter is nothing else but *subjective idealism*[114] – and this is pretty much what H. Poincaré's and E. Mach's (and, half a century later, W.K. Heisenberg's) efforts brought about. B. Russell himself acknowledged the work of his esteemed predecessors [46], p.131:

> There are, it is true, two authors, both physicists, who have done something, though not much, to bring about a recognition of the problem as one demanding

[113]Any scientist of today can just look at self and try to answer a simple question: how much time an active professional can realistically spare for a study of a new – and very difficult – subject without sacrificing any of the (obviously more important) career related activities.

[114]While some of the philosophers mentioned later in connection with subjective idealism (like D. Hume and E. Mach) are better known as radical empiricists, the latter can be considered just another form of subjective idealism. Indeed, in the absence of any objective universals, any generalization indispensable in science of any kind gets relegated to the realm of free enterprize of the thinking subject.

> study. These two authors are Poincaré and Mach, Poincaré especially in his *Science and Hypothesis*, Mach especially in his *Analysis of Sensations.* Both of them, however, admirable as their work is, seem to me to suffer from a general philosophical bias. Poincaré is Kantian, while Mach is ultra-empiricist; with Poincaré almost all the mathematical part of physics is merely conventional, while with Mach the sensation as a mental event is identified with its object as a part of the physical world. Nevertheless, both these authors, and especially Mach, deserve mention as having made serious contributions to the consideration of our problem.

The "problem demanding study" mentioned in the quotation above is that of the relation between "sense data" and various objects of physics. We can see that B. Russell, while praising the two semi-amateur philosophers for their contribution, makes sure to point out the modest extent of the latter ("have done something, though not much") and – of course – the relative lack of (compared to his own, apparently) philosophical schooling and sophistication that had resulted in their "suffering from a general philosophical bias." The obvious implication of this light scolding delivered by the future great polymath is the existence of *the correct* unbiased philosophy. The two physicists/mathematicians turned philosophers would not have been called biased had they been devoted and staunch *Russellians*, as opposed, to, for example, Kantians like H. Poincaré.

But, more seriously, differences between the philosophies of H. Poincaré, E. Mach and B. Russell himself are more superficial than the latter is willing to admit. Subjective idealism is indeed their common denominator – that makes them all philosophical close relatives of the classics of the genre G. Berkeley and D. Hume, the relation to whose philosophy of B. Russell's logical atomism we discussed at some length in an earlier section of this appendix. In application to problems of (natural) sciences, all these systems boil down to the same general idea. Namely, all objective reality – if it exists, which itself is a big "if" – is only given to us via "sense data," and all we can hope to do is to bring some order in it by doing a sort of generalized "regression curve fitting" to that sense data. This is precisely the "free invention of laws of nature by the intellect" that the early "absolutely relativistic" A. Einstein was so fond of. What B. Russell added to the work of his philosophical cousins was a "rigorous derivation" of the notions of a (point) time moment and a point in space from physics by means an almost verbatim use of the development of the notion of a limit in calculus.

To summarize, by the time of B. Russell's revolt against idealism[115] and monism, very similar philosophical ideas had been already brewing – and, moreover, seemingly produc-

[115] As we see, the idealism related (as opposed to monism) component of the revolt turned out to be of a

ing groundbreaking results like the Machist A. Einstein's special (and a bit later general) relativity theory – inside the physics community. So, naturally, when philosophers (like B. Russell and G.E. Moore) came out with similar proposals, an acceptance of them by at least a certain segment of physics community was made so much easier. A typical "synergy" and "cross-fertilization" started taking place. The new philosophy was sufficiently simple to be readily assimilated by anyone without any philosophical training and background which further facilitated its acceptance by (part of) physics and other natural sciences community.

As far as professional philosophers of the period are concerned, an explanation that appears to be a plausible one is that one of the factors working for the acceptance of the new "truncated" logic – besides the fact that the system of Hegel in its full original form was still very poorly understood by the majority – was that, at the time, the tendency to "professionalisation" and "industrialization" of all academic disciplines, not excluding philosophy, was beginning to gain momentum. As a result, the now famous "publish of perish" mentality was beginning to get hold of the general academic community. In such environment, a steep learning curve started being implicitly considered a drawback of the corresponding direction. Again, any academic of the present can think about the current situation where a graduate student – typically a young person in early- or mid-twenties – is required to begin producing his or her own work as early as a year or two into the period of graduate study. Under such conditions, a study of a topic that can take close to a decade to master sufficiently for thinking about trying to make a meaningful contribution begins sounding not very different from a recipe for a career suicide. So when a radical – which can still be an understatement – simplification of philosophy, and logic in particular, was proposed, the reaction from both graduate students and their advisors – even though it might have been rather complex and multifaceted – almost certainly had a side to it largely equivalent to a sigh of relief. Any community, if pressured for being productive, will find a way. This revision of philosophy towards (a lot) greater simplicity was likely a sort of a reaction of the philosophical community to the overall process of "industrialization" of academia. Speaking of B. Russell, it is known that his specifically philosophical fame began with a paper titled "On denoting" [49], where he claimed that the prior difficulties of logic stemmed from careless use of language and notation (predating the work of his future favorite pupil). So, at that time, musings about the hair condition of the King of France (a nonexistent character) were already considered acceptable topics of research in philosophical logic (fundamental philosophy). The task of producing publishable papers in philosophy was becoming accessible to people with a background of a typical graduate student.

more declarative nature. But, on the other hand, one should always remember that it was mostly B. Russell's colleague G.E. Moore – and not so much himself – who was crusading specifically against idealism.

As for objective – deeper societal – reasons for the severely truncated philosophy getting acceptance, it appears to be a more difficult task to point them out in a reasonably coherent fashion. So, without attempting any investigation that would likely require significant time and effort dedicated just to it, we will only point out the obvious. Philosophy, just like any other form of the collective societal consciousness, is a product of the given society and its current practices, in their current respective forms. Any societal form, as a form of *universal matter* (or, rather, substance) possesses a (dynamic) moment of progressive development. On the other hand, as a *particular form* of universal matter, it also possesses a (static) moment of *status quo* maintenance. This means, at the most general level, that any societal form – simply by virtue of being a particular finite form – always exhibits regressive (or anti-progressive, conservative) tendencies in all of its facets. In particular, philosophy, as one of these – albeit very specific – facets, is also subject to exhibiting conservative tendencies. One of specifics of philosophy is that it is "located" at the forefront of human (i.e. intelligent form of matter) progress in a sense, by virtue of its subject matter – the pure content of thought. Due to this specific attribute, any conservative tendencies in society might take on a somewhat amplified appearance when reflected in the mirror of philosophy. In this regard, it is also useful to recall that, in its present phase of society development, many objective tendencies "make their way" without humans either consciously acting with the corresponding purpose in mind or even passively reflecting on the tendency being at work. Rather, most human "agents" are motivated by their specific narrow interests that, on the surface, might have nothing in common with the corresponding objective tendencies using the said interests as their "vehicles." A situation of this kind could as well have taken place in the beginning of 20th century. The "Great Simplification" of fundamental philosophy (general philosophical logic) made it possible to ensure a steady stream of research publications, even by novice authors, and, objectively, largely "behind the back" of philosophers, applied some braking force to the wheels of future progress.

It is interesting to note that, even though the conservative objective tendencies work largely in the background, so that quite possibly none of the "simplificators" themselves neither desire nor clearly realize or anticipate the objective results of their work, they still come to the surface in places and can be found there upon a close scrutiny. Since philosophy (in its most fundamental part) became a theory of thought in the most general sense, conservative tendencies in the latter would likely show themselves directly on the surface in the form of some kind of claims about allegedly fundamentally unsurmountable limitations of the capabilities of rational thought, intelligence etc. Indeed, in [46] (p.68), we find the following claim:

> It [the modern logic] has, in my opinion, introduced the same kind of advance

> into philosophy as Galileo introduced into physics, making it possible **at last** to see what kinds of problems may be capable of solution, and what kinds **must be abandoned as beyond human powers**.

We clearly see the emphasized finality of the results ("at last") and the direct statement of "human powers" apparently fundamental limitations expressed quite empathically: "problems must be abandoned." In the work of L. Wittgenstein, the same "limiting" motives are seen even more clearly (as we know by now, he was a great champion of clarity). First of all, as we remember all too well, the main pathos of [50] is nothing else but a "closure" of philosophy as it had been previously conceived and its relegation to the status of an "activity" consisting of looking for "metaphysical, nonsensical propositions" in what scientists might produce using whatever methodology they please. So what did the chief philosophy abolisher think about the limits of intellect and rational knowledge in general? In fact, we have already discussed this issue in this appendix, but let us quickly reiterate [50], 6.52, 6.521, 6.522:

> We feel that even when *all possible* scientific questions have been answered, **the problems of life remain completely untouched**. Of course there are then no questions left, and this itself is the answer.
>
> The **solution** of the problem of life **is** seen in the **vanishing of the problem**.
>
> There are, indeed, things that cannot be put into words. They *make themselves manifest*. They are what is **mystical**.

So, from life onwards, including anything related to society, everything is "mystical," and completely and fundamentally beyond the reach of rational thought. One can't even ask ("sensible") questions about these matters, let alone expect any reasonable answers.

But probably the most direct indication as to the overall conservative/regressive nature of the radical philosophy revision and the rejection of the classical tradition in the beginning of 20th century – that had been already taking place before that – is B. Russell's own admission of the real reasons of the said rejection [46], p.20:

> To us, to whom safety has become monotony, to whom the primeval savageries of nature are so remote as to become a mere pleasing condiment to our ordered routine, the world of dreams is very different from what it was amid the wars of Guelf and Ghibelline. Hence William James' protest against what he calls the "block universe" of the classical tradition; hence Nietzsche's worship of force; hence the verbal blood-thirstiness of many quiet literary men. The **barbaric**

substratum of human nature, unsatisfied in action, finds an outlet in imagination. In philosophy, as elsewhere, this tendency is visible; and **it is this, rather than formal argument, that has thrust aside the classical tradition** for a philosophy which fancies itself more virile and more vital.

Recalling that, for B. Russell, the adjective "formal" is an identical synonym of "rational," we see here a clear exposition of the essentially irrational anti-reason roots of the abandoning of the classical tradition of panlogism. It is ironic – and at the same time tragic – that the "verbal blood-thirstiness of many quiet literary men" was going to find some serious and gruesome satisfaction no more than a year after [46] was published. The "wars of Guelf and Ghibelline" then started looking like a very mild warm-up next to the famous Verdun "meat-grinder," the wide use of chemical weapons and flame throwers. Also emblematic is B. Russell's choice of reference figures in this quotation. Both W. James and F. Nietzsche are clearly philosophers of the kind that nobody would think about consulting on matters of logic, and ways of reason in general. (In fact, it would be fair to say that they were ideologists more than philosophers in any proper sense.) This quotation implies that anyone whose interest lies in the sphere of science, reason, and progress would be better advised to ignore the intellectual (or, perhaps, more precisely, ideal, since the word "intellectual" sounds a lot like "related to reason") products of the "tendency" whose content was an expression of the "barbaric substratum of human nature" (apparently meaning its anti-intellectual side) and the result of which was "thrusting aside of the classical tradition."

Finally, let us amuse ourselves a bit by seeing how dialectics can get the better of those who deny its existence. When B. Russell decided to revolt against idealism (alongside monism), the revolt led him, as we have seen, to the empiricism very similar[116] to that of E. Mach (who, incidentally, also shared B. Russell's stated preference of natural sciences – in particular, physics – to social disciplines as applications of logic). E. Mach's empiricism, in its turn, was shown before to be nothing else but a modernized form of subjective idealism in the best traditions of G. Berkeley. This is really a simple but still a very good example of the dialectical unity of opposites: what appears to be an ultra-realism (empiricism) turns out to the same as the (equally ultra) subjective idealism. Indeed, such ultra empiricism denies the reality of anything but the immediate sense data. In particular, any objective unity of that immediately given surface is also denied (and sometimes given the label of "metaphysics"). Since that objective unity is in reality the same as the inherent (pure, but not *a priori*) content of thought, the latter disappears from the radical empiricist's "philosophical radar" as well. Thus the "intellect" becomes the demiurge of laws of nature that

[116]In this regard, it is hard to refrain from referring to B. Russell's qualification of the belief that ice and water are just different forms on the same substance as prejudice.

have no other source left apart from a "free invention" by the said intellect (as the early A. Einstein – then a devout E. Mach follower – firmly believed). The intellect itself – besides being free in its inventions – acquires a fully self-subsistent quality, independent of the chaotic physical reality (the very existence of which is suspect, since only sense data is given to any carrier of the intellect) consisting, at best, of a bewildering multitude of mutually independent "atomic facts." Thereby one obtains subjective idealism in its full glory and without any significant effort. Indeed, as we have seen in this appendix, the post-revolt B. Russell carries on polemics with G. Berkeley and D. Hume (while paying homage to both – recall the "irrefutable" scepticism of the latter and "very powerful attack" of the former) but never directly with Hegel.[117]

B 20th century theoretical physics between dialectics and metaphysics

One of the main declared goals of B. Russell's revision (by means of truncation) of (philosophical) logic was clearing it of "metaphysical lumber." Let us take a quick look at the results actually obtained. According to Stanford Encyclopedia of Philosophy, "the word 'metaphysics' is notoriously hard to define." Reading B. Russell books on philosophy, however, makes is reasonably clear that, for him, "metaphysical" is a synonym of "not given in or directly derivable from experience." Indeed, in his [46], we see the word combinations "ultimate metaphysical truth," "incredible accumulations of metaphysical lumber," "audacious metaphysical theorizing" (ironically, about the existence of various objects of physics at the time no physicists is looking at them – per the letter of G. Berkeley's teachings), "unnecessary metaphysical assumption of permanence," "independent metaphysical reality," "superfluous (fictitious) metaphysical entities" that make the above conclusion fairly easy to arrive at.

The rather obvious problem associated with clearing all metaphysical lumber that B. Russell had in mind is simply that a reduction of cognition to simply an analysis and sorting of immediate sense data makes rational cognition as such impossible, so some sort of generalization is going to be done as long the latter still exists. Put slightly differently, any kind of thinking is going to make use of some philosophy (i.e. logic in the general sense) whether the thinker admits it or not. The only question is what kind of philosophy it is going to be. As Hegel liked to point out ([1], p.37), "logic receives full appreciation of its value only when it

[117]It is interesting to note that "The Science of Logic" contains references to works and views of many philosophers, with Kant being the leader, but there is not a single mention of Berkeley, and exactly one (in direct relation to Kant) of Hume.

comes as the result of the experience of the sciences." In this appendix, we are going to take one such science – physics – and take a closer look at it from the specifically logical angle, concentrating on the period encompassing the "new" (relativistic and quantum) physics that happens to mostly coincide with the period in philosophy following B. Russell's "revolt" and the subsequent "anti-metaphysical" reductionist movement in logic. Our main interest will be in seeing what took the place of the banished metaphysics, and whether whatever took its place deserves the label of metaphysics itself. 20th century physics happens to present a particularly fortunate case for such a study since it began facing new challenges putting extra demands on its logical aspect at about the same time.

For a preliminary estimate, let us again turn to the testimony of one of central figures of the "new" theoretical physics, the person responsible to a large extent for the creation of the *relativistic quantum* (i.e. both relativistic and quantum by design) theory in its (mostly) modern form. As we have already reviewed in Appendix A, R.P. Feynman admits in his popular book "The Character of Physical Law" [48] that "guessing nature's laws" is "an art." B. Russell's absence of a rational method comes to mind right away while reading these words. Slightly more specifically, R.P. Feynman mentions "think of symmetry laws," "put the information in mathematical form," "guess equations," for particular approaches to that art that had worked in the past. But right away he warns: "When you are stuck, the answer cannot be one of these, because you will have tried these right away. There must be another way next time." So all these "tricks" seem to be just "single use" ones. Again, B. Russell's "direct philosophical vision" of a genius becomes easy to recall. A genius seems to be required to invent a new trick that has not been used before every time physics theory "gets stuck." Still, there has to be some logic behind these tricks taken in their totality.

What this logic really is for modern theoretical physics is going to be our main focus in this appendix. A bit more to the main point, in the context of this whole article, we want to find out if it proved possible to develop physics theory and meet its new challenges without the help of the best logic had to offer at that time – the same best that was truncated from the contemporary philosophy by B. Russell and his followers. Something else had to take its place. From R.P. Feynman's testimony, we can see that, on the surface (at the level of being, using Hegel's terminology), it (that something else) looks like a collection of unpredictable ad hoc tricks invented anew by physicists presumably possessing extraordinary abilities. What does it look like at the level of essence? This is what we want to find out. If rational dialectics is the (only) correct ideal representation of thought understood dialectically (i.e. both objectively and subjectively), the epistemological story of physics in 20th century, upon closer scrutiny, might end up looking like what Hegel anticipated (by observing these tendencies in sciences of his time) a century earlier [1], p.726:

> For cognition has collected experiences tendentiously, only so that it could attain its simple definitions and principles; and it has preempted the possibility of empirical refutation by taking experiences and accepting them as valid, not in their concrete totality but selectively, as examples that can then be used on behalf of its hypotheses and theories. In this subordination of concrete experience to presupposed determinations, the foundation of the theory is obscured and is only indicated according to the side that suits the theory; and, quite in general, the unprejudiced examination of concrete perceptions for their own sake is thereby much impeded.

In the next section of this appendix, we consider probably the most characteristic example of the "new" physics theory at work. It is actually a bit more than just an example: as we will see later in this appendix (and as it is widely believed anyway), it laid the foundation for that essence of the "new" physics logic we wish to determine. We assume that anyone caring to read this appendix is familiar with the main contents of special relativity which is rather elementary. For general relativity, that is more technically challenging, we include a brief summary of main ideas and results, to make the exposition self-contained. One of the main innovations of the relativity theories being a different than before view on space and time, we consider the logical notion of space and time, from the point of view of dialectical logic, in the next section. Then we go back to relativity to find out what it would have looked like had its author been aware of the proper logical status of space and time, which the philosophy of the period was in principle capable of clarifying (if it were not for the reductive movement it was going through). In the following section, we identify the actual logic (i.e. its essence) behind the "new" physics. In the same section, we also briefly comment on what this logic should have been (or what it will eventually have to become) instead. In the following section, we go from the essence of that logic to its appearance and actuality and see how it looks on the surface – it, not surprisingly, indeed looks a lot like R.P. Feynman described. Having come "up" from the essence though, we are able to understand why it looks like that. In the following section of the appendix, we review the physicists' own views on philosophy and logic of their science. Finally, in the last section, we briefly address the possible counterargument making use of the obvious tremendous progress in technology that took place during 20th century, which should have been impossible had the fundamental science been led off due course in any major way.

B.1 A famous example

The example we are going to start with is the much celebrated A. Einstein's relativity – of both special and general variety. Let us begin with a bit of a background. As most scientists and engineers remember, the nature of radiative matter (in particular, visible light) had been the subject of close scientific investigation since early 19th century. It was found that light behaved like a wave in some medium (exhibiting interference and diffraction) that is also polarizable. The latter property suggested the existence of a transverse component in the corresponding wave and thus – according to the general knowledge about wave motion existing at that time – a "quasi-rigid" nature of the hypothetical medium (called *ether* – or, equivalently, *aether*). On the other hand, that medium apparently provided negligible resistance to, for example, planets on their orbits thus presenting an obvious contradiction – according to the available knowledge – with its quasi-rigid nature. Additionally, the famous Fizeau experiment with light and moving water gave an indirect confirmation to the hypothesis of the ether not being fully drawn into the motion of physical bodies it was assumed to permeate. So when the no less famous Michelson-Morley experiment was performed towards the end of 19th century, the assumption of Earth moving through the ether (which was assumed to be stationary with respect to Sun) at a speed of around 30 km/s was made, and the results appeared to rather strongly reject such hypothesis[118] (but were consistent with a speed about an order of magnitude lower).

At the same time, on the theoretical front, J.C. Maxwell developed a theory of electromagnetism using a simple (fluid) mechanical model of ether as a guiding principle. While he realized that the mechanical model was a very preliminary one, he nevertheless seemed to hold a firm belief that this still largely mysterious medium was real and, as such, took part in the universal motion, i.e. possessed its own dynamics [52]:

> My object in this paper is to clear the way for speculation in this direction, by investigating the mechanical results of certain states of tension and motion in a medium, and comparing these with the observed phenomena of magnetism and electricity. By pointing out the mechanical consequences of such hypotheses, I hope to be of some use to those who consider the phenomena as **due to the action of a medium**, but are in doubt as to the relation of this hypothesis to the experimental laws already established, which have generally been expressed

[118] In the language of elementary statistics, one can say that the results of the Michelson-Morley experiment were used to test the hypothesis H_0: $v = 30$ vs. the alternative H_1: $v < 30$, and H_0 ended up being strongly rejected by these results. But if just the presence of the hypothetical "ether wind" had been the main question (and it was, as far as special relativity is concerned), the correct null hypothesis to be tested would have been H_0: $v = 0$ with the alternative H_1: $v > 0$.

in the language of other hypotheses.

The equations that J.C. Maxwell derived in the quoted article (and revised slightly later) thus had a phenomenological flavor as they were derived not from the still unknown microscopic dynamics of the medium (ether), but rather as a mathematical generalization of several experimentally found laws (such as Faraday's law of induction) of electro-magnetic phenomena. The resulting equations (now bearing Maxwell's name) had the derived form in a frame of reference where the medium was assumed to be at rest as a whole and would change their form in any other inertial (moving at a constant speed) frame of reference. H.A. Lorentz, a couple of decades later, found that Maxwell's equations maintained their original form if the standard transformations to a moving frame of reference were replaced by different ones which also changed the time variable – the now famous Lorentz transformations. H.A. Lorentz himself originally interpreted the new time variable as an auxiliary formal one, not directly related to the physical time.

So this was roughly the situation when the young philosophical disciple of E. Mach (who was also a talented physicist that had just done some remarkable work on Brownian motion in the classical physics tradition) A. Einstein came to the scene. To summarize: there was the largely mysterious universal medium – the supposed carrier of electromagnetic fields and visible light (and possibly gravitation) – that possessed some seemingly contradictory characteristics. On the other hand, there were rather nice and simple phenomenological equations for electromagnetic fields which looked especially simple in one special (idealized) frame of reference and which would also look somewhat different in other inertial frames (but only slightly so for any relative speeds attainable on or close to the surface of Earth) which, in addition, kept the same form under Lorentz transformations. Let us note in passing that, for a true classical tradition physicist, such puzzling characteristics of the medium would provide a challenge and a sign that a lot more work needs to be done to get on terms with it. For someone familiar with the dialectical logic, that contradiction in the behavior of excitations in that medium would provide a hint that a resolution is in order – possibly including a new form of excitation of the medium not encountered or overlooked before.

For a typical Machist philosopher though, it is different: the task is to find *the simplest description* of the experimental data, and the fewer entities are needed for such a description the better. But no scientist is able to fully follow such an extreme logic – including E. Mach himself when he takes off his proverbial philosopher's hat – since scientists just tend to spontaneously believe in reality of their constructs and think they uncover true ways of nature. So what happens when a scientist takes a particular liking to Machist philosophy? This is where the modern day scientific metaphysics (i.e. absolute and final laws) shows up. As a matter of fact, the strict undeviating Machism by itself is not a source of such neo-metaphysics. For Mach the philosopher, any law of nature is strictly subordinate to observed empirical sense data and thus cannot be given an absolute "sacred" status [53], p.316:

> All auxiliary conceptions, laws, and formulae, are but quantitative norms, regulating my sensory representation of the facts. The latter is the end, the former are the means.

Thus any laws are *the means* to strictly empirical *ends* and thus, clearly, are to be changed and corrected whenever any disagreement between them and experience derived data is detected. The only function of all possible laws – and other theoretical constructs like atoms – is to help represent "facts of the senses." Such auxiliary means are not to acquire any self-subsistence resembling *a priori* laws of metaphysics [53], p.314:

> Now one might be of the opinion, say, with respect to physics, that the portrayal of the sense-given facts is of less importance than the atoms, forces, and laws which form, so to speak, the nucleus of the sense-given facts. But unbiased reflexion discloses that **every practical and intellectual need is satisfied the moment our thoughts have acquired the power to represent the facts of the senses completely**. Such representation, consequently, is the end and aim of physics; while **atoms, forces, and laws are merely means facilitating the representation**. Their value extends as far, and as far only, as the help they afford.

Any theoretical constructs, for Mach the philosopher, are ways of summarizing (or "compressing" in the modern computer and computation derived language of many branches of science and engineering) the facts of experience – and much cannot be expected of them as a consequence [53], p.314:

> If ordinary "matter" must be regarded merely as a highly natural, unconsciously constructed mental symbol for a relatively stable complex of sensational elements, much more must this be the case with the artificial hypothetical atoms and molecules of physics and chemistry. The value of these implements for their special, limited purposes is not one whit destroyed. As before, **they remain economical ways of symbolizing experience**. But **we have as little right to expect from them**, as from the symbols of algebra, **more than we have put into them**, and certainly not more enlightenment and revelation than from experience itself.

So strict philosophical Machism seems to be impervious to metaphysics. However, it naturally invites it, so to speak. Namely, in its pure form, it makes science impossible in exactly the same way it banishes metaphysics. By demoting the universal to the status of just some artificial subjective means of an economical description of the particular and the singular, it essentially removes the main subject matter from any science – transforming the latter into a kind of applied information engineering at best. Therefore no serious and devout scientist can fully accept this logic.

On the other hand, simplicity and "economy of thought" as the main guiding principle makes perfect sense within this philosophical paradigm. Indeed, since all laws are just subjective "free inventions" whose only purpose is the simplest description of the *given experimental data*, with no pretense to objective universality, they have to be made as simple as the given data affords – with the understanding that they (the laws) are going to be changed as soon as some data not fitting the old economical description well enough is found. It is very similar to what happens every day in fitting regression models to all kinds of empirical data. If a linear regression, for example, gives a good fit, it should be preferred to more complicated models because it is simpler. Nobody would insist on keeping the regression linear, however, if additional data didn't fit a linear model any more. The reason for such flexibility is the explicitly empirically descriptional nature of the regression model to begin with. The problem is that, when going gets hard in fundamental science, this very principle of (descriptional) simplicity may present a rather strong temptation – especially to younger people naturally more prone to rush conclusions (remember the "finality" of young B. Russell theories, for example) on one hand, and less burdened with logical and philosophical background on the other. Not wanting to give up the scientific search for the universal truth, such younger daring minds can be tempted to take some of the simple "freely invented" rules – whose logical goal is just a concise description of *some* data – and endow them with the status of a universal objective law. If – as it often happens in the most basic sciences such as physics – the "freely invented" in such a hybrid manner law allows for a quantitative formulation, the whole apparatus of mathematics (conceptually simplest and therefore the most thoroughly developed of all sciences) can be brought to bear on the issue exploring the resulting domain of formal possibility (in Hegel's terminology). Occasionally, very beautiful (in some regard) theories can be created this way. If the domain of their applicability is sufficiently remote from the current everyday practice, the difference between formal and real possibility may stay inconspicuous for quite some time. This is – in short – how the modern day scientific metaphysics seems to have originally come about. Philosophically, the main source of it appears to be a somewhat surprising at a first glance unity of Mach-Avenarius ultra empiricism (using B. Russell's characterization of it) – that has subjective idealism[119] as its natural *other* – and the classical physics sometimes spontaneously dialectical but still largely naive (relying on directly visualizable mechanical models) realism (materialism).

Let us now get back to our main example of such modern metaphysics in action. Recall what the young A. Einstein knew about light and electromagnetism: the largely mysterious ether with puzzling seemingly contradictory characteristics and nice and simple phenomenological equations of electromagnetic fields which changed their form in any other (than the one in which the ether was at rest) inertial frame of reference, but happened to keep the same form under Lorenz transformations. There were also rather inconclusive results of the Michelson-Morley experiment on ether drift detection. In Einstein's own words [54]:

> Why must I in the theory distinguish the K system above all K' systems, which are physically equivalent to it in all respects, by assuming that the ether is at rest relatively to the K system? For the theoretician such an asymmetry in the theoretical structure, with no corresponding asymmetry in the system of experience, is intolerable. If we assume the ether to be at rest relatively to K, but in motion relatively to K', the physical equivalence of K and K' seems to me from the logical standpoint, not indeed downright incorrect, but nevertheless unacceptable.

As we noted earlier, the problem discussed in the quotation above acquires a decidedly scholastic flavor if one simply remembers that Maxwell's equations at that time (which is still true now) were of purely phenomenological variety and thus other terms could likely be added to them upon closer study and any relative speeds of K and K' system where any experiments were conducted were many orders of magnitude lower than the characteristic speed scale of the equations themselves – the speed of light c. Thus any experimentally observable differences between K and K' were negligible, and the assumption of "physical equivalence" of these two systems was ungrounded. But being a talented and devout physicist, a philosophical Machist, and a young man at the same time (a potentially dangerous combination as we have discussed), he was already looking – consciously or otherwise – for simplest descriptional schemes that he was ready to elevate to the status of "beautifully simple" fundamental laws of nature. The differential equations which Maxwell himself considered a phenomenological "first approximation" acquired a much more foundational –

[119] E. Mach himself complained in [53] (p.48): "I have been accused of idealism, Berkeleyanism, even of materialism, and of other '-isms,' of all of which I believe myself to be innocent." Indeed, idealism and Berkeleyanism as its radical version were not explicitly built in Mach's system by the author but are implied by it. In a nutshell, one cannot banish the universal from the Universe: if it is denied its objective moment, it reappears in a totally subjective form.

almost demiurgical – character for the young talented physicist/Machist philosopher A. Einstein [55]:

> Before Maxwell people conceived of physical reality – in so far as it is supposed to represent events in nature – as material points, whose changes consist exclusively of motions, which are subject to total differential equations. After Maxwell they conceived physical reality as represented by continuous fields, not mechanically explicable, which are **subject to partial differential equations**.

We see how the idealistic other side of the explicitly empiricist Machism shows up in the neo-metaphysical views of A. Einstein: the fields are some realities that are fundamentally "subject to partial differential equations": equations that are just subjective approximate descriptions of some aspect of nature, which – according to the classical physicist Maxwell – had just its surface scratched by his work, act as something primary taking precedence over nature itself. In the same article, A. Einstein makes this point clear [55]:

> Thus the partial differential equation came into theoretical physics as a servant, but little by little it took on the role of master.

It has to be said that the neo-metaphysical tendency objectively brought about by physics coming to close contact with higher forms – compared to the mechanical one – of the universal motion, the main content of which was the "promotion" of phenomenological descriptions to the status of fundamental laws, had been active before A. Einstein's seminal work [55]:

> By the turn of the century the conception of the electromagnetic field as an irreducible entity was already generally established and **serious theorists** had given up confidence in the justification, or the possibility, of a mechanical foundation for Maxwell's equations.

It is worthy of note that, according to A. Einstein circa 1931, not all physicists had given up the inquiry into the mysteries of the ether, but only "serious theorists." The latter group apparently did not include, for example, the Nobel laureate (and the teacher of many such), the discoverer of electron, and one of the last representatives of the classical tradition in (theoretical) physics J.J. Thomson who was able to achieve some progress along these lines of inquiry [56], [57]. Granted though, J.J. Thomson was not a pure theorist, so it is possible that he was not included in that list not due to being considered insufficiently serious.

So, as far as we know, that was already A. Einstein's mindset when he took up the problem of light and ether. Lorentz transformations that kept the (near-sacred already for

A. Einstein) form of Maxwell's differential equations intact were a priori bound to play some exceptional role. It was also clear that these transformations left the speed of light c formally intact (thus automatically making it the highest possible speed). Now, with metaphysical way of thinking already at work, even the empirical data – as Hegel had explained a century earlier – were being looked at from the corresponding angle. From that angle, the inconclusive data of the Michelson-Morley experiment were taken as almost a conclusive experimental *proof* of the speed of light being the same in any reference frame. It was then a matter of elementary algebra to turn things around[120] by making the constancy of the speed of light an absolute (metaphysical) principle and deriving the Lorenz transformations from it. A paradoxical but simple and "beautiful" neo-metaphysical physical theory was born. But what about the controversial universal medium – the ether? The now common view is that A. Einstein's special relativity put an decisive end to the history of the ether by proving it to be just a nonexistent fictitious entity, similar to the *caloric* of the early thermodynamics. However, A. Einstein himself, being a talented and dedicated physicist, understood[121] that the truth could not be that simple. The obvious reason was any accelerated (including rotational) mechanical motion: a force was required to change the velocity of any object which meant that acceleration could not be pronounced to be "absolutely relative" unlike constant speed [54]:

> To deny the ether is ultimately to assume that empty space has no physical qualities whatever. The fundamental facts of mechanics do not harmonize with this view. For the mechanical behaviour of a corporeal system hovering freely in empty space depends not only on relative positions (distances) and relative velocities, but also on its state of rotation, which physically may be taken as a characteristic not appertaining to the system in itself. In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space. Since he classes his absolute space together with real things, for him rotation relative to an absolute space is also something real. Newton might no less well have called his absolute space "Ether"; what is essential is merely that besides observable objects, another thing, which is not perceptible, must be looked upon as real, to enable acceleration or rotation to be looked upon

[120]In a very similar fashion, for example, if we know that the Pythagoras theorem is valid for any right-angled triangle, then we can prove that the Pythagoras theorem being valid for a triangle implies that the triangle is right-angled.

[121]It has to be said here that it appears that he changed his mind by drifting more away from purely descriptive Machism and to the classical tradition in physics a bit later, during his work on gravitation. As late as 1910, he wrote in [58]: "It follows that a satisfactory theory is impossible without renouncing the existence of some medium filling the whole space."

as something real.

A. Einstein also understood that E. Mach's interpretation of acceleration as being relative to the distant stars (the so-called Mach's principle) could not be a satisfactory one [54]:

> It is true that Mach tried to avoid having to accept as real something which is not observable by endeavouring to substitute in mechanics a mean acceleration with reference to the totality of the masses in the universe in place of an acceleration with reference to absolute space. But inertial resistance opposed to relative acceleration of distant masses[122] presupposes action at a distance; and as **the modern physicist** does not believe that he may accept this action at a distance, he **comes back** once more, if he follows Mach, **to the ether**, which has to serve as medium for the effects of inertia.

As we can see, when A. Einstein puts on a classical tradition physicist's "hat," the ether comes back. Under what conditions does it go away then, and in what sense did relativity put an end to the ether (assuming it did)? In A. Einstein's own words, the ether becomes an "empty hypothesis from the standpoint of special relativity" [54]:

> Certainly, from the standpoint of the special theory of relativity, the **ether hypothesis** appears at first to be an **empty** hypothesis. In the equations of the electromagnetic field there occur, in addition to the densities of the electric charge, only the intensities of the field. The career of electromagnetic processes in vacuo appears to be completely determined by these equations, uninfluenced by other physical quantities. The electromagnetic fields appear as ultimate, irreducible realities, and at first it seems **superfluous to postulate** a homogeneous, isotropic **ether-medium**, and to envisage electromagnetic fields as states of this medium.

Recall that special relativity is the result of *postulating* the constancy of speed of light in all inertial reference frames. If it is viewed, according to E. Mach's philosophy, as an economical descriptive scheme intended to "fit" certain experimental data well, then it makes full sense "postulating" anything, and it may prove indeed "superfluous" to introduce some component of such a scheme (like, for instance, a quadratic term in a simple regression in case the linear model fits the data well as is). But a phenomenological descriptive model

[122] Recall that A. Einstein wrote this in 1920 (when he was already over forty, by the way). But in his original general relativity article [59] published in 1916, he was still siding with Mach relating acceleration to distant masses. Once more, we see an example of his drift towards classical tradition in physics and away from Machism.

is just that, and as such, cannot be used to make predictions and generalization beyond the set of conditions under which it was obtained. Special relativity, on the other hand, seems to forget (or not fully understand from the beginning) its real gnoseological status, and starts acting as a fundamental "ultimate" theory. But since, according to the older and wiser version of A. Einstein himself, there is convincing evidence for an ether (provided by inertial resistance to any acceleration – including that in nearly empty space), then – it would appear – that no theory with a pretense to a fundamental status (as opposed to just that of a phenomenological description) can afford to claim to have provided a proof of its non-existence. The wiser A. Einstein agrees to that rather obvious and unavoidable assessment [54]:

> More careful reflection teaches us however, that **the special theory of relativity does not compel us to deny ether**. We may assume the existence of an ether; only **we must give up ascribing a definite state of motion to it**, i.e. we must by abstraction take from it the last mechanical characteristic which Lorentz had still left it.

And this is where the neo-metaphysical logic shows its "true colors," so to speak. Since some universal medium is impossible to deny without allowing action at a distance through empty space or ignoring the phenomenon of inertia, we are not going to deny it – says the creator of absolute relativity – but we will *forbid ourselves* "to ascribe" any form of motion to it. Is this tabu on ascribing motion to the ether supposed to mean that *it really is alien to motion*, unlike any other objective reality? Then it is a strong statement indeed: the clearly universal medium supposedly permeating the Universe and responsible for inertia – no less – and thus the reason behind Newton's second law (among numerous other laws, no doubt), stays eternally unmoved and unmovable. Even if it somehow does not have any parts, being some mysterious absolute continuum with no discrete moment whatsoever (again, unlike anything previously known to mankind), it still is located in space – just like anything exhibiting inertia. So moving "past it" is definitely possible – and therefore it is going to possess some mechanical motion in the frame of reference of the moving object, which – according to special relativity – is as good as any other. In addition, it has to interact with all weighty matter – since it is the source of inertia – somehow "reacting" to acceleration. How is that possible without some motion of its own? Indeed, if an object localized in space (say a racer on a bicycle) attempts acceleration, the ether is going to engage in interaction with the object by providing resistance to that acceleration the measure of which can be found (at least approximately) with the help of the second Newton's law. It is exceedingly clear that not all ether in the Universe is engaged in that particular interaction which is going to be localized in some vicinity of the object. Thus different "parts" of the ether are going to behave differently, just like it is the case with the ordinary weighty matter – simply because the two are closely connected.

The other alternative is that the proscription of ascribing motion is literally just that. Namely, the ether participates in the universal motion, interacts with weighty matter, but we are going to stoically ignore all of this in our theoretical constructs. One possible reason for such a position is easy to see: we feel that the dynamics of the ether and its interactions with weighty matter is just *impossibly difficult to comprehend* – at least for the modern science as we know it. So we are going to just use the ether *as a formal reason* for phenomena like inertia, without trying to go deeper. In one of the examples A. Einstein used to illustrate scientific thinking, there were two teapots, with one boiling and the other sitting quietly. First, we feel puzzled at the difference, but then notice something blue under the first teapot, but not the second. This observation – just an asymmetry at this point – tells us that something between them is different and thus the observed difference in their behavior is not that puzzling any more. So it looks like what A. Einstein is proposing is to treat the ether in the same manner as the gas flame was treated in that little example – as just a formal ground for inertia – *and stop at this point*. But we have not been able to find such explicit admission anywhere in A. Einstein's works or in the works of his numerous followers. So that's probably not what they had in mind.

A. Einstein, being a talented physicist, most likely realized that the idea of an objectively real ether interacting with all material objects in a very noticeable way but at the same time completely devoid of motion would not seat well with any other scientist not prone to mysticism. So he tries to make it more believable by using an example [54]:

> Think of waves on the surface of water. Here we can describe two entirely different things. Either we may observe how the undulatory surface forming the boundary between water and air alters in the course of time; or else – with the help of small floats, for instance – we can observe how the position of the separate particles of water alters in the course of time. If the existence of such floats for tracking the motion of the particles of a fluid were a fundamental impossibility in physics – if, in fact nothing else whatever were observable than the shape of the space occupied by the water as it varies in time, we should have no ground for the assumption that water consists of movable particles. But all the same we could characterize it as a medium.

Note that water in this example is seen to be in motion on the surface. So the analogy with the ether which supposedly cannot move (and cannot be at rest as well) is faulty – that is probably the reason A. Einstein himself refers to this example as "halting." Also, the supposed “fundamental impossibility” of small floats immersed in water and experiencing its action is far from impossibility in the case of the ether: any material object possessing a mass and moving with changing velocity plays a role of such a small float. All such objects demonstrate to us that the action of the ether they constantly experience is localized in their immediate vicinity implying that the ether acts differently in different locations and thus cannot possibly be immune to motion and change.

That “halting” analogy with water burdened with “fundamental impossibility” of being probed with small floats is then used to justify the purely formal descriptional treatment of the electromagnetic field [54]:

> We have something like this in the electromagnetic field. For we may picture the field to ourselves as consisting of lines of force. If we wish to interpret these lines of force to ourselves as something material in the ordinary sense, we are tempted to interpret the dynamic processes as motions of these lines of force, such that each separate line of force is tracked through the course of time. It is well known, however, that this way of regarding the electromagnetic field leads to contradictions.

In fact, physicists of the classical tradition – including A. Einstein himself when he speaks from that point of view – would not insist on the dynamics of the electromagnetic field involving moving separate lines of force: it may or may not have that particular form. What they – for example, J.J. Thomson – insist on is that the electromagnetic field is some form of excitation of a universal medium filling the physical space. If a certain way of regarding the electromagnetic field leads to a contradiction, the reason for that is most likely – aside from possible mistakes made by those who found these contradictions – that the form of this dynamics is new to physics and still needs to be discovered. A resolution of these contradictions would then involve such a discovery. As an aside, it is impossible to not to express – half jokingly – a mild degree of astonishment that anyone willing to admit the existence of a physical reality residing in space and not subject to motion in that space can be averse to contradictions. Indeed, the very next paragraph of [54] contains the following passage:

> Generalising we must say this: There may be supposed to be extended physical objects to which the idea of motion cannot be applied. They **may not be thought** of as consisting of particles which allow themselves to be separately tracked through time. In Minkowski's idiom this is expressed as follows: Not every extended conformation in the four-dimensional world can be regarded as

> composed of world-threads.[123] The special theory of relativity **forbids us to assume** the ether to consist of particles observable through time, but the hypothesis of ether in itself is not in conflict with the special theory of relativity. Only **we must be on our guard against ascribing** a state of motion to the ether.

It is hard not to notice a classical tradition physicist struggling with a Machist philosopher inside A. Einstein's head. He just seems to be unable – being a classical Faraday-Maxwell-Boltzmann type physicist by training and in heart – to directly state that the ether resides in space but is unable to move in space. (If it is objectively real then either different parts of it can move in space differently or it has be perfectly "rigid" permanently at rest, on the scale of the Universe, no less. In the latter case, there would exist one very special global absolute frame of reference, but that latter possibility sounds extremely metaphysical in a bad sense anyway.) So he says "may not be *thought*," "theory forbids *us* to *assume*," "*we* must be on *our* guard against *ascribing*," keeping these statements as subjective as possible, trying (and failing) to reconcile the simplistic "freely invented laws of nature" with the nature itself.

The neo-metaphysical logic, as we see here, has a habit of vacillating between the points of view of a subjective empirical description and an objective fundamental law of nature, not quite daring to unite these two points of view in their natural synthesis which we will discuss briefly soon. For the time being, let us follow A. Einstein in his intellectual journey into the physics of ether – the existence of which, as we see, he did not think about denying (once he was able to overcome his excessive youthful enthusiasm about the "absolute relativity"), unlike some of his hasty followers – a bit more. Specifically, after he developed his theory of gravitation and gave some more thought to its content – from a classical tradition physicist's standpoint again – he realized that, if gravitation is fundamentally just a manifestation of curving of space (or, for A. Einstein, space-time), then it follows that space cannot be empty since in that case there would be nothing to get curved. Thus space has to be filled with some universal medium (which could just as well be called ether) [54]:

> This space-time variability of the reciprocal relations of the standards of space and time, or, perhaps, the recognition of the fact that "empty space" in its physical relation is neither homogeneous nor isotropic, compelling us to describe its state by ten functions (the gravitation potentials g_{mn}), has, I think, finally disposed of the view that space is physically empty. But therewith the **conception**

[123] One can note here an early example of the characteristic tendency of the "new" theoretical physics of hiding the lack of rational comprehension behind mathematical (i.e. "external," "devoid of reason," in Hegel's terminology) formulations.

> **of the ether has again acquired an intelligible content** although this content differs widely from that of the ether of the mechanical undulatory theory of light. The ether of the general theory of relativity is a medium which is itself devoid of all mechanical and kinematical qualities, but helps to determine mechanical (and electromagnetic) events.

It is somewhat amusing to note A. Einstein's magnanimous authorization of the ether existence in this passage: "the conception of the ether has again acquired an intelligible content" – implying that it had lost that intelligible content before. Indeed, in his "special relativity" earlier years, he was largely siding with the still popular even now opinion of the ether being completely eliminated from physics. (One can recall, for example, his stating that "it follows that a satisfactory theory is impossible without renouncing the existence of some medium filling the whole space" from 1910 that we cited earlier in this section.) Later though, when his theory of gravity had been developed, it apparently occurred to him – as it would to any classical tradition physicist – that special relativity could not afford to deny the ether existence if it was going to lay any claim to being a fundamental theory. Also amusing is the persistent claim of the ether being "devoid of all mechanical and kinematical qualities" (in spite of residing in the usual three-dimensional space) but, at the same time, somewhat mysteriously "helping to determine mechanical and electromagnetic events." A few paragraphs later, in the same work, A. Einstein concludes:

> According to the general theory of relativity **space without ether is unthinkable**; for in such space there not only would be no propagation of light, but also no possibility of existence for standards of space and time (measuring-rods and clocks), nor therefore any space-time intervals in the physical sense. But this ether may not be thought of as endowed with the quality characteristic of ponderable media, as consisting of parts which may be tracked through time. The idea of motion may not be applied to it.

Still, as we see, he keeps insisting on the ether being eerily absolutely alien to motion, unlike anything else known to man so far. One has to note though – one more time – that the phraseology used by A. Einstein in making such claim is again decidedly subjective in the latter passage: "ether may not be *thought of* as endowed" and "the *idea* of motion may not be applied to it." The classical physicist part of him appears to be simply unable to admit in a straight and unequivocal fashion an existence of a real physical entity devoid of motion. It is also important to note that the mature A. Einstein of 1920 (post general relativity but still pre his decades long polemics with N. Bohr on the foundations of quantum mechanics) is convinced that propagation of light is inherently related to the ether ("in such space there would be no propagation of light"), in rather stark contrast with his earlier absolutised Machist views.

Speaking of general relativity which is A. Einstein's theory of gravitation, it presents a turning point of sorts in theoretical physics after which the neo-metaphysical logical method, the content of which is the main subject of our discussion here, became widely accepted and emulated, especially in the realm of grand unification theories. So, to see the above mentioned method at work in its original setting, we are going to briefly discuss the logical aspect of general relativity mostly following the article [59] published in 1916 and containing the final version of A. Einstein's theory of gravity.

A. Einstein begins, in Section 2 of [59], with a thought experiment involving two deformable spherical bodies, labeled S_1 and S_2, rotating with respect to each other around a common axis. It is then found that, while the shape of one of these bodies is a perfect sphere, that of the other one is an ellipsoid of revolution. The question is then posed as to the reason for this difference. A. Einstein writes [59]:

> No answer can be epistemologically satisfactory unless the reason given is an *observable fact of experience.*

There are two important moments in this short quotation. The first is that A. Einstein is using a *philosophical* argument (he is looking for an "epistemologically satisfactory" answer) in a *physics* article showing that physicists of that era still took philosophy seriously and made use of it in their investigations, in contrast with our days. The second is that the reason has to be – according to him – an observable fact of experience. Indeed, the reason has to be *material* and therefore *in principle* observable, but not necessarily observable *at the same time as the difference in question is observed*, as it (the reason) may well happen to be simply more difficult to observe than the difference, the human senses often needing various "amplifiers" to observe material phenomena. But, as we will see shortly, the reason A. Einstein is looking for here is a *formal* reason, similar to "something blue" under the boiling teapot from the example we mentioned earlier.

Having found no observable cause inside the system consisting of the two bodies, A. Einstein turns to the "distant masses" outside which "partly condition" the mechanical behaviour of the two bodies in question [59]:

> The cause must therefore lie outside the system. We have to take it that the general laws of motion which in particular determine the shapes of S_1 and S_2, must be such that the mechanical behaviour of S_1 and S_2 is partly conditioned,

in quite essential respects, by distant masses which we have not included in the system under consideration.

As we have noted already, this is nothing else but E. Mach's point of view A. Einstein had reconsidered by 1920, on the (classical physics realism derived) grounds of absence of action at a distance, which led him to the reevaluation of his view on the ether. Then he formulates a very important (coming fully highlighted in the text of [59]) principle:

> *The laws of physics must be of such a nature that they apply to systems of reference in any kind of motion.*

One should note that no classical physicist – and no supporter of dialectical logic for that matter – would have anything to say against this claim. Clearly, any objective laws have to be still valid regardless of the current frame of reference. It is true, however, that they might look simpler in some frames of reference than in others, which is not a surprise for anyone in possession of some experience in natural sciences and engineering. For instance, any problem with spherical symmetry looks a lot simpler in spherical coordinates compared to Cartesian.

Then A. Einstein considers another thought experiment with two frames of reference, far from any other massive bodies, with a single free mass moving with a constant velocity with respect to the first frame, K. The second frame of reference, K', is moving with a constant acceleration with respect to K. That single mass, regardless of its specific composition, will then be moving with a constant acceleration with respect to K' which happens to be the same kind of motion it would experience in a (constant) gravitational field. A. Einstein concludes – still being on a quest for "absolute relativity" (like in his earlier days at this point) – that one cannot say which one of the two frames is the "really" accelerated one. The reason is – according to A. Einstein – that one could as well consider the system K' to be the unaccelerated one, with the region in question being "under the sway of a gravitational field." What follows from these observation is not really new but very important for general relativity to be constructed here.

> This view is made possible for us by the teaching of experience as to the existence of a field of force, namely, the gravitational field, which **possesses the remarkable property of imparting the same acceleration to all bodies**.

Indeed, this was already known to Newton, the author of both the main law of mechanical motion dynamics (the second Newton's law) and the law of gravitation, both of which were of a phenomenological nature – as had been freely admitted by Newton (recall his famous *hypotheses non fingo*). Newton, being the great physicist that he was, most likely realized that any inquiry in the nature of inertia and gravitation at his time would have been pointless as physics as science was just making its first steps, and any investigation of the micro-world had not yet began. (Granted, in early 20th century, the situation was a lot better but arguably not quite ripe yet for such an inquiry. The electron, for example, had been experimentally discovered just a couple of decades earlier.) It is worth noting that, at the time of writing the article [59], as we have seen, A. Einstein was still in the state of denial of the ether existence which he would only admit a few years later. Thus the rather obvious, for a classical physicist, conclusion from the above observation that both the inertial resistance and gravitational attraction have a very similar *mechanism* (in the preferred language of classical physicists of the time), or *essence* (in the preferred language of classical philosophers), could not have occurred to him at that time. So he went for a Machist style *description* instead.

It had been known for a long time that any non-inertial frame of reference still allowed for consistent description of mechanical phenomena as long as the forces of inertia appearing in such a reference frame (that are most likely consequences of the ether "activation") are taken into account. In particular, if the accelerated frame of reference moves at a constant acceleration, the corresponding force of inertia would act exactly like a constant gravitational field. But such a description would have been local, and would not have related the gravitational field to its source in any way. So A. Einstein conducts another thought experiment in Section 3 of [59]. In that experiment, a frame of reference K' rotates uniformly relative to an inertial frame K along an axis z passing through their common origin. Then the diameter and the circumference of the circle are measured "with a unit measure infinitely small compared with the radius," and the ratio is computed. The conclusion is as follows [59]:

> If this experiment were performed with a measuring rod at rest relatively to the Galilean system K, the quotient would be π. With a measuring rod at rest relative to K', the quotient would be greater than π. This is readily understood if we envision the whole process of measuring from the "stationary" system K, and take into consideration that the measuring rod applied to the periphery undergoes a Lorentzian contraction, while the one applied along the radius does not.

Let us pause for a few moments to point out a somewhat amusing fact that the result just quoted (the ratio exceeding π) is *directly opposite* to that obtained by P. Ehrenfest in 1909 (known as the Ehrenfest paradox) from that same Lorentzian contraction which had the ratio ending up *less* than π due to the contraction of the *circumference itself*, as opposed to

A. Einstein's favorite "measuring rod." Apparently, P. Ehrenfest envisioned his stationary measuring rods applied to a rotating circumference (he considered a rotating disk or cylinder) which contracted – as opposed to the rods – resulting in the smaller than π ratio. It remains to be noted that, if one took a circle (in any physical form) and glued the required number of "infinitely small" rods to the circumference filling all of it, then rotating the circle at any speed would simply yield the ratio of circumference to diameter *equal* to π as the Lorentzian contraction would affect the circumference and the rods in the same way. But the actual inequality direction (whether the ratio is greater or less than π) is unimportant to the thought experimenter in this instance – as long is the ratio is *different* from π and hence Euclidean geometry can be argued to be *no longer applicable*. A similar thought experiment is then performed to convince the author – using the famous special relativistic time slowdown that leads, in particular, to the twins paradox – of [59] that in non-inertial frames of reference time cannot be synchronized throughout. The conclusion the author makes is that non-Euclidean geometry should be used for describing mechanical motion in non-inertial systems. As was anticipated in the previous section of [59]:

> It will be seen from these reflexions that in pursuing the general theory of relativity we shall be led to a theory of gravitation, since we are able to **"produce" a gravitational field merely by changing the system of coordinates**.

Highlighted in the quotation above is the main idea of [59]: since gravitation appears to act on all matter in a *universal* way, **its effect could be described** by assigning it to some inherent characteristics of space and time (or simply spacetime in the preferred language of the relativity generation of physicists). At the time of the original publication of [59], its author still did not realize – as he would do a few years later – that empty space as such *could not* get the influence of gravitating bodies "imprinted" in any way, including that of metric change.

The next step is noting that a gravitational field – by means of its universal (just like it is the case for inertia) action on all known forms of matter – can be locally eliminated by a transformation to a non-inertial system of reference (a free-falling system) moving with constant acceleration equal to that caused by the gravitational field. In such system, there will be no gravitational field and hence the special relativity with its flat Minkowski "space-time" metric would apply. The transformation back to the original system would then be in general non-linear and produce a generally non-flat space-time metric $g_{\tau\sigma}$ where the indices τ and σ range from 1 to 4, with indices 1 to 3 corresponding to the space coordinates and index 4 to the time one. The conclusion is therefore as follows [59]:

> From the considerations of Section 2 and Section 3, it follows that the quantities

$g_{\tau\sigma}$ are to be regarded from the physical standpoint as the quantities that describe the gravitational field in relation to the chosen system of reference.

The resulting expression for the infinitesimal interval square $ds^2 = \sum g_{\tau\sigma} dx_\sigma dx_\tau$ is then claimed to be "no longer dependent on the orientation and the state of motion of the 'local' system of coordinates, for ds^2 is a quantity ascertainable by rod-clock measurement of point-events infinitely proximate in space-time and defined independently of any particular choice of coordinates."

Once it is established that gravitational field is to be described by a space-time metric, what remains is to find the correct equations for a test particle motion in such a field on one hand and for the field itself on the other. Since the (pseudo)-metric is allowed to be arbitrary, the mathematical apparatus of Riemannian geometry is reviewed in the next several sections of [59], including connections, covariant derivatives, and the curvature (Riemann) tensor. Since "gravitation occupies an exceptional position with regard to other forces," an equation of a particle motion in a gravitational field is understood as that of a *free* particle in a curved space, where that very curvature – expressed by the metric – is the manifestation of gravitation. So the equation of motion is simply that of a free particle in a general curved space:

$$\frac{d^2 x^\mu}{d\tau^2} = \Gamma^\mu_{\nu\rho} \frac{dx^\nu}{d\tau} \frac{dx^\rho}{d\tau},$$

which goes over to the standard Newtonian equation of a free particle motion if the Cristoffel symbols $\Gamma^\mu_{\nu\rho}$ vanish, i.e. in flat space and Euclidean coordinates.

As far as the field equations go, for them to be generally covariant, it is stated that, in free space, they have to take the form of a vanishing of some tensor. But demanding that the Riemann tensor vanish is considered to be "going too far" since this would mean a complete absence of any curvature and hence gravitational field. On the other hand, if the vanishing tensor is a symmetrical one of rank 2 directly related to the curvature tensor, then we are guaranteed the correct number of equations equal to the number of independent metric components. Thus the symmetric contraction of the curvature tensor – the Ricci tensor (or, equivalently, its divergence free modification – the Einstein tensor) is chosen for this role. In general, the field equation – by analogy with the classical Newtonian gravity equation that has the ponderous matter density on the right-hand side – is obtained from the free-space equation by inserting the energy-momentum tensor $T_{\mu\nu}$ as the source of the gravitational field:

$$G_{\mu\nu} = \kappa T_{\mu\nu},$$

where $G_{\mu\nu}$ is the Einstein tensor, and κ is a positive constant.

Then it is shown that, in the first approximation, the classical Newton's gravitation law is recovered, and in the second – a perihelion precession. The observed perihelion precession of Mercury was known to exceed the classically calculated result due to influences of other planets, by about $43''$ per century. That was found to be almost exactly equal to the precession predicted by the general relativity, as a correction to the classical result (which, by itself, predicts no precession at all). A. Einstein's conclusion from these two observations is as follows [59]:

> These facts must, in my opinion, be taken as a convincing proof of the correctness of the theory.

The author is certainly entitled to an opinion, and even a favorite one at that. Let us however briefly review the soundness of the ground on which such a favorite opinion may be based. Two facts are quoted: the reproduction of Newton's law if higher order corrections are neglected and the apparently correct prediction of the observed difference in perihelion precession for one planet. As far as the former one goes, it was essentially built in the proposed theory from the beginning in that the field equation was constructed so that the Newtonian limit would obtain correctly. Namely, the adopted field equation has the matter density (in the Newtonian limit) as the source of the field, and the equation of motion – in the same limit – goes over to Newton's second law with the time component of the metric playing the role of the force potential. The field equation then implies that the potential leads to a divergence-free field in free space which has to satisfy the inverse square law in a spherically symmetrical case. As to perihelion precession prediction, as the author himself admitted in the publication preceding the final general relativity article [59], that a good agreement was found only for Mercury, but not, for example, for Earth and Mars. Thus, objectively, the picture is not quite that of a convincing proof, especially given the quite drastic change in the way the nature of gravitation is seen that was proposed in [59].

According to this proposition, gravitation is not a force of the kind similar to, for example, the electrostatic force. Rather, it is identified with the space-time curvature itself. The latter curvature, whose manifestation is gravitation, is created by massive matter (which is generalized, in accordance with special relativity, to energy-momentum). But nothing else is explained. Namely, the ability of endowing space-time with curvature is seen as an inherent attribute of matter that cannot be understood further. Put slightly differently, the proposed essence of gravitation – the space-time curvature – is simply named and described phenomenologically, but not studied in its own right and brought into some higher unity in any way. Thus the general relativity has to be classified – from the point of view of the dialectical logic – as a *phenomenological descriptive scheme* rather than a *proper theory.*

What is remarkable about relativity – both special and general – is that, almost since its inception, it has been hailed as an example not just of a successful physics theory, but also of a finest piece of thought and logic. For instance, E.T. Jaynes who was highly critical of quantum mechanics which he referred to as "a peculiar mixture describing in part realities of Nature, in part incomplete human information about Nature," considered both relativity theories – including their logical (i.e. philosophical) aspect – a high example to be emulated by theories of the future. Let us remember however, that our main interest in the relativity theories is motivated by them being an example of a solution of logical problems by physicists left without proper philosophical "support" – in part, due to the "reduction" of logic undertaken in early 20th century as discussed in the previous appendix. In particular, the notions of space and time came to the attention of physicists in relation to the problems related to the "less tangible" forms of matter. We address these basic notions in the next section.

B.2 A brief logical aside on space and time

As we have seen, when physics faced the problems of radiative matter and, more generally, that of matter forms on the microscopic scale, the demands imposed by the subject matter on the logical component of physics exceeded those seen before. In particular, the fundamental question of the true nature of space in time came to the forefront of physics in early 20th century and got addressed in A. Einstein's relativity theories – both special and general – in a rather radical fashion that to this day generates vigorous discussions. One of prominent 20th century philosophers of science, H. Reichenbach, writes in the Introduction to his book [60] devoted to this subject:

> In the course of the last century the scientists themselves elaborated the epistemological foundations as well as the content of scientific theories... Thus we are faced with a strange result that during the last century an exact theory of knowledge was constructed not by philosophers but by scientists, and that in pursuit of particular scientific investigation more epistemology was produced than in the process of philosophic speculation. And the problems thus solved were truly epistemological problems.

As we mentioned earlier in this article, scientists facing problems, that placed – due to the specificity of their subject matter – higher than before demands on logic, found themselves without appropriate philosophical help and were forced to tackle the corresponding logical ("truly epistemological" in H. Reichenbach's language) problem themselves. These scientists

– such as A. Einstein, N. Bohr, W. Heisenberg and others – were extremely gifted mathematicians and inventive engineers, but generally ill-prepared philosophers. No amount of mathematical sophistication and engineering savvy could compensate for more than two millennia worth of logical development, as H. Reichenbach admits in the same Introduction a few lines later:

> Gradually, however, the situation has become too complicated for the scientist. He can no longer work out the actual philosophic implications, for the simple reason that one individual is not capable of carrying on scientific and philosophical work at the same time.

And, indeed, these scientists could not carry on philosophical work at the required level. Predictably, the epistemological solutions they came up with turned out severely lacking (recall A. Einstein's definition of time as a clock indication as one of the most prominent examples of such deficiencies). What is interesting though is that H. Reichenbach finds such philosophically ignorant creativity actually beneficial for science:

> The philosophical analysis of the meaning and significance of scientific statements can almost **hinder the processes of scientific research and paralyze the pioneering spirit**, which would lack the courage to walk new paths without a certain amount of responsibility.

As far as the nature of space and time is concerned, H. Reichenbach's another admission in the Introduction section of [60] makes it clear that philosophers were actually happy to follow the lead of scientists – even in the logical aspects of the problem that had traditionally belonged to the domain of philosophy:

> For the theory of space and time comprehensive material was available, arising on the one hand from the mathematical analysis of geometry, on the other hand from Einstein's theory of relativity. This theory provides a vivid example of the fruitfulness of physical questions for philosophical explication. Thus a **philosophy of space and time is nowadays always a philosophy of relativity** – this duality probably characterizes best the method of scientific analysis which is the basis of such a philosophy.

In this regard, it appears timely to point out that no amount of mathematical (i.e. quantitative) analysis of anything can do much to clarify its qualitative nature if it hasn't been clarified *before* any quantitative analysis. The reason is that, logically, quality comes before quantity, as we will briefly review later in this section. Also, as correctly noted by H. Reichenbach, the relativity theories indeed raised the question of the nature of space and time and proposed a certain answer. This answer, as we will argue below, was rather unsatisfactory. So if one continues to identify the subject of space and time with that of (absolute) relativity from the two namesake theories, not much progress beyond that point is likely to be made.

So let us revisit the issue from the standpoint of dialectical logic and try to clarify the status of relativistic – and post-relativistic – innovations in this direction. Clearly, both space and time are very elemental categories that should appear in an early stage of a consistent logical exposition. In Hegel's system, this corresponds to the Doctrine of Being expounded in Book One of [1]. The first category, from which the exposition begins, is that of *pure being* which upon closer inspection turns out to be the same – by virtue of being pure and devoid of any distinct features – as *pure nothing.* On the other hand though, they are distinct: being is the opposite of nothing. Their truth is therefore resides in their unity and inseparability and is found in the transition between them which is the *becoming* – the first concrete category of the objective logic [1], p.59:

> *Pure being and pure nothing are therefore the same.* The truth is neither being nor nothing, but rather that being has passed over into nothing and nothing into being – "has passed over," not passes over. But the truth is just as much that they are not without distinction; it is rather that *they are not the same*, that they are absolutely distinct yet equally unseparated and inseparable, and that *each* immediately *vanishes in its opposite.* Their truth is therefore this *movement* of the immediate vanishing of the one into the other: *becoming*, a movement in which the two are distinguished, but by a distinction which has just as immediately dissolved itself.

Becoming is the most elementary logical category that is not abstract (as opposed to pure being and pure nothing). It expresses the constant flow of all things on their surface – the universal motion seen from the most basic perspective: as a constatation of perpetual change. That perpetual change though has a relative moment to it, just like everything else: it has its own quiet side. Taken from this relatively quiet angle, the incessant motion of becoming (with its two moments – *coming-to-be* and *ceasing-to-be* – that are the direct descendants of pure being and pure nothing) settles down and becomes *determinate being*, or *existence* [1], p.81:

> The equilibrium in which coming-to-be and ceasing-to-be are poised is in the first place becoming itself. But this becoming equally collects itself in *quiescent unity.*

> Being and nothing are in it only as vanishing; becoming itself, however, is only by virtue of their being distinguished. Their vanishing is therefore the vanishing of becoming, or the vanishing of the vanishing itself. Becoming is a ceaseless unrest that collapses into a quiescent result.

That quiescent result is the existence itself [1], p.81:

> Becoming, as transition into the unity of being and nothing, a unity which is as existent or has the shape of the one-sided *immediate* unity of these moments, is *existence.*

Existence is thus nothing else but sublated becoming – the "static" moment of the unity of being and nothing. Existence also can be considered a determinate being, i.e. a being that is not pure anymore but rather being with some determinateness in it that is necessarily distinct from the being itself and forms its negation, or *non-being.* Existence is therefore no longer simple and immediate. It can however be made simple again by sublation of that distinction resulting in a self-subsistent entity considered a single whole and termed *something* [1], p.88:

> The distinction cannot be left out, for it *is.* Therefore, what de facto is at hand is this: existence in general, distinction in it, and the sublation of this distinction; the existence, not void of distinctions as at the beginning, but as *again* self-equal *through the sublation of the distinction*; the simplicity of existence *mediated* through this sublation. This state of sublation of the distinction is existence's own determinateness; existence is thus *being-in-itself*; it is existent, *something.* Something is the *first negation of negation*, as simple existent self-reference.

Something, however simple and self-referential, has the dynamic process of becoming in its roots which implies that it has that dynamic moment of transition in itself: something is equal to itself and not equal to itself at the same time – it is *changing something*, and what it is changing into is also something – an *other* [1], p.89:

> Something *is*, and *is* therefore also an existent. Further, it is *in itself* also *becoming*, but a becoming that no longer has only being and nothing for its moments. One of these moments, being, is now existence and further an existent. The other moment is equally *an existent*, but determined as the negative of something – an *other.* As becoming, something is a transition, the moments of which are themselves something, and for that reason it is an *alteration* – a becoming that has already become *concrete.*

The other is most immediately just another something, indifferent to the original one. So, at first, both of them appear to be self-equal and completely separate from each other. They are both *other* with relation to each other. Thus any something is also an other. If we consider other in its own right, we will see that anything defined as only an other necessarily has the moment of self-equality [1], p.92:

> The other which is such for itself is the other within it, hence the other of itself and so the other of the other – therefore, the absolutely unequal in itself, that which negates itself, *alters* itself. But it equally remains identical with itself, for that into which it alters is the *other*, and this other has no additional determination; but that which alters itself is not determined in any other way than in this, to be an other; in *going over* to this other, it *only unites with itself.*

Thus we arrive at the two *moments* of any something that are inseparable. In the more modern language, they can be called the moment of self-equality and the moment of self-inequality (or simply change). Hegel calls them *being-in-itself* and *being-for-other*, respectively [1], p.92:

> The something *preserves* itself in its non-being; it is essentially *one* with it, and essentially *not one* with it. It therefore stands in *reference* to an otherness without being just this otherness. The otherness is at once contained in it and yet *separated* from it; it is *being-for-other.*
>
> Existence as such is an immediate, bare of references; or, it is in the determination of *being.* However, as including non-being within itself, existence is *determinate* being, being negated within itself, and then in the first instance an other – but, since in being negated it preserves itself at the same time, it is only *being-for-other.*
>
> It preserves itself in its non-being and is being; not, however, being in general but being with reference to itself in contrast to its reference to the other, as self-equality in contrast to its inequality. Such a being is *being-in-itself.*

Both moments are moments of something, i.e. of any physical object that is subject to constant change but at the same time maintains its self-identity. These two moments can be thought of as the more developed original and maximally abstract pure being and nothing. The latter are united in becoming, then in existence which gives rise to something understood as a relatively stable entity separate from – but still in an inextricable connection to – other such entities [1], p.92:

> Being and nothing in their unity, which is existence, are no longer being and nothing (these they are only outside their unity); so in their restless unity, in becoming, they are coming-to-be and ceasing-to-be. – In the something, being is *being-in-itself.* Now, as self-reference, self-equality, being is no longer immediate, but is self-reference only as the non-being of otherness (as existence reflected into itself). The same goes for non-being as the moment of something in this unity of being and non-being: it is not non-existence in general but is the other, and more determinedly – according as being is at the same time *distinguished* from it – it is *reference* to its non-existence, being-for-other.

Now we can try to make some logical sense of space and time. In the section of "The Doctrine of Being" dedicated to quantity, Hegel indicates that space and time as such are two examples of *pure quantity* that is important to distinguish from determinate quantity (magnitude) and measure. In passing, we can note – as we have already mentioned – that the distinction between pure and determinate quantity is still largely lost on modern science and scientists which has led and keeps leading to numerous misunderstandings. Hegel expresses this point about space and time as follows [1], p.156:

> Space, time, and the rest, are extensions, multitudes; they are a going-out-of-self, a flowing that does not however pass over into the opposite, into quality or the one, but, as this coming-out-of-self, are rather a perennial *self-producing* of their unity.

and, on the next line:

> Space is this absolute *being-outside-itself* that is equally absolutely unbroken, a being-other over and over again which is self-identical; time is an absolute *coming-out-of-itself*, the generation of a one, of a point in time, a now which is immediately its coming-to-nothing and, again, the continuous coming-to-nothing of this vanishing; so that this self-generation of non-being is just as much simple equality and identity with itself.

This passage clearly indicates that both space and time are absolute, i.e. abstract notions and – as pure quantities – are uniform and self-identical, with no boundaries and determinations anywhere. However we find here their characterizations but not their definitions. At this point, they are still taken as representations of sense data: we understand that all physical objects exist in space and time and that the latter are pure quantities, but not yet their true meaning.

To get hold of that meaning, let us make use of the two moments of any physical entity (represented logically by *something* from Hegel's system) we have reviewed in the beginning of this section. We already know that space and time as such are abstractions that are logically pure quantities (so do not possess any measure if taken as such – in their original purity). But what are they abstractions of? Clearly, given their extreme generality, they have to be abstractions of something very general and basic. In fact, one can see their "glimpses" already at the level of becoming and existence as a sublation of becoming. There, however, they are still found in an *in-itself* state and not yet *posited*. The possibility of these abstractions becomes sufficiently developed at the level of *something* with its two inextricable moments. It is the *universal abstractions* of these two moments that are commonly known as space in time, respectively. Let us begin with time. We have the following definition.

Definition 7 *Time is the pure universal abstraction of the being-for-other (self-inequality) moment of all existent material entities.*

The word "universal" in the definition above means that the abstraction is applied to *all* existent entities. One might argue for its redundancy here since all the categories of Hegel's system on which this definition is based are already universal. We would not object to such criticism but are going to leave that adjective in the definition for additional emphasis. The meaning of the word "pure" is that the abstraction is performed from all aspects of the existents except the *being-for-other* moment that expresses their involvement in the universal motion of (formed) matter. One could also rephrase this definition by stating that *time is the pure abstraction of the universal motion*. Specifically, when one performs such pure abstraction, not just all forms of the universal motion are abstracted away – in that case we obtain energy – but also from the moving matter, leaving only motion as simply motion, without forms and without anything existent moving.

As we have already indicated, time is a *pure quantity*. Therefore the issue of its going faster or slower depending on the conditions (the central theme of both relativity theories) does not arise at the level of the fundamental definition.[124] Once the notion of time as pure quantity is established, one can consider determinate quantities and measures. A determinate quantity of time is obtained if some boundary is set. For instance, one could set some material process running (to establish the starting point), wait a bit and then stop it (to establish to ending point). Then we can claim that the process had been running for a certain determinate time quantity. Any other process that started and ended simultaneously

[124]Recall the definition of time adapted in special relativity: time is the indication of a clock. What appears rather amazing is that many scientists and philosophers since have made the claim that A. Einstein deeply reconsidered the fundamental concept of time not just in physics but in *philosophy* as well.

with the first one would have been running for the same determinate time quantity. In order to provide a measure of time, a comparison of the determinate quantity to be measured with some other determinate quantity playing the role of a standard is required. Clearly, the most convenient choice for a standard would be some *periodic* material process since it would allow for measuring time intervals of various magnitude. This is where the issue of time going faster or slower depending on conditions can come up. Consider, for example, some imaginary astronauts using a grandpa's pendulum clock on their trip to the Moon and back. That clock would slow down by a factor of about 2.5 once they arrive and stop completely during their weightless journey. Would it mean that time stops for space travelers and slows down for Moon dwellers? The answer is obvious, and to convince themselves of its validity, the astronauts would just have to take an electronic or simple mechanical spring powered watch along the pendulum clock on their trip. On the other hand, can there exist conditions affecting the speed of the processes taking place in watches of those types as well or any other periodic process that could be used as a time keeping standard? The answer appears to be almost equally obvious: any material process can be affected by the environment simply by virtue of the universal bond present in all of matter. No periodic process used for time keeping can be an exception. For example, designers of diver watches pay special attention to waterproof qualities of their products since an ingress of water inside the watch body typically means the speed of the time keeping process going to zero.

So periodic processes can change their speeds depending on conditions. What about the determinate quantity of time itself? Put slightly differently, in the spirit of physics, does there exist absolute time similar to Newton's? First of all, determinate time and any time measure has a relative aspect to it, as was noted by A. Einstein. Consider, for example, space travelers from a science fiction book on their way to a distant planet system. Due to the anticipated uneventful but lengthy phase of flight through interstellar space, they choose to enter the state of induced anabiosis, in order to have more useful time left in their physical lives for the much more interesting exploration activity once they arrive. In that state, all processes in their organisms slow down considerably thus slowing down their natural aging process as well. So *as far as their physical lifespan is concerned*, time can be said to have slowed down also. On the other hand, all systems of their spaceship will have aged much more upon arrival compared to the effective aging they themselves will have experienced. This phenomenon of time relativity has been known for a long time and is even reflected in everyday language. So we can hear that the "biological clock" of a person leading healthy lifestyle "is ticking" significantly slower than that of someone leaving in adverse conditions.

This however is not quite the time relativity which is the subject of the two relativity theories. In both of these theories, time slowing down or speeding up implies that the speed of *all* possible processes is slowed down or sped up *by the same factor*. If this had indeed been the case, one would have been justified speaking of the (determinate) *time itself* changing its pace as opposed to just *particular processes*. In such case, any possible standard process used for time keeping would have changed its pace in the same proportion making it impossible to certify the phenomenon by means of local measurements. It would have been only discoverable by a later comparison of elapsed times – like in the famous "twins paradox" from the special relativity. Such a universal uniform change of the speed of all material processes would have to have some fundamental material cause. In the general relativity, gravitation is supposed to provide such a universal cause. In the special one, there is none, and the claimed change of time pace is a direct consequence of the postulated absolute maximum speed (which is equivalent to that speed being independent of the reference frame) combined with the clock synchronization procedure utilizing signals propagating with such universal maximum speed.

Let us now turn to space. While time is a pure quantity representing a pure universal abstraction of the *being-for-other* moment of all material entities (represented at this logical level by Hegel's *something* category), space can be likewise associated with a universal pure abstraction of the other moment. We arrive at the following definition.

Definition 8 *Space is the pure universal abstraction of the being-in-itself (self-equality) moment of all existent material entities.*

Note that, taken according to this original definition, space is a *pure quantity* and as such does not yet possess any determinate quantity related characteristics and, in particular, dimensionality. The latter appears at the next stage of logical development when boundaries in space are introduced. There it is revealed that space is three-dimensional, and to develop measure, a standard of length is required which is typically chosen to be something as rigid and unchanging as possible. The reason is obviously that, in order to measure what is a perfect idealized stillness (absence of any change), something extremely impervious to change is needed. When spatial measurement are performed, the assumption of the absence of change in the measured objects and distances[125] is also always made. Indeed, it would make little sense, for example, to measure and report on the height of a snow pile if the temperature outside suddenly changed to 20 degrees Celsius.

So what about spatial contraction as a fundamental property of space-time? The only rational sense that can be assigned to it is that, under certain conditions, all material entities change their spatial dimensions in the same exact way. For this to happen, some fundamental

[125]This is so unless an explicit time dependence – and thus the associated spatial motion – of the latter is implied and mentioned.

universal material cause has to be at work. In other words, a certain form of matter (and a certain form of the universal motion) has to affect all forms – including itself – in this particular fashion. In the general relativity, there is a candidate for such a form of universal motion – the still mysterious gravitation. In the special relativity – again, just like in the case of time rate change – there is no such candidate, besides the empty space-time itself which, accidentally, is still widely believed to have been finally fully divested of the ether by special relativity. But – as the older and wiser A. Einstein admitted (as we reviewed in the previous section of this appendix) – empty space as such cannot have any physical properties and can only appear to possess them due to matter in various forms (abstractions of which space and time actually are).

Let us now turn to the absolute space and time of Newton's mechanics. What is its logical status from the point of view of Hegel's dialectics? First, space and time as pure quantities have a clear absolute moment to them simply by the virtue of being universal abstractions. As we have discussed, determinate time and space and time and space as measures have a relative moment to them as well. But what is the meaning of their absolute aspect? The existence of an *absolute time measure* is equivalent to that of a periodic process *unaffected by any material conditions* which can play the role of a standard of time measure. Clearly, an existence of such process sounds not very likely, and if we make a particular emphasis on the word "any" from the previous sentence, it begins sounding plain impossible. On the other hand, for any specific application of a time measure, a process is needed that is only unaffected by the specific conditions to be encountered in that specific case. Such existence sounds plausible in principle, and has been verified in situations encountered by the humanity so far. There are also no convincing reasons to believe that finding such a process for any specific conditions should become absolutely impossible in the future (unless we choose to postulate such an impossibility). Thus – given what we know at this time and due to the infinite variety of forms of matter and the universal motion and their combinations – an absolute time measure almost surely does not exist, but a suitable time measure for *any* set of material conditions does exist with the same certainty. We see that – just like anything else – time measure has an absolute and relative moments to it. The situation is the same with space (length) measure for the same basic reason. Thus Newton's absolute time and space measures[126] indeed make sense as a typical for any science idealization which can in principle be well approximated in any given situation if sufficient care is taken.

But how about gravitation that is supposed to act in the same way on absolutely all forms of matter? This very assumption lies in the foundation of the general relativity theory

[126]These are not to be confused with Newton's absolute space as an absolute reference frame, with respect to which the absolute mechanical motion of a particular body can be regarded.

and justifies the description of gravitation by means of a space-time metric. To answer this question in a qualified manner, one would need to understand the nature of gravitation, i.e. to determine the dynamics of the particular form of matter responsible for the phenomenon of gravitation and the relations of this form of matter to the currently known forms. Before such investigation is performed, we can only guess that it is likely that the "quanta" of form of matter responsible for gravitation are not themselves subject to gravitation in the same way the currently known forms are. That particular form of matter is quite possibly nothing else but the ether allegedly ousted from physics by the special relativity but welcomed back to it 15 years later by the wiser version of the author of that theory [54], like we reviewed in the previous section of this appendix.

Let us briefly comment on Newton's "objectivation of space" pointed out by A. Einstein in [54]: "In order to be able to look upon the rotation of the system, at least formally, as something real, Newton objectivises space." The same comment would apply to any acceleration. As we know from the previous section, A. Einstein himself rejected E. Mach's proposal according to which any acceleration of an object in open space would have to be related to distant stars thereby justifying its reality. This was one of the reasons the originator of both relativity theories had to admit the existence of the same ether that had been so nonchalantly dismissed – in the name of descriptional simplicity and "elegance" – by the young and careless version of himself about 15 years prior. The close relation of gravitation to inertia lying at the foundation of the general relativity theory suggests their common nature and their medium – the ether – as the natural reference of any accelerated motion.

It would be also useful to point out that the existence of ether – somewhat reluctantly admitted by A. Einstein in [54] and accompanied by repeated warnings "against ascribing a state of motion" to it, in the best traditions of subjective idealism – does not in any way undermine the relativity of mechanical motion. That particular relativity was apparently held especially dear by the author of the two famous namesake theories – lying at the core of his scientific and philosophical views. If the ether is indeed a real physical medium – as opposed to simply a mathematical construct – it certainly possesses a state of motion at any time, whether we are willing to ascribe it or not. Also, we can be certain that this overall state of motion is very complicated including various "sub-states" at all scales – from microscopic to intergalactic. Relativity of mechanical motion for A. Einstein means that, first, the same universal laws of physics apply in all frames of reference, and second, that there does not exist an absolute mechanical motion (and thus a state of an absolute still) – with respect to some special reference frame. Once rational understanding of the ether and its relations to and interactions with nucleons and macroscopic objects is achieved and expressed in the form of laws of physics, these laws will apply in all possible frames of reference if appropriate provisions (like, for instance, the introduction of the centrifugal and Coriolis forces in rotating frames of reference in Newtonian mechanics) are made that are obtained from the same laws. Also, the existence of a universal medium engaged in constant complicated motion in no way implies the existence of a special absolute frame of reference. That would have been the case for absolutely motionless (Lorentzian) ether: the frame of reference of the ether is the special one and any motion with respect to it is the absolute motion. But for ether involved in complicated multi-scale motion – which the real physical ether undoubtedly is – any particular macroscopic mechanical motion would be relative to that of the "local" mass of ether of the scale comparable to that of the object itself. So no frame of reference could be considered universally special, and the relative aspect of any particular mechanical motion would remain intact.

To wrap up our brief excursion into the logic of space and time, let us emphasize one more time that space and time as such are abstractions and, therefore in anything real and finite, they always appear in an indivisible unity. This unity can be identified as the main source of the objective illusion of space and time themselves (in their determinate form) being real and capable of mutual transmutation. The latter observation becomes especially relevant when fast motions (on the scale of everyday experience) come into consideration. In such cases, the ideal separation of the two abstract moments of any existent that give rise to space and time, respectively, becomes subjectively (i.e. from the point of view of a thinking subject) more difficult. For a simple example, consider an apple that first grows on a tree, becomes ripe and then drops to the ground and gradually rots finally dissolving into the soil by the next year. In this case, it is straightforward to identify (and imagine such identification) this slowly changing apple as the same apple and also to take its size measurements and record that slowly changing size as a function of time. Space and time aspects of the same apple appear perfectly separate in this process of the apple evolution. On the other hand, consider a small explosive charge that is actually allowed to explode. In this case, it quickly disappears as a single compact object in a small fraction of a second (and thus looses both of its abstract moment by virtue of ceasing to exist as such). Still, we can understand that, in that fraction of a second, it still existed as an object of an increasing size (so that it had a certain space dimension at every time moment), until it could no longer be considered a single object any more. But, compared to the case of the apple, this process is a lot more difficult to imagine. Here it might appear that the object's self-inequality moment suddenly prevailed over the self-equality one, i.e. its space turned into time. So when something as fast moving as light came into physicists's attention, and the associated theoretical difficulties showed up as well, it was objectively relatively easy to let one's imagination suggest such space to time and back transmutations. The existence of space and time mixing formal transformations of the only known equations and the lack of knowledge of the logical status of space and time (that were known only "intuitively" to most scientists) made such an act of creative imagination even more likely.

B.3 Relativity revisited

Finally, let us – for the sake of amusement if nothing else – indicate how both relativity theories could be brought into conformance with the logic of space and time by means of a minimal revision. With a view towards describing a seemingly universal mode of matter interaction – the gravitation – by means of the corresponding change of geometry, first we want to bring space and time under a common descriptional scheme. The reason is that we expect some change of the metric (scale) of time to be necessary for modeling an accelerated (by means of gravity or some other universal cause) motion of a physical object (particle) as a free motion. Enter the 4-dimensional space-time as in special relativity. But now we have to take the logical status of space and time as universal abstractions properly into account. As we have seen, time is – simply put – the universal abstraction of motion (self-inequality of all existents) and space is the universal abstraction of their still (self-equality). To make space and time commensurable coordinates of the same coordinate system, one needs to introduce a universal coefficient with a dimension of spatial velocity. Since space and time as such are abstractions, the coefficient needs to be abstract (i.e. absolute) as well. The special relativity's proposition is to use the speed of light in vacuum (i.e. the speed of propagation of a *particular form of matter*) in the role of such absolute[127] coefficient. So an absolutisation of a particular form of matter[128] took place at the very outset of the theory. In order to avoid such logical mistake, the universal velocity-like coefficient has to be chosen to be truly absolute and thus not tied to any particular form of matter and the universal motion. The only suitable choice is to make it infinite, or – for the purpose of specific calculations – much larger than any other speed involved (similar to the "big-M" in the corresponding method in optimization). Indeed, the meaning of such absolute speed would be that of the speed of abstract (pure) motion (remembering what time really is)

[127] The irony here is that special relativity – as the name indicates – set out to eliminate absolute space and time from physics. But the absolute promptly came back in disguise of an absolute speed. The speed of light is rarely referred to in this way in relativity books and articles since it would probably sound a bit awkward. However science fiction authors were quick to notice and exploit the newfound status of light and its speed. Multiple references to flying at the speed of "0.99 of the absolute" and similar to that can be found in many books about future interstellar travelers.

[128] This absolutisation – a deification of sorts, in fact – is easy to notice for any reader of A. Einstein's works on relativity. Light and "light-rays" play a decidedly sacred role there, acting as ultimate arbiters for any space and time related measurements.

expressed in the same units as a speed of a spatial motion of particular forms of matter. Such absolute (abstract) speed clearly has to exceed any particular real one,[129] and not just the currently known ones, but any that can possibly be discovered in the future. Let us denote such absolute speed by U. The fourth (or zeroth) coordinate corresponding to time and commensurate with space coordinates will then be $x_0 = Ut$. It makes sense to keep pseudoeuclidean Minkowski metric of space-time with the metric coefficient corresponding to x_0 (before gravitation is considered) equal to -1. The reason is that the different sign of the coordinate corresponding to time emphasizes its opposite nature with respect to space.

The speed of light – just like any other real characteristic of matter and the universal motion – has to lose its sacred status and get "demoted" back from the absolute (abstract) to the real. In particular, there is no reason to postulate its absolute maximum[130] character. Now, as anyone can recall, in special relativity, the sole reason for coordinate transformations between inertial systems to involve the value of the speed of light is precisely that absolute maximum character. In the absence of that postulate, Lorentz transformations go over into Galilean ones, with time recovering its invariant status. Put slightly differently, if the parameter c (the real propagation speed of some particular matter form) in Lorentz transformations is replaced by an appropriate abstract speed-like parameter U, all specifically relativistic effects disappear when the limit $U \to \infty$ is taken. This means, in particular, that the especially puzzling and inexplicable paradoxes such as the "twins paradox" disappear as well. It is useful to note in this regard that some of the conclusions of special relativity

[129] Proclaiming the speed of light absolute, and thus absolutely not exceedable in principle, at the time when physicists just began scratching the surface of the micro-world, was arguably an act that required a very young person's reckless abandon and almost complete lack of any philosophical burden. Indeed, as everyone knows, A. Einstein was barely over 25 when he made the historic proposal – in the form of a postulate, no less.

[130] D.C. Miller, a former president of the American Physical Society and chairman of the division of Physical Sciences of the National Research Council, devoted a significant part of his scientific career to the refinement of Michelson interferometer, and conducted the most extensive series of experiments on the dependence of the speed of light on the direction of propagation. The summary and conclusion of more than two decades of these efforts are presented in his article [43]. He was able to conclusively rule out the hypothesis of the constancy of the speed of light. Speaking of the original and widely publicized – although much less precise and orders of magnitude less extensive – Michelson-Morley experiment, D.C. Miller writes in [43]:

> However, and this fact must be emphasized, *the indicated effect was not zero*; the sensitivity of the apparatus was such that the conclusion, published in 1887, stated that the observed relative motion of the earth and ether did not exceed one fourth of the earth's orbital velocity. This is quite different from a null effect now so frequently imputed to this experiment by writers on Relativity.

– including the ones that are used routinely in practice – are still valid. One of prominent examples of this sort is experimental high energy physics with its use of particle accelerators. It is true that no particle accelerated by an electromagnetic field can exceed the speed of light, just like, for example, a pneumatic gun bullet cannot exceed the speed of sound in the air. It is also very possible that the kinetic energy of such particles rises faster than square of their velocity since some electromagnetic matter (most likely the ether in the corresponding form of excitation) is going to "attach" to the particle (which itself is most likely is just some specific localized stable form of the ether excitation) making its effective mass larger. J.J. Thomson, in particular, explored some preliminary models of this sort.

The more interesting question though is how such an adjustment of the absolute speed-like coefficient allowing to combine space and time variables in the same coordinate system affects the program of "geometrization" of physics set in motion by general relativity. Recall that the main idea of the latter is based on the *equivalence principle* according to which gravitation, due to its universal character, can be described entirely by the metric of space-time, i.e. by its geometry. To clarify this issue, let us consider a simple thought experiment (one of favorite A. Einstein's hobbies). Imagine a giant capacitor with a uniform electric field inside. Suppose also that all objects residing in the capacitor have the same charge to mass ratio. In that case, they all will be moving with the same acceleration a. Let us consider two reference frames: K which is at rest with respect to the capacitor and K' moving with the constant acceleration a in the direction of the electric field (which we can assume to coincide with the common x coordinate). Then K' can be considered to be described by a Euclidean (Minkowskian) metric, and the metric associated with K can be calculated from that using the standard rules of (pseudo)-Riemannian geometry. The coordinate transformation from K' to K will be $x = x' + \frac{at^2}{2}$, $y = y'$, $z = z'$, $t = t'$. Here we have already taken the $U \to \infty$ limit in these coordinate transformations. To find the metric components in system K, let us reinstate the abstract speed U and take this limit later, so we can see the effects of such geometric description of the physics inside our capacitor more clearly. The resulting metric components in system K then become $g_{xx} = g_{yy} = g_{zz} = 1$ and $g_{00} = -1 - \frac{2ax}{U^2}$, where $x^0 = Ut$ is the coordinate corresponding to time.

The covariant equation of motion of a particle in general relativity reads:

$$\frac{d^2x^\mu}{d\tau^2} = \Gamma^\mu_{\nu\rho}\frac{dx^\nu}{d\tau}\frac{dx^\rho}{d\tau}, \tag{24}$$

where the Greek indices run from 0 to 3, $\Gamma^\mu_{\nu\rho}$ are the Christoffel symbols describing the metric connection

$$\Gamma^\mu_{\nu\rho} = \frac{1}{2}g^{\mu\sigma}\left(\frac{\partial g_{\sigma\nu}}{\partial x^\rho} + \frac{\partial g_{\sigma\rho}}{\partial x^\nu} - \frac{\partial g_{\nu\rho}}{\partial x^\sigma}\right),$$

and τ is some affine parameter, typically chosen to be the proper time. Now, it is straightforward to verify that the only non-vanishing values of the connection coefficients $\Gamma^{\mu}_{\nu\rho}$ are

$$\Gamma^{1}_{00} = -\frac{1}{2}\frac{\partial g_{00}}{\partial x} = \frac{a}{U^2}.$$

The covariant equation of motion (24) then simplifies to

$$\frac{d^2x}{d\tau^2} = U^2\left(\frac{dt}{d\tau}\right)^2\frac{a}{U^2},$$

or, in terms of the system K time t,

$$\frac{d^2x}{dt^2} = U^2\frac{a}{U^2} = a. \tag{25}$$

We have thus recovered the constant acceleration[131] via a description by means of a space-time metric. Recall that, in the present description, there is no constant field in space, and free particles accelerate just because one of the metric components (that for the time coordinate) depends on the space coordinate x: $g_{00} = -1 - \frac{2ax}{U^2}$. Let us now recall that the parameter U has to be set infinite, so the time component g_{00} of the metric is still not different from (negative) unity. At the same time, as is seen from the expression (25), the equation of motion "compensates" for that infinite factor U (by means of the coordinate x^0 moving with the constant infinite speed U) making the final result independent of it.

The particle acceleration in the resulting description is attributed not to the action of the electrostatic field (the inner "mechanism" of which we could study upon gathering sufficient courage and not expecting "final" and "elegant" results in short order) but to the rather miraculous behaviour of time that chooses to go slower closer to the negative plate of the capacitor. Thankfully, since we are using space and time correctly – as universal abstractions – and, as a consequence, the parameter U has to be taken as infinite, that time slowing down effect is purely formal and disappears completely upon taking the limit $U \to \infty$. Practically, this means that if we take sufficient care[132] of measuring time once it is treated as measure, we will see that its rate does not depend on the position inside the capacitor. Of course, under the conditions of our rather silly thought experiment, there is little doubt about time uniformity inside the capacitor.

[131] It has to be stated here that, since the example concerns particles accelerated by an *electric field*, we have to assume that the speed of particles involved are much smaller than the speed of light c, with respect to the capacitor. As was already mentioned, for speeds comparable to c, acceleration will no longer be constant, due to an increase of the "effective" mass and a possible change of the "effective" charge (the true nature of which is still unknown).

[132] This means that we do not try to emulate the imaginary naive astronauts who claim that time stops completely during their weightless flight, based on the modified special relativity time definition: "time is the indication of a pendulum clock."

We can easily modify this thought experiment for the case of gravitational field inside a relatively small volume (compared to the size of the source of the field) in which it appears almost uniform. The conclusions will be exactly the same: in the geometrical description, there is no force field but the time metric component gets modified to reflect time slowing down closer to the source of the gravitational field, with a replaced by the gravitational acceleration g, and x denoting the coordinate pointing in the direction of the field source. And again, the infinite value of U appropriate for the parameter characterizing time as such in spatial units would ensure that the time slowing down effect is purely formal – just a different way to mathematically describe the field of constant acceleration of any nature. More complicated cases – like a spherically symmetrical gravitational field of a star or a planet – require a bit more work. Fortunately though that work (and then some) has been already done by several generations of researchers in general relativity, most of them brilliant mathematicians. Indeed, it is straightforward to observe that, in order to bring any general relativity result in compliance with the proper logic of space and time, it is sufficient to replace the speed of light c (the "incarnate" absolute) with U (the proper abstract absolute), which is clearly simply equivalent to taking the limit $c \to \infty$ in any general relativity expression. This implies that any effect inversely proportional to c is purely formal. Put slightly differently, any such effect is not a consequence of the equivalence principle, but rather of light and electromagnetism absolutisation of special relativity, i.e. of the identification of some properties of a particular form of the universal motion with those of space and time themselves.[133] In fact, in case of gravitation, there is not a single piece of experimental evidence directly relating it to the speed of propagation of *electromagnetic* waves and interactions. This makes it plausible that any occurrence of the speed of light c in any expression describing gravitation can be an artefact of something else: in this case it is simply the universalization (deification) of light and electromagnetism.

Let us consider a few well-known examples from general relativity. Newton's law of gravitation is obtained from the modification of the time component g_{00} of the metric (much like in our original example) that has the form $g_{00} = -1 - \frac{2\phi}{c^2}$, where $\phi = -\frac{GM}{r}$ is Newton's gravitational potential. Taking the limit $c \to \infty$ (or replacing c with the proper abstract speed U), one can see that the apparent slowing down of time in gravitational field is not a real effect, but rather a descriptional artefact. On the other hand, considering the equation of motion of a test particle in the gravitational field described by the metric just cited, one obtains that the parameter c cancels from the final expression that takes the Newtonian form

[133] This is a logical mistake which can be confirmed experimentally as well which was done conclusively by D.C. Miller [43] almost a century ago, as we have already mentioned.

again:

$$\frac{d^2\mathbf{x}}{dt^2} = -\nabla\phi.$$

Thus the geometric description of gravitation faithfully (i.e. independently from electromagnetism absolutisation) reproduces Newton's law. What about other (post-Newtonian) effects? The famous perihelion shift often cited as one of the main confirmations of general relativity, which was able to predict the difference between Newtonian prediction (due to influence of other planets) and the observed quantity for the case of Mercury, is inversely proportional to c^2 and thus is a (vanishing) artefact of the electromagnetism absolutisation. Same is true about the spherically symmetrical Schwarzschild metric that depends on the gravitational radius of the gravitating body $r_g = \frac{2GM}{c^2}$ that vanishes in the limit $c \to \infty$. The vanishing of the gravitational radius in turn removes the deviation of the Schwarzschild metric from (pseudo)-Euclidean. We arrive at the flat space-time (i.e. flat space and uniform universal time).

Let us now briefly summarize what we have found about the logical status of the program of geometrization of physics that got started by the general relativity and received further development in various mathematical constructs involving hidden (compactified) dimensions, from Kaluza-Klein type of theories to the modern String Theory. We have seen that the general relativity, as the first of all theories of this type, is built on two main assumptions (postulates) of objective physical content – speed of light constancy (absolute maximality) and gravitation-inertia universal equivalence – and one methodological requirement of full covariance of its equations in all possible coordinate systems. It was shown in general relativity to be possible to provide a description of the phenomenon of gravitation in a purely geometrical fashion via a metric tensor of space-time. Such a description was explicitly constructed to reproduce the existing (Newtonian) laws of gravitation and test particle dynamics in the limit of low (compared to the speed of light) particle speeds and relatively weak gravitational fields. Besides reproducing the classical results, a number of predictions was made that were not accounted for by the classical theory. The speed of light constancy assumption contains a basic logical mistake[134] described in this section of this appendix, and is factually false, as was shown conclusively by the almost three decades long research of the former APS president D.C. Miller described in his article [43].[135]

[134]Given the main focus of this appendix – the *logic* of science – we would like to emphasize that the logical mistake that assumption makes is not of the formal (or mathematical) logic variety that a follower of B. Russell's logical atomism, for example, could detect. It belongs to the realm of what Hegel referred to as objective logic and that B. Russell's philosophy completely omits.

[135]We urge anyone with a genuine interest in fundamental physics to take time (dedicate a whole evening or even weekend to the reading) and read this article carefully. A significant degree of both enlightenment and enjoyment is guaranteed. The amount of preparation, effort, and sheer patience that went into the

On the other hand, the gravitation-inertia equivalence has been found to hold for all known forms of matter acting on the scale gravitation happens to be relevant. So the use of the equivalence principle as a foundation of a valid phenomenological description of gravitation appears to be justified. As we have seen, however, a removal of the speed of light constancy postulate from the theory foundation leaves the classical results intact but makes most, if not all, new (post-classical) predictions – including the perihelion precession of an orbital motion and time slowdown in a gravitational field – disappear. What is even more remarkable, the very core construct of general relativity – curved space-time whose non-Euclidean metric is essentially identified with gravitation by the theory – goes over to just the Euclidean space metric and uniform time. The classical gravitation is still present though by virtue of the space-dependent time metric, the deviation of which from the uniform is infinitesimally small. The formal reason accelerated motion due to gravity is still reproduced by the description is that the covariant equation of particle motion contains an infinitely large factor in the time component that combines with the infinitesimal difference of the time metric from the uniform in just the way to produce the correct acceleration. What this means is simply that the principle of equivalence alone without the speed of light absolute maximality postulate does not lead naturally to curved space-time.

The geometric-like description of the classical gravitation is just a manifestation of the fairly elementary mathematical fact that *any phenomenological law stating the presence of a potential force field can be cast in the form of the time metric dependence on the spatial coordinates containing the potential of the force in question.* This form of the force field mathematical representation introduces a local time which slows downs compared to the invariant asymptotic (i.e. far from all sources of the field) time in the direction of the force produced by the field. If the field imparts different accelerations to different particles, the description still works, but the local time becomes particle specific. If the acceleration is universal – like in the case of gravitation – the local time becomes universal as well. In the latter case, the temptation to pronounce this universal local time real may indeed arise. On the other hand, if time and space are treated in a logically correct way – as universal abstractions from matter – the resulting time slowdown is negligible (vanishing in the correct limit and thus purely formal) in either case. The reason is that the "speed" of time taken in its proper definition – if forced to be compared to any speed of spatial motion of real objects – is infinitely greater[136] (since it is an *abstract* formal speed). Therefore the local

experiments is truly astounding. But so are results that go much beyond a simple confirmation that the speed of light is not the same in all reference frames.

[136]It is amusing to note that this feature of time has been long noted and is reflected, for example, in literature where one can find numerous passages describing like everything stands still but time still flies, in various forms of expression.

time slowdown mathematically describing any real spatial motion is going to be negligible on that time specific scale. It is also worth emphasizing that the general change of metric *of space and time as such* is not consistent with their proper nature as *abstractions from all matter*. Being such high level abstractions devoid of any specific finite content, they simply cannot acquire any specific determinations like a non-trivial metric. The Euclidean metric is a direct consequence of the space uniform[137] and unbounded character in all three of its dimensions.

To wrap up our short excursion into the basics of the logic of space and time and its immediate ramifications, let us say a few more words about the special relativity, its logical and experimental foundations, and its rational content. Recall that before the special relativity was actually proposed in 1905, physicists had began an inquiry in the nature of radiative matter, in particular, visible light. The celebrated Fizeau experiment in 1851 on the speed of light in moving water showed an absence of a direct speed addition between light and water thus indicating that the hypothetical luminiferous ether is not completely entrained by moving matter. In his 1910 account [58] of the special relativity, A. Einstein describes the theoretical implications of this result as follows:

> This experiment showed the hypothesis of the complete carrying along of the ether to be unacceptable, so that only two possibilities remained:
>
> 1. The ether is completely immobile, i.e. it does not take part in the motion of the matter at all.
> 2. The ether inside the moving matter is movable, but it moves with a velocity different from that of the matter.
>
> One cannot go very far in developing the second hypothesis without introducing arbitrary assumptions about the relationship between the ether and matter in motion. In contrast, the **first hypothesis is perfectly simple**, and its development with the aid of Maxwell's theory **does not necessitate any** arbitrary **assumption** that **might complicate the foundations** of the theory.

Since the subject of our discussion is the *logic* of science, in the above quotation, we have highlighted the most relevant logical points. According to the young and daring A. Einstein, a choice between possible hypotheses should be made based on the *simplicity* of the anticipated ensuing development, regardless of other considerations – like, for instance, all previous

[137] It cannot be anything else by virtue of being a full abstraction from all material existents, as any difference in any space characteristics could only be caused by those of material objects. But the latter have been fully abstracted from in the process of obtaining the logical notion of space.

experience with real physical entities. If the ether and ordinary (known) matter interact, – and this is obviously the main presumption here – their relation with respect to spatial motion is almost surely not going to be absolute (abstract), but real as well. This means that the ether entrainment by matter is going to be neither perfect nor nonexistent, and could approach these two extremes under some special conditions. Such conditions have to be understood in the course of the corresponding inquiry that most likely – almost surely, in fact – would turn out to be neither easy, nor quick and susceptible of a solution by a single heroic effort of a young prodigy. As to the foundations of the theory, they are bound to get complicated, but far from arbitrary. On the other hand, they are going to be such as to reflect the real essence of the ether dynamics.

Anyone familiar with E. Mach's philosophy can see it to be the clear inspiration behind the quotation just shown. Recall that, according to E. Mach, science is all about looking for *most economical descriptions* of the observed phenomena, and not much above that. Thus any descriptive *principles* can be "freely invented" (as the younger A. Einstein liked to say) as long as a good "fit" can be obtained to the empirically observed data. Of course, science has always strove for more than that, and it was that contradiction and its (unfortunate) resolution which gave rise to the modern scientific metaphysics as we will discuss in more detail in the next section of this appendix.

When J.C. Maxwell came up with his famous equations of the electromagnetic field, he – as we already mentioned earlier – considered them just a phenomenological "first approximation" to the proper theory of electromagnetism which he began developing but could not fully succeed.[138] H.A. Lorentz then used Maxwell's phenomenological theory combined with a simple model of ponderous matter as a collection of charged ions to see what predictions would be obtained for some phenomena involving interaction of light with matter. One of his main motivations was the decision between Fresnel's and Stokes' models of the ether interaction with matter. In the former, the ether was assumed to be stationary, and in the latter, partially entrained by moving material objects (just like the two alternative listed by A. Einstein in the quotation we have just discussed). Assuming Fresnel's model, the validity of Maxwell's equations for the ether dynamics, and the charged ion model for ponderous matter, H.A. Lorentz was able to obtain good agreement with experimental data on the Fizeau experiment, Doppler effect, light aberration, but encountered difficulties with some polarization phenomena and, most prominently, failed to predict the results of the famous Michelson-Morley experiment. A. Einstein describes H. Lorentz's achievements in

[138]Later, as the descriptive (superficial) tendency in physics started gaining ground (as we have already mentioned before and will discuss some more in the next section), these phenomenological equations got "promoted" to the status of an absolute law of nature and made a basis of further – this time mostly mathematical – development.

the following words [58]:

> Assuming that ether is completely immobile, H.A. Lorentz conceived in 1895 a very satisfactory theory of electromagnetic phenomena, a theory which not only permitted a quantitative prediction of Fizeau's experiment, but also provided a simple explanation of almost all the experiments that one can imagine in this sphere.

Lorentz himself, however, at the time of developing his theory, saw it mostly as a test of the Fresnel's model which he was leaning towards. At the same time, he realized that his theory was just a preliminary investigation into the true nature of the ether and electromagnetism, and in no way any kind of a final "simple explanation" [61]:

> It is not my intention to enter into such speculations more closely, or to express assumptions about the nature of the ether. I only wish to keep myself as free as possible from preconceived opinions about that substance, and I won't, for example, attribute to it the properties of ordinary liquids and gases. If it is the case, that a representation of the phenomena would succeed best under the condition of absolute permeability, then **one should admit of such an assumption for the time being, and leave it to the subsequent research, to give us a deeper understanding**.

If the absolute permeability of the ether indeed takes place and if the Sun is at rest with respect to the frame of reference connected with the ether, then the relative speed of the ether of around 30 km/s should be observed on the Earth surface. This was the main hypothesis tested in the Michelson-Morley interferometer experiment. The experiment failed to produce results compatible with such relative speed, but some definite evidence for a lower speed (of around 5 to 7 km/s by the authors' own estimation) was nevertheless obtained [62]:

> **The actual displacement was certainly less** than the twentieth part of this, and probably less than the fortieth part. But since the displacement is proportional to the square of the velocity, **the relative velocity of the earth and the ether is probably less than one sixth the earth's orbital velocity**, and certainly less than one fourth.

We clearly can see the *actual displacement* (of interference bands) described in the Michelson-Morley experiment account. Also, a quick glance at the results reveals the clear *periodic* structure (just smaller in amplitude) that was expected to obtain if the relative speed of the ether of around 30 km/s[139] indeed took place. Thus the experiment appeared to have given *evidence against* the Fresnel-Lorentz hypothesis of an absolutely permeable immovable ether, and – at the same time – *evidence for* the Stokes' hypothesis of partial entrainment of ether by moving material bodies. However, A. Einstein's interpretation of these results was quite different [58]:

> This difference between the routes should have depended on the orientation of the equipment; one should have observed a displacement of the fringes the moment AB', instead of AB,[140] coincided with the direction of the earth's motion. However, **nothing of the kind was observed**, and as a result **the foundation of Lorentz's theory seemed extremely shaky**.

We see that, out of the two highlighted claims, the second one is a (conditionally on the experiment showing similar results during a different season) correct conclusion from the interferometer experiment results, but the first one is not: a clear displacement exhibiting the expected periodicity was in fact observed. One should also note that the cited claim was made in 1910 when A. Einstein supposedly had access to the text of [62] which might have not been the case during his "annus mirabilis" 1905 when he published the original special relativity article [63]. It would also be worth pointing out that these results appear to be fully in line of what someone belonging to the classical tradition in physics would expect. Namely, the ether assumed to be a real – if not yet well understood – form of matter interacting with known matter forms behaves just like any other interacting forms observed before did: it shares *some* of the moving bodies' spatial motion. Clearly – as A. Einstein correctly noted in one of the quotations given earlier in this section – moving forward with this hypothesis would involve very considerable difficulties, especially taking into account some already noted contradictory properties[141] of the ether. That is not what E. Mach (A. Einstein's favorite philosopher during his early years) advised to do. His epistemological holy grail was to be found in "the economy of thought": as simple descriptive scheme fitting the observed empirical data as possible. So the "annus mirabilis" version of A. Einstein was – possibly not fully realizing it – looking for just that. In his decade later account of the

[139] What should be mentioned here, for the sake of completeness, is that it was also possible that the Sun was not stationary with respect to an absolutely permeable ether, and the observed speed of no more than 8 km/s was actually the absolute value of the vector sum of the Sun velocity and that of the Earth on its orbit at the time of the year (July) the experiment took place. Realizing this, Michelson and Morley intended to repeat the experiment during a different season, but, for some reason, never did.

[140] AB' and AB here refer to the two arms of the interferometer.

[141] For example, light polarization suggested transverse character of the corresponding oscillations which so far had been only observed in solid bodies. On the other hand, the apparently unchanged motion of planets over long time periods indicated negligible resistance on the ether part.

historic events of 1905, he writes [64]:

> Anybody who tried to replace the Lorentz's theory with some other one agreeing with experimental facts would be forced to admit **this undertaking to be absolutely hopeless given the current state of our knowledge**.

The highlighted phrase is fully correct factually and also logically where it aligns well with a typical classical tradition view. Indeed, developing the Stokes' hypothesis of a partially entrained ether would involve the study of its essence and dynamics which appears to be a formidable task even now (making such comparisons, however, one should keep in mind that more than a century has been almost wasted as far as studies of the ether go). So "the current state of our knowledge" would have to considerably improve, but this is what science is supposed to be about, after all. The young A. Einstein, as we have already seen, had different views, and decided to go the way of reconciling Lorentz's theory with its special reference frame connected with the absolutely permeable ether with the Galilean relativity of mechanical motion resulting in Newton's laws invariance in any inertial reference frame. In the next paragraph of [64], he writes:

> Under these circumstances, one can ask one more time whether the Lorentz's theory or the speed of light invariance principle is incompatible with the principle of relativity. A precise inquiry shows that both principles are compatible, and that the Lorentz's theory does not contradict the principle of relativity. However, **our ideas about time and space have to undergo a fundamental transformation**. It is also easy to see that we should reject the notion of a luminiferous ether.

Anyone reading this passage would notice right away that, first of all, the Lorentz's theory and the speed of light invariance principle are incompatible with each other. In the Lorentz's theory, the speed of light has the value *c in one frame of reference only* – that connected to the ether. Also, the Lorentz's theory could be made compatible with relativity, or, more precisely, frame of reference independence principle[142] expressing objectivity of the respective laws of nature. To achieve that, Maxwell's equations would have to be made more precise to include the speed of the reference frame with respect to the ether, in addition to the speed

[142] Of course, given the evidence of Michelson-Morley and much more extensive and thorough D.C. Miller's interferometer experiments, such efforts directed at Lorentz's stationary ether theory would not be justified. The essence of real physical ether would have to be studied thus continuing the original Maxwell's (and J.J. Thomson's) program.

of light in the ether.[143]

Such a route would have been unacceptable to the young A. Einstein though, since he was looking – not fully realizing that – for a *simple description*, as opposed to the objective nature law. Apparently, partly due to his inexperience and philosophical (logical) ignorance, partly due to his predilection to mathematics, he confused the two goals (which confusion then greatly proliferated). His proposal was – as the quotation above makes clear – to consider *every* (inertial) reference frame, *regardless of the state of its motion*, to be at rest with respect to the ether. Such apparent logical impossibility then required the sacrifice of the classical science notions of space and time whose ideas were to "undergo a fundamental transformation." The ether clearly had to lose its status of a real physical entity and – originally – disappear completely, any experimental evidence notwithstanding. The only remnant of the banished ether was – like the proverbial smile of a Cheshire cat – that now unchanged and proudly universally constant speed of light. Recall however, that, only five years later, the older and wiser A. Einstein – upon some reflection on the physical meaning of his general relativity – would rescind that ether ban and let it back into the physics building, although in a somewhat demoted position. Physicists – and "serious theorists" at any rate – would be allowed to tolerate the ether in the building, but forbidden to communicate with it: for example, to "assign any state of motion" to the ether. So whatever state of motion the latter chose to have was relegated to its personal business and had to go unassigned by the serious theorists.

Now let us recall what that fundamental transformation was that the notions and space and time had to experience. We read in the original special relativity article [63]:

> Thus with the help of certain imaginary physical experiments we have settled what is to be understood by synchronous stationary clocks located at different places, and **have evidently obtained a definition** of "simultaneous," or "synchronous," and **of "time." The "time" of an event is that which is given simultaneously with the event by a stationary clock located at the place of the event**, this clock being synchronous, and indeed synchronous for all time determinations, with a specified stationary clock.

So time was defined as *an indication of a clock*.[144] We won't repeat the silly examples involving imaginary naive astronauts and pendulum clocks but will note that, logically speaking,

[143] To give a simple analogy, if the laws of hydrodynamics are known, the motion of, say, a kayak in a lake can be adequately described even in a moving reference frame in which the water in the lake would have a steady current.

[144] For the sake of objectivity, one has to note that, in the definition given by the "annus mirabilis" A. Einstein, it is the *"time" of an event* which is defined, i.e. the *determinate* time, in Hegel's terminology.

this definition is a clear step back from the somewhat implicit and intuitive, and not sufficiently articulated (the omission which we tried to make up for in the beginning of this section), but nevertheless spontaneously dialectical notion of Newton and the classical tradition. The clocks whose indication from then on were identified with time as such[145] are supposed to be synchronized by means of light signals – thanks, of course, to the light newfound status of a universal constant and – as a consequence – time incarnation. The latter metaphor is actually only partially metaphorical. In the special relativity, time literally runs with the speed of light. To see this, one could consider, for example, the famous time contraction (slowdown) for fast moving objects that gives rise to the notorious and mystical "twins paradox." The expression for the latter is $\Delta t' = \Delta t\sqrt{1 - \frac{v^2}{c^2}}$ which can be rewritten as

$$\frac{\Delta t'}{\sqrt{c^2 - v^2}} = \frac{\Delta t}{c}, \tag{26}$$

where Δt and $\Delta t'$, respectively, are time intervals measured by the clocks of the stationary observer (the stay-at-home twin) and the moving one (the space traveler twin). The meaning of (26) is clear: while the speed of the idle twin's time (in suitable units) is c, that of the traveler's is $\sqrt{c^2 - v^2}$. This can be most easily interpreted by stating that the total speed of time is always c (this absolute moment of time is personified by light and its rays). One can chase that absolute time though. If one decides to do that (instead of sitting on the couch) by means of flying through space at speed v, his or her personal time will go just fast enough (in the direction always orthogonal to that of the flight) to maintain the overall time speed at the value c. That personal time speed is thus $\sqrt{c^2 - v^2}$ which goes to zero when your spaceship approaches the sacred speed c. At this point, the sceptics might jump in and start whining about relativity and all inertial systems being exactly equivalent, and asking silly questions as to how would you know whether you are chasing time or just sitting idle, as long as your spaceship's speed is constant. Those naive sceptics obviously think that one cannot tell a spaceship from a house and that one could chase something as quick and indefatigable as time without a serious cash outlay that is not easy to forget (here is the *asymmetry* required for the explanation). Indeed, it is very unlikely that those ultrarelativistic spaceships are going to ever become exactly cheap, even on a Black Friday sale.

Moreover, A. Einstein put quotation marks on the word "time" in his article, indicating, quite possibly, the makeshift status of the proposed definition. The later "promotion" of this definition to the fundamental status happened with the help of other physicists and philosophers. Also, A. Einstein had no idea (or, at least, we could find no evidence of his being aware of such difference) of the difference between pure and determinate quantities, so the only definition he could possibly give was of determinate time which indeed, as we have seen, has a relative moment to it.

[145]This is quite a demotion: from the status of a universal abstraction to just a mere physical clock indication – one has to feel sorry for father time.

On a more serious note though, let us briefly discuss the rational side of special relativity. Evidently, in spite of all its logical deficiencies and plain disagreement of its foundations with extensive experimental evidence (like the interferometer experiments results), it was able to make verifiable predictions and overall enjoyed tremendous success – to the point of becoming the main cornerstone of the whole modern physics. In a nutshell, the main reason for this success – if one decides to adhere to purely scientific/technical reasons – is that it absolutised some specific features of the *electromagnetic* fundamental interaction, and, at the present stage of the society development, this is the only type that has been brought into the sphere of active and wide-spread practical use. Indeed, gravitation is only the object of passive resistance to, and the strong interactions are only used in nuclear reactors and have been brought under (very limited) control only by means of extensive experimentation. As to the controlled fusion, it is now approximately in the same place it was half a century ago. So whenever the special relativity and its specific effects are encountered anywhere in the practical sphere, it is always in connection with electromagnetism, for which it makes some rational sense. It was shown, for instance, in the special relativity that Maxwell's equations are covariant under Lorentz transformations, meaning they keep their form in the new coordinate system obtained from the original by means of a Lorentz transformation (boost) with a relative speed v, provided the components of the electric and magnetic fields are also transformed in the way proposed in [63]. This, in particular, provides some potential insight on the behavior of fast moving charged particles moving in an electromagnetic field (like in all modern particle accelerators). In fact, it is this covariance of Maxwell's equations that provided the original incentive and temptation for announcing the variables of Lorentz transformations the "true" space and time coordinates, contrary to the meaning H.A. Lorentz himself was assigning to them. It is also true that no charged particle accelerated by means of an electromagnetic field can exceed the speed of light, just like an air gun bullet cannot exceed the speed of sound in air. Also, the effective mass of such charged particles was observed to grow as their speeds approached the speed of light. The latter observation is not very surprising as well and does not *require* postulating any mystical properties of time and empty space for its rational explanation. Again, for a reasonably well-understood analogy, one can refer to the history of supersonic flight with its much higher power requirements compared to what could have been anticipated based on early experiences.

In fact, J.J. Thomson (see, for example [65]) derived the effective mass increase effect for a charged particle motion that was later found to be in good agreement with experiment as early as 1881. His model was still phenomenological but went one step lower (or higher, depending on how one chooses to count) compared to just using bare Maxwell's equations. Namely, he introduced the notion of *Faraday tubes* understood as "tubes of electric force, or rather of electrostatic induction" that "have their seat in the ether." They are treated as full fledged physical objects capable, in particular, of spatial motion. As J.J. Thomson demonstrates, no introduction of separate magnetic field with its own tubes is needed, since "if we keep to the conception of tubes of electrostatic induction we can explain the phenomena of the magnetic field as due to the motion of such tubes." In particular, it is shown in [65] that, if a spherically shaped *electrically charged particle* moves even through vacuum (with no other electromagnetic fields present) with a constant speed v, then in the limit $v \to c$, all Faraday tubes associated with the particle charge will arrange themselves at the right angle to the direction of travel. The resulting momentum of the moving sphere then becomes $mv + I$ where m is the mass of the sphere itself, and I is momentum of the field attached to the sphere, or, put slightly differently, ether "dragged along" by the sphere's Faraday tubes (which are apparently some forms of the ether excitation that are not yet explored in J.J. Thomson's approach). The effective mass increase the sphere experiences is then equal to I/m which can be seen to become infinite in the limit $v \to c$, thus making the speed of light c (measured relative to the ether at the location of the particle in question, of course) not exceedable by *electrically charged bodies*. On the other hand, one has to admit that, as far as the economy of thought goes, simply *postulating* c (with respect to absolutely anything) as the absolute maximum speed of *anything* clearly runs epistemological circles around any other approach – at the negligible expense of some "fundamental transformations of the notions of space and time" and the ensuing "reduction" of scientific methodology.

B.4 Mathematical neoplatonism as an easy way out of the objective-subjective contradiction

What can be called – following B. Russell's favorite terminology – *scientific metaphysics* (which is the main subject of this appendix) is the methodology of science that gradually replaced the classical tradition during the period of several decades spanning the late 19th to the early 20th century, at least in the realm of fundamental physics. The theories of relativity created during this period and currently considered an integral part of the foundation of the whole physics – if not the scientific world outlook in general – are prime examples of this methodology. The interesting – although not at all unexpected – point in this regard that the central idea of the special relativity, which started the process of deviation of fundamental physics from the classical tradition, hinged on an absolutisation of Maxwell's equations developed fully in the scope of the classical tradition.

J.C. Maxwell himself was a prototypical representative of the classical tradition in physics that, philosophically, can be characterized as a *spontaneous dialectical materialism* (realism). The main distinguishing feature of the classical tradition – and this is what makes it spontaneously dialectical – is its focus on looking for *essence behind the phenomenological appearance* that typically constitutes any directly observed data. In this sense, it is the opposite of Machism that makes an *economical description* the explicit goal of science. The mainstream classical tradition approach consisted – as was correctly noted by its many critics – of searching for a *mechanical* essence of the observed phenomena. The most recent triumph of this approach took place in the form of the development of a molecular-kinetic theory of thermodynamics in the works of J.C. Maxwell, L. Boltzmann and others.

In order to properly understand the nature and origins of both the classical tradition and the (neo)-metaphysics that largely replaced it in the realm of fundamental physics, let us recall what thought and knowledge are, in the fundamental sense. The former should be understood as the *ideal moment* of the totality of the human purposeful nature-transforming activity (practice), and the latter is the sum total of the results of the former, up to a certain point in time. Both are – using modern terminology – dynamic processes that evolve in constant interaction: thought creates new knowledge which then effects new thought. Both exist and evolve in an inseparable unity with the other – material – moment of the human practice taken in its totality. It is known that all sciences have their roots in some aspects of the human practice. For example, astronomy largely grew out of the needs of navigation in the open sea. Since the human practice in general – seen as one of forms of the universal motion – is already an advanced one at that, its ideal moment is well-defined and can evolve in relative separation from the material one. This is even more so with regards to sciences which are "embodiments" of particular aspects of this general ideal moment of the human practice. Still, such separation can never be complete. As a result, all sciences – along with possessing their own logic of development and history – carry all the traits of the "greater" human practice coming in particular historically transient forms. These days, for instance, a prominent such trait present in all sciences is their "industrial" organization which we will have more to say about a bit later.

Let us now turn to theories. Properly speaking, starting from the first half of 19th century, a *theory* should be understood as an *exposition of the subject matter concept*. If the notion of a concept is to be taken at the logical level achieved by the time just mentioned, providing an exposition of the latter implies uncovering the subject matter *essence*, study of it in its own right, followed by the logical movement back to the phenomenological level via the study of the *appearance* (how the essence appears on the surface to account for the observed phenomena) and *actuality* (how the subject matter acts in a wider context). Any study revolving in the sphere of *being*, exploring the subject matter qualitative and quantitative characteristics, including the development of various measures and phenomenological relations between them, belongs to the necessary preliminary stage of investigation that precedes the development of a theory proper. To make the necessary distinction between the pre-theoretical and proper theoretical stages of investigation, we will refer to any constructs belonging to the former one as *phenomenological descriptions*. Note that, in current scientific practice, such constructs are called *phenomenological theories*, in case their such status is recognized, which is not always the case.

One of the earliest examples of a phenomenological description is the Ptolemaic model of the Solar system planets observed motion developed almost two millennia ago which is so accurate that it is still in use as the basis for construction of planetariums. Naturally, phenomenological descriptions precede theories not only in the objective logic of science development but also in the history of sciences. Leaving aside biological and social sciences and looking only at those dealing with the physico-chemical typological unity inside the universal motion, we can notice that proper theories (i.e. those uncovering the essence behind the phenomenological surface) begin making their appearance in the second half of 17th century when the hypothesis of chemical elements constituting substances was first put forward by R. Boyle. Since then, it had taken about two centuries to develop the periodic table of elements and discover many new substances and their compositions. On the astronomy front, the Copernican model was proposed in the first half of 16th century, greatly enhanced later in the same century by G. Bruno, and followed by Kepler's quantitative laws in early 17th century. Finally, towards the end of 17th century, the foundations of a proper (essence revealing) theory of planetary motion were established by Newton. About two centuries later, S. Newcomb produced calculations, based on Newton's laws of dynamics and his gravitation law – albeit with the power value in the latter equal to 2.0000001612 instead of simply 2 – that were made an international standard for all planets ephemerides in the solar system and used throughout most of 20th century.

In their turn, Newton's laws of dynamics and of gravitation were both phenomenological descriptions, albeit very fortunate ones in that they were able to capture the laws of the corresponding phenomena with a very high degree of precision and had a particularly simple form at the same time. Their essence still needs to be studied, and proper theories of them are still to be produced. On the other hand, in these phenomenological laws, the sphere of being of spatial (mechanical) motion found its comprehensive exposition, including quantity and measure. Thus mechanical form of the universal motion could serve as a basis (ground) for a rational comprehension of other forms should it happen to lie at their foundation in some way. Since it was reasonably clear that the mechanical form was the simplest, most elementary one, the idea of an explanation of all physical phenomena by means of their reduction to mechanical motion became the central one of the classical physics tradition. Chronologically, it can be placed – not including its formation period and counting just the time when the classical direction was the predominant one – in the interval from late 17th to early 20th century,[146] or from Newton to Boltzmann. The two main achievements – especially from the logical standpoint – of the classical period is the development of proper theories of planetary motion and thermodynamics. In both cases, mechanical motion was shown to be the essence of the corresponding phenomena, and the laws of the latter were shown to appear on the surface as a consequence of the laws of mechanics acting "behind the scene." In the former case, such reduction[147] was conceptually relatively straightforward since planetary motion *is* of mechanical nature after all. The latter case is still not fully conceptually understood and is generating debates on, for example, the fundamental reason for irreversibility present in thermodynamical phenomena, as opposed to the laws of mechanics on which thermodynamics is based. This predicament is a consequence of the *spontaneous* (not explicitly articulated) character of the classical tradition's dialectics (and of the further reduction of the dialectical moment in 20th century fundamental physics).

Let us turn our attention to this very dialectical moment the classical tradition in physics somewhat unconsciously possessed. In a few words, it amounted to the belief, shared by the representatives of this tradition, that, behind the immediately observed phenomena, there was *something else distinct from them* that was responsible for their *unity* and – if identified and studied properly – would be able to rationally account for all their apparent multitude. That other form of motion was believed to be the mechanical one which – thanks to Newton's discoveries – was already well understood and also happened to be the most elementary form of motion known to science. With planetary and other complex motions, it was relatively straightforward requiring little more than a good deal of mathematical prowess since these motions already were mechanical in nature. It was still very impressive that something as apparently simple as Newton's laws could be used to successfully explain such complex phenomena as, for example, ocean tides. These successes were also largely the reason behind the somewhat exaggerated faith in the power of mathematics that is so widespread in theoretical physics today. The story of thermodynamics turned out to be more complicated, in that some serious struggle had to be endured with the advocates of a purely descriptional logic, before the molecular-kinetic theory finally prevailed. However, questions revolving around irreversibility, the "arrow of time," and the apparent lack of *continuity* of the laws of thermodynamics with those of mechanics on which the former were based, still lingered.

The main reason for the latter uncertainty was, as have pointed out already, the *spontaneous* character of the classical tradition's dialectics. It took the form of the so called

[146] It is interesting to note that Hegel's main work was created right in the middle of this period.

[147] Here, besides just planetary motion on their orbits, other related theories developed on the basis of classical mechanics should be mentioned like, for example, Laplace's dynamic theory of tides.

(and later much maligned) *mechanicism*, which exhibited itself in many physicists' of the period conviction that all physical phenomena could be in principle simply *reduced* to mechanical motion in possibly very complicated but still unquestionably *continuous* fashion. Behind this conviction, there was the old pre-dialectical (metaphysical) belief that Nature does not tolerate discontinuities, and the latter could only appear as a result of a lack of understanding on someone's subjective part. One of the main advances of Hegel's dialectical logic however was precisely the realization that the empirically observed multitude cannot be brought under the "umbrella" of the same unity without a logical "mechanism" – both in an objective and a subjective sense – for the creation of discontinuous "jumps" out of continuous changes and vice versa. One of the central notions of Hegel's logic is that of *sublation* by means of which something can cease to exist as a self-subsistent entity but at the same time continue to function as a moment of a higher unity thus creating a discontinuity while, at the same time, preserving the continuity of its own. The lower unity, in Hegel's preferred metaphoric language, "founders to the ground," forming the basis of the higher unity. The latter acquires its own laws, different from those of the lower unity, which does not preclude it from forming the basis of the higher one. Put slightly differently, the higher unity can and cannot be "reduced" to the lower one at the same time. Or, looking at it from the subjective angle, the "reduction" in question has a posited discontinuity moment and cannot be obtained in a "naive" direct fashion.

Speaking of the overall logic of the scientific method taken as a whole, Hegel gives a brief sketch of it in the last chapter of [1] titled "The absolute idea." Thus he says about the beginning of a science:

> Because it is the beginning, its content is an *immediate*, but one that has the meaning and the form of *abstract universality.*

But the immediate in question is not something specific given in the senses. Rather, it is a simple universal abstraction. Its immediate quality is due to its simplicity and its self-referential status [1], p.738:

> At the beginning of finite cognition universality is likewise recognized as an essential determination, but only as thought – and concept determination in opposition to being. In fact this *first* universality is an *immediate* universality, and for that reason it has equally the significance of being, for *being* is precisely this abstract self-reference.

Every science, in Hegel's view, is characterized by its own universal abstraction that serves as its beginning.

The method that begins with that universal abstraction acts differently from the "finite cognition of the understanding" (pre-dialectical logic of empiricism and metaphysics) which "picks up, still externally, whatever in the abstractive generation of the universal is left out of the concrete," in that it "finds, and recognizes, the determination of the universal within it," without bringing additional determinations, features etc. from the empirical multitude in an ad hoc fashion. In this regard, the method is properly analytic [1], p.741:

> To this extent the method of absolute cognition is *analytic*. That the method finds the further determinations of its initial universal simply and solely in this universal, constitutes the concept's absolute objectivity, of which the method is the certainty. – Equally so, however, is the method *synthetic*, for its subject matter, while immediately determined as the *simple universal*, through the determinateness which it has in its very immediacy and universality, proves to be an *other*.

On the same page, it is stated:

> This no less synthetic than analytic moment of the *judgment* through which the initial universal determines itself from within itself as the *other of itself* is to be called the *dialectical moment*.

Thus the original simple universal abstraction develops a distinction **from within itself**, without any external ad hoc additions (for example, by means of postulates hastily constructed from some arbitrary chosen empirical observations). That distinction found within the original universal abstraction is then developed further into an *opposition*, the second universal which is the negative of the first [1], p.744:

> The *second* universal that has thereby arisen is thus the *negative* of that first and, in view of subsequent developments, the *first negative*. From this negative side, the immediate has *perished* in the other; but the other is essentially not an *empty negative*, the *nothing* which is normally taken to be the result of dialectic, but is rather the *other of the first*, the *negative* of the *immediate*; it is therefore determined as the *mediated* – contains as such the *determination of the first* in it. The first is thus essentially *preserved* and contained also in the other.

The second universal, by virtue of containing within itself the first one of which it is also a negation, taken on the meaning of a *negative as such*, or a "concentrated negation." Because of that, it is also can be seen as a *contradiction* [1], p.745:

> It is *the other*, therefore, not of a one to which it is indifferent; in that case it would not be *an other*, nor a reference or relation. It is rather the *other in itself*, the *other of an other*; hence it includes its own other within itself and is consequently the *contradiction*, the *posited dialectic, of itself.*

Such contradiction is what, upon a "nontrivial" (not into the null) resolution, can lead to a creation of a new, higher level unity, that *sublates* the unity whose universal abstraction has started the process just sketched. This is indeed the key point of the dialectical method [1], p.746:

> In this turning point of the method, the course of cognition returns at the same time back into itself. This negativity is as self-sublating contradiction the *restoration* of the first *immediacy*, of simple universality; for the other of the other, the negative of the negative, is immediately the *positive*, the *identical*, the *universal.*

It is important to note that such contradiction resolution – the famous *third* term in the dialectical "triad"[148] – is a concrete dynamic entity [1], p.747:

> It is *just as much* immediacy *as* mediation – though these forms of judgments, that the third *is* immediacy and mediation, or that it *is the unity* of the two, are not capable of grasping it, for it is **not a dormant third** but, exactly like this unity, **self-mediating movement and activity**.

Even though the result of the contradiction resolution is something "complex" from the point of view of the original unity, it can play the role of a basic universal abstraction of the new – higher – unity, the role of a new beginning [1], p.747:

> Now this result, as the whole that has withdrawn into itself and is identical with itself, has given itself again the form of immediacy. Consequently, it is now itself all that the starting point had determined itself to be. As simple self-reference it is a universal, and in this universal the negativity that constituted its dialectic and mediation has likewise withdrawn into simple determinateness, which can again be a beginning.

[148] Here, Hegel goes to a great length emphasizing the unimportance of counting and assigning numbers. He points out that the third term can be just as well be called the fourth if the distinction and the opposition (as the developed distinction) are counted separately. In the past, such mindless formal application of the dialectical triad gave the dialectical method somewhat of a bad reputation which was part of the reason for philosophy going off its proper route a bit later.

Here, Hegel points out that it might appear that the new beginning would have to be analysed in its determinations that were found in it at the previous stage. Such an approach however would belong to the pre-theoretical stage of investigation ("a mode of cognition that searches for its subject matter") which only "states of it what it *is*, without the necessity of its concrete identity and of its concept."

In Hegel's view, this is the logic according to which nature creates "innovations" and therefore is also the logic that rational cognition should follow. On this route, new typological unities are discovered and rationally comprehended, the specific content becoming richer as cognition follows the routes of nature (and completes them along the way) [1], p.750:

> The determinateness which was the result is, as we have shown, itself a new beginning because of the form of simplicity into which it has withdrawn; since this beginning is distinguished from the one preceding it by this very determinateness, cognition rolls onwards from content to content. First of all, this forward movement determines itself in that it begins from simple determinacies, and the following become ever *richer and more concrete*.

Let us now briefly revisit the case of fundamental physics taken in the context of the overall rational cognition process. The historically first developed and the best understood branch of physics was the classical mechanics, the foundations of which were laid by the famous Newton's laws. As we know, the fundamentally basic character of mechanical motion and the classical mechanics high degree of development prompted physicists of the classical period to treat the mechanical form of the universal motion as a foundation for higher, more complicated forms, such as thermodynamical and electromagnetic. This overall program brought success (some lingering questions notwithstanding) in the former case, but encountered significant difficulties in the latter where the ether, for example, was displaying some contradictory (from the point of view of known models of mechanical motion) properties. Thus the classical (mechanistic) physics found itself at a junction where further progress was found to be very difficult, if not impossible, without some change in the basic logic of investigation. One possibility – not realized at that time – was making use of the advances in logic made by the classical philosophy (and summarized in Hegel's "The Science of Logic") by early 19th century. Indeed, the apparent contradictions between the known characteristics of mechanical motions – including waves in various media – and those of electromagnetic and optical phenomena could have been taken as a hint that a more complicated logic compared to that of a simple reduction could be at work here. Suitable phenomenological models could have been used in the meantime as temporary substitutes for a proper theory.

How could the logic of a dialectical transition from the mechanical form of the universal motion to what could be termed the (proper) physical form (situated between the mechanical and chemical forms on the ladder of large typological unities) look like? Let us try to sketch the answer which should not be conceptually very complicated due to the basic nature of the purely spatial motion that constitutes the mechanical form. Due to this simplicity, we can just follow the steps of the famous triad (in its extended *quartic* version).

1. The first universal (identity). Rather clearly, the basic abstraction of the mechanical form of motion is just spatial motion itself, with no further determinations (such as speed).

2. The distinction (diversity). Since that abstract featureless motion that is the first universal takes place in *space* which is three-dimensional, it inherently contains a distinction within itself. That distinction has to do with the *direction* of spatial motion.

3. The opposition (developed diversity). Once the distinction inside the first universal has been identified, it can be developed further. In our case, the diversity concerns the direction of spatial motion. If we "distill" that moment of change to its pure form, we obtain the *pure direction change* – the *rotational* motion. In the opposition it plays the role of negative of the motion along a given direction. Since it is the concentrated opposite of the fixed direction motion, it contains the latter within itself, constituting its *other*. It therefore negates what is contained within. Looked upon from this angle – and also objectively – it represents a *contradiction*.

4. The resolution. Any contradiction, as we already know, can be resolved into the *null*. In this case, any spatial motion that involves directional change is a constant resolution of this contradiction. Here, however, our focus is the mechanical form of the universal motion taken in its totality. So the resolution we are looking for has to result in something new, capable being a first universal of a higher form of the universal motion, and, given what we know now, it has to be capable of producing spatially compact stable (dynamic) formations. Mechanically, the motion mode we are looking for has to be neither translational nor rotational, but it has to be both at the same time. The only form that that satisfies all these requirements is the *vortex* motion.

It is not very surprising that the special role of the vortex form of mechanical motion had been felt, if not clearly understood, since at least the time of R. Descartes who made attempts to explain the genesis of matter in general and planets in particular via the properties of vortices of ether consisting of spherical particles. J.C. Maxwell used an ideal incompressible liquid in [66] and [52] for an illustrative model of Faraday's lines of force of an electromagnetic field. While the lines of an electrostatic field were modeled by tubes containing a straight flow of the fluid, those of magnetic field were depicted as consisting of molecular vortices of the same (imaginary) fluid. Vortex hypothesis of atoms was proposed by W. Thomson (Kelvin) in 1870's and further developed by others including J.J. Thomson who later switched to the better known plum pudding model of atom, due to difficulties encountered in the course of developing the vortex model. In his own view, the corpuscular theory was less fundamental but – for the time being – much easier to obtain results with [67]:

> The corpuscular theory of matter with its assumptions of electrical charges and the forces between them is not nearly so fundamental as the vortex atom theory of matter, in which all that is postulated is an incompressible, frictionless liquid possessing inertia and capable of transmitting pressure. On this theory the difference between matter and non-matter and between one kind of matter and another is a difference between the kinds of motion in the incompressible liquid at various places, matter being those portions of the liquid in which there is vortex motion. The simplicity of the assumptions of the vortex atom theory are, however, somewhat dearly purchased at the cost of the mathematical difficulties which are met with in its development; and for many purposes a theory whose consequences are easily followed is preferable to one which is more fundamental but also more unwieldy.

Indeed, the theory of vortex motion was not sufficiently developed at that time and is still relatively lacking now, in spite of the significant progress that has been made since then due to the needs of new technical disciplines such as aerospace engineering. Still, these advances in the understanding of vortex motion in gases, coupled with the discoveries of an atom nucleus, elementary particles, and their properties made in 20th century allow for a much better assessment of the role vortex motion can play as a fundamental dialectical (in the sense explained above) "link" between the mechanical and proper physical forms of the universal motion. A survey of the known properties of vortex motion and of some preliminary models of elementary particles, radiative matter, and fundamental interactions that can be built on its basis is given in [68]. It is clear that a lot of work needs to be done in this direction before a proper concept of the physical form of the universal motion is developed, but the preliminary results look promising.

Recall that the development of a theory of the mechanical form of the universal motion begins with Newton's laws which are themselves are of a phenomenological variety and thus still need to be rationally understood. In particular, the issue of Newton's "space objectivation" (or the nature of material bodies' inertial resistance to velocity change), that A. Einstein liked to point out, still needs to be resolved. It is very possible that, in order to resolve it and uncover the true nature of the laws of mechanical motion, the physical form of the universal motion needs to be sufficiently understood first. Even though the situation may appear to be somewhat of a circular nature, this is a perfectly normal process of knowledge advancement according to the dialectical logic [1], p.750:

> It is in this manner that each step of the *advance* in the process of further determination, while getting away from the indeterminate beginning, is also a *getting back closer* to it; consequently, that what may at first appear to be different, the *retrogressive grounding* of the beginning and the *progressive further determination* of it, run into one another and are the same.

In the case at hand, going forward in understanding of the physical form of the universal motion turns out to coincide with establishing the proper foundation of the mechanical form.

Let us now turn to the genesis and logical content of the true logic of the modern (20th century) physics. Any science and any particular theory within a science – just like any purposeful human activity – necessarily possesses both objective and subjective moments. (The latter one has to be understood in a "good subjective" sense: not as a synonym of "wilful," "whimsical" or "idiosyncratic," like it is often done.) Any human activity, including sciences, is an attribute of active *subjects* in pursuit of some goal. Many such goals – especially "large scale" ones – are objectively determined and thus not purely subjective. But all have a subjective side to them. A simple example of such indivisible unity of the objective and subjective from the realm of fundamental physics is furnished by different formulations of mechanics: Newtonian, Lagrangian, and Hamiltonian. All three are (objectively) equivalent, but each one has its advantages that depend on the type of a mechanical problem that needs to be solved. So the choice between the three is subjective as it depends on the particular activity of the given subject. On the other hand, such choice is dictated by the objective characteristics of the problem in question and therefore has an objective moment to it as well.

The objective and subjective moment of a science are opposite and indivisible. Thus any science is a contradiction if considered from this angle which is fundamental for it as it is for any specific form of human activity. But for science – as a quintessence of sorts of all *rational* human activity – this aspect is especially important. Generally speaking, science moves forward in the course of constant resolution of this contradiction. Scientific knowledge arises from subjectively posed questions which in turn reflect on practical problems that also have a clear subjective side to them. It is true, as one of the originators of the new physics W. Heisenberg[149] liked to point out that any scientific content reflects on nature as it appears

[149]One of W. Heisenberg's better-known quotes from his book "Physics and Philosophy" [70] reads: "What

in active human subjective interaction with it. On the other hand, it is also true – contrary to what W. Heisenberg (who did not study dialectics, as we will see soon) believed – that (proper) scientific content reflects on "nature itself," or, in Hegel's preferred language, on nature "in and for itself." In a nutshell, the reason is that any human activity – including science – is a manifestation of the social form of the universal motion and thus of nature itself. The laws of nature do not find their full expression without the activity of higher forms of the universal motion, including the social (the current quasi-intelligent transitional and the future fully intelligent) one. The unavoidable "subjective" mistakes and fallacies that accompany the process of scientific inquiry also have their own objective aspects (often closely related to the characteristics of the social form itself) and get corrected in the due course (which might take a relatively long time).

In the relatively short history of modern physics (counting such from Galileo, for instance), there were several periods when further progress required an advancement of methodology. Newton's work, for example – including his development of calculus of infinitesimals – was a major advance that set physics on its path of developing a proper theory of mechanical motion and also provided the necessary conditions for future rational understanding of the (proper) physical form of the universal motion. At such critical junctions, however, the always present in science tendency of overemphasizing its subjective aspect grew invariably stronger. Not surprisingly, the difficulties encountered by the molecular-kinetic theory of thermodynamics and by the initial attempts to develop the proper theory (i.e. the theory identifying and studying the essence behind the phenomenological appearance) of electromagnetism and optics brought about another wave of such subjectivism in physics. The main point of such subjectivism lies in the denial of any objectively significant essence (which in the classical tradition, that was only *spontaneously* dialectical, took the form of a *mechanism*) behind the multitude of observed phenomena. Thus its main recommendation is to look for the best possible (most economical, aesthetically pleasing etc.), from the point of view of some subjective criterion, *phenomenological description* which, from the subjectivistic point of view, is the only goal of science. One can readily recall our previous discussion of the (physical and philosophical) direction headed by E. Mach and W. Ostwald which insisted on molecules being just convenient theoretical constructs[150] proving to be useful for obtaining the best phenomenological description. The same direction also saw the abstractly understood (as some universal quantity of nothing in particular that just happens to

we observe is not nature itself, but nature exposed to our method of questioning." In a different work of his, it is stated: "Natural science, does not simply describe and explain nature; it is part of the interplay between nature and ourselves."

[150]Later, however, W. Ostwald accepted the reality of molecules following J. Perrin's experiments on Brownian motion.

be conserved[151]) *energy* as a possible cornerstone of a future unified description of physics phenomena. The following rather colorful passage extolling the virtues of energy at the expense of those of matter was written by W. Ostwald in 1907 [69]:

> While energy becomes clear and more confirmed as a reality, the claims of matter disappear and matter is left without any rights except those of tradition. Matter must not only tolerate energy on an equality as the progressive textbooks of the natural sciences today demand, but it must even yield its place unconditionally and withdraw as a superannuated dowager upon her reservation where, surrounded by a court of adherents of the past, she may await her approaching dissolution.

As was already mentioned in the main body of this article, W. Ostwald's abstract descriptive energetics – seemingly defeated in thermodynamics – did not keep physicists waiting for long, ready to make its more successful appearance in optics, electromagnetism, and the just formed physics of atoms and subatomic particles.

The difficulties encountered by the classical physics in uncovering the essence (understood as a mechanism) of electromagnetic and optical phenomena activated – just like in the case of thermodynamics – the subjective bias in science methodology. A. Einstein describes this phenomenon as follows [58]:

> At first the physicists did not doubt that the electromagnetic phenomena must be reduced to the modes of motion of this medium. But as they gradually became convinced that **none of the mechanical theories of ether provided a particularly impressive picture of electromagnetic phenomena**, they got accustomed to considering the electric and magnetic fields as entities whose mechanical interpretation is superfluous. Thus, they have come to view these fields in the vacuum as special states of the ether that **do not require an analysis in greater depth**.

Notice the clear indication of the refusal of the physicists mentioned in this passage to probe the *depth* (i.e. essence in the philosophical language) of the electromagnetic phenomena due to mechanical (direct reductionist) theories failing to provide an "impressive picture." Thus attempts at developing a proper theory get abandoned due to their *degree of difficulty* (the apparent implication here is that science is supposed to be easy) in favor of a more or less fitting *superficial phenomenological description*.

[151]Recall R.P. Feynman's very similar description of it more that half a century later.

It is interesting to note that not all physicists of the period welcomed the strengthening subjective purely descriptive trend in their science. J.J. Thomson, for example, saw this process in somewhat different light. In the preface to his book [65], he writes:

> The use of a physical theory will help to correct the tendency which I think all who have had occasion to examine in Mathematical Physics will admit is by no means uncommon to look on analytical processes as the modern equivalents of the Philosopher's Machine in the Grand Academy of Lagado, and to regard as the **normal process of investigation** in this subject the **manipulation of a large number of symbols** in the hope that every now and then some valuable result may happen to drop out.

Indeed, once a physical theory (that reveals and studies the essence behind phenomena) gets replaced with a mathematical (quantitative) description of the phenomena, the logical basis for such a description (the unity behind the observed multitude) is lost, and the description in question – in spite of its degree of apparent mathematical sophistication – becomes arbitrary and subjective in the ordinary sense. Specifically, in the potentially infinite multitude of observed phenomena, those chosen for designing the descriptive scheme in question end up being selected on the basis of certain subjective preferences. The descriptive scheme itself is then designed to "fit" the observed results, and, if it happens to be able to fit a sufficient number of them reasonably well, it gets accepted as a theory (even though it is not a theory in the proper sense). Then further experiments (and even practical applications) get designed with the theory in mind, and the results not quite fitting the scheme either get regarded as being due to errors in the experimental design or discarded, like it happened, for example, with D.C. Miller's and others' interferometer experiments.

For the first about two centuries of classical physics, it was always accompanied by the subjective descriptive tendency but the spontaneously dialectical direction (in its mechanistic form) had been able to prevail if not without some losses.[152] By the end of 19th century, the spontaneous mechanistic dialectics had apparently largely exhausted its potential for further progress, and a transition to the full fledged rational dialectics was objectively needed. Unfortunately, dialectical logic, the compendium of which had been given in "The Science

[152]For an example of such a loss, recall the still widespread view that thermal energy (heat) cannot be fully converted to mechanical one (to work), and that some of that heat has to be given away to a cold reservoir in proportion given by the famous Carnot principle. The latter however was developed under the assumption of an existence of *caloric* and is only true for circular processes with the same body of gas. In a simple isotermic expansion of an ideal gas, *all* heat transferred to the gas is converted into mechanical work. One could also note that the *caloric* theory was an earlier example of an objectivised subjective description that was however later overcome by the classical tradition.

of Logic," had not become the logic of scientific inquiry in physics by that time (or by the present time for that matter). Thereby the stage was set for the decisive advancement of the (20th century version of) scientific metaphysics, the logical content of which we now summarize.

In short, this version of scientific metaphysics can be concisely called the *mathematical neoplatonism*, and, logically speaking, it constitutes the result of an incorrect (i.e. regressive, not conducive to progress of the social form of the universal motion) resolution of the contradiction between the subjective and objective moments of the particular science content. The laws of mechanical motion dynamics were discovered by Newton just a couple of decades after J. Watt's invention of the steam engine that started the industrial revolution with its wide application of various relatively simple machines. This was the time of practical mastery of the mechanical form of motion which was also at the center of attention of fundamental physics of the period. The particular simplicity of mechanical motion and the related high degree of precision of (phenomenological by their genesis and content) Newton's laws – as well as the high precision of the Newton's law of gravitation within the solar system – made that contradiction hidden for a while. One of the consequences of that hidden status of the contradiction was the unconditional belief of most classical physicists in the absolute objectivity of physics and its laws some of which were already viewed as exact and "final."

The ultraempiricist purely descriptive interpretation of science of E. Mach also denied the contradiction between the objective and subjective moment of the latter by proclaiming an "economical description" that "works" in the pragmatic sense the end goal of scientific inquiry. One can say that Machist philosophy of science is just a direct opposite of the classical physics objectivism[153] in that it denies the objectivity of any science laws (but not of nature itself) and makes them purely subjective "free inventions of the intellect." The mathematical neoplatonism proper arises as a result of *objectivation* – and hence *absolutisation* – of subjective phenomenological descriptions presented in a mathematical form. When the reductionist mechanistic approach of the classical tradition started encountering increasing difficulties, when this approach began failing to provide "particularly impressive pictures" (using A. Einstein's expression quoted earlier) of various physical phenomena, the descriptional Machist trend activated, in which phenomena eluding mechanical reductionist explanations were treated as some entities that "do not require an analysis in greater depth."

Physics however could not simply abandon the absolute objectivity of its laws of the

[153]Recall that E. Mach himself denied any accusations of idealism. Indeed, his ultraempiricism (here, by the way, we are using B. Russell's characterization) taken strictly without any extension does not declare any primacy of the ideal over the material. It naturally passes over into idealism however if developed just a bit further.

classical tradition by fully adapting Machist subjective views of situational "curve fitting" to the observed "points" of the phenomena record. In other words, the contradiction between the science objective and subjective moments came to the fore and required a resolution. The proper resolution implied adapting the rational fully articulated (as opposed to implicit and spontaneous) dialectical point of view and – in a few words – abandoning the mechanical *reductionist* approach in favor of that of *sublation* of the mechanical form of motion by the physical one. Unfortunately, the subjective philosophical (logical) level of the leading physicists of the period made such mode of resolution practically impossible. Matters were not helped by the highly arcane form in which the dialectical logic was presented in Hegel's main work coupled with the difficulty level (at least for someone with limited exposure to it) of its content. The additional important unfavorable factor was the backward drift of sorts in philosophy that ended up altogether abandoning the dialectical logic (and all what Hegel referred to as the objective logic or the objective content of thought) in favor of just the formal logic in a more mathematical guise. Thus the resolution of the contradiction between the objective and subjective moments of cognition that actually happened to take place in physics was that of a non-dialectical kind. Specifically, as we already mentioned, it took the course of objectivation of phenomenological descriptions by assigning them – out of necessity – an absolute status.

As we mentioned a number of times earlier in this article, A. Einstein was one of the pioneers of the new approach. Fittingly, in his younger years, he was a stanch adherent of E. Mach's philosophy of "thought economy" and "free invention of physics laws." At the same time, as we discussed earlier, he was a very talented physicist with mostly classical tradition training where the (implicit) belief in the objectivity of physics laws was particularly strong. On top of all that, he was young, fearless, and philosophically naive (as an a consequence of being young). Thus A. Einstein happened to be a perfect fit for playing the role of that necessary transitional link between the classical tradition and the advancing mathematical neoplatonism. So when he started thinking about electromagnetism and its relation to mechanical motion with its invariance with respect to Galileo transformations, his thoughts were clearly moving along the lines of an "economical description," or "making things fit." At the same time – and this was a critical transition point – he did *not* think about his constructs as simply subjective descriptions, some sort of "curve fits." For him, they were objectively significant, just like in the classical tradition. Also, what "had to go" to make the fit work (to make the contradiction disappear), did not matter that much, as long as the result could be achieved in the most economical (or "elegant") way. If that had to be the traditional (i.e. spontaneously dialectical) notions of space and time, that was fine as well. This is where youth and philosophical "freshness" were helpful. The young A. Einstein's work was also the place where explicit empirically derived *postulates* made their entry in a fundamental natural science that was not explicit metaphysics. The science movement alongside mathematical (external, formal) logic, which Hegel had warned against repeatedly, commenced. The newly adapted method, of course, received further development which we will briefly discuss a bit later in this section.

Special relativity was also special in that it was the first of "crazy theories" setting the corresponding trend in fundamental physics which was a direct consequence of the adapted mathematical neoplatonism overall methodology. As we already mentioned several times, special relativity is the result of an absolutisation and universalization of some particular material properties of electromagnetism and transformation properties of its phenomenological approximate equations. The corresponding "price" was a whole gamut of clear paradoxes,[154] all stemming from moving the "misfit" between Newton's laws and Maxwell's equation to... space and time which lost their status of *universal abstractions* they already (somewhat implicitly) possessed in the classical physics and became just some "quantities" (i.e. just some logically fuzzy "things" that can be measured and assigned numbers) standing in subordinate relations to "light rays."

From the standpoint of further scientific progress, the most significant disadvantage of such phenomenological description objectivation (often accompanied by its universalisation) approach is clearly the limits it sets on further investigation of the essence of the phenomena whose phenomenological description was objectivised and universalised in the process of arriving at the corresponding postulates of the mathematical neoplatonist theory in question. In case of special relativity, the most immediate "victim" is the electromagnetism itself whose essence – most likely directly related to some particular form of excitation of the ether – has not been investigated in a concerted fashion since Maxwell's times. This has clearly greatly delayed the development of a proper theory (concept) of electromagnetism and caused the corresponding delay in the overall scientific progress. Due to the corresponding

[154]Probably the first of such paradoxes that is encountered by any new student of special relativity is that of an imaginary space traveler who, after some painstaking acceleration, is zooming past his friend at the speed, say, just a leisurely walking pace worth less than the speed of light. The friend then switches on a flashlight pointed in the same direction the moment the traveler races past her. What does the traveler see? The ray from the flashlight imperiously disappearing in the distance at the speed of 300,000 km/s (instead of the naively anticipated 5 km/h), laughing at his efforts at catching it. How can *this* be possible, asks the puzzled student. This is just the way space and time are, answers the teacher. And, indeed, the traveler's efforts are not waisted. What he is *really* doing is chasing... time, i.e. getting younger than his "stationary" friend. How is that possible? Very simply: *time is what a clock shows* (which is a breakthrough in philosophy, by the way, according to some philosophers), and clocks – by fiat – are set with light rays. So time is light (a particular form of matter moving through space), and thus can be chased by moving through space as well. And the other way around: light is time, and therefore chasing it by moving through space is an exercise in futility.

universalisation taking place on a particularly grand scale by virtue of the pioneering status of special relativity in this regard, the full list of “victims” is considerably longer.

General relativity, as we know, was borne out – logically speaking – of adjoining the *equivalence principle* (of inertia and gravitation) to the postulates of special relativity (along with expanding the postulate of relativity to arbitrary reference frames). Thus the absolutised *electromagnetism* has become an integral part[155] of the description of *gravitation* to be developed. As we have reviewed in some details earlier in this appendix, the main result was a *description* of gravitation in terms of a metric of space-time. In the limit of low (compared to the speed of light) speeds and weak gravitational fields, the Newton's law of gravitation is reproduced. The epistemological problem created here is that, while it is understood that Newton's law is a phenomenological approximation derived as a generalization of the solar system astronomical data, general relativity is believed to provide an *exact* law (at least as long as quantum effects can be neglected) by virtue of it being derived from “the first principles.” Such a belief is typically held in a complete denial of a purely descriptive nature of the theory from the epistemological point of view.

In particular, it turns out that, as we already mentioned, the best fit to the observed motion of the solar system planets is provided by the Newton's law with the power value equal to 2.0000001612, as opposed to just 2. For the moon, the corresponding best power turns out to be approximately 2.00000004, i.e. closer to 2. Additionally, as A. Hall showed in [71], the observed difference from the Newton's law based prediction in Mercury perihelion precession disappears if the power equal to 2.00000016 (i.e. same as the one employed in Newcomb's tables) is used instead of Newton's exact 2. All these facts indicate that the more precise gravitation law is different from just an inverse power one and that – since the best effective inverse power *increases* with distance – gravitation field strength drops off *faster* than Newton's phenomenological inverse square. For a typical classical tradition physicist, these observations would supply at least a hint at the existence of some “friction” (i.e. energy transformation from the gravitational to some other form) present in gravitation. This

[155] The irony here is that a *unification* of all known fundamental interactions has become one of the main themes in theoretical physics since the second half of 20th century. A. Einstein himself reportedly spent a couple of decades in (unsuccessful) attempts to unify gravitation and electromagnetism. The unification to be achieved was – of course – understood in the neoplatonic fashion: as a single mathematical descriptional scheme for all interactions. But here we see that electromagnetism lies (although in an implicit, hidden, not “officially” recognized way) at the very *foundation* of the theory of gravitation per se. Doesn't this make any further unification superfluous? On a serious note though, since general relativity is a phenomenological description incorporating both Lorentz transformations valid for Maxwell's equations and the equivalence principle possibly accurate to a high degree for gravitational phenomena, it should be able to provide a particularly good fit for *electromagnetic phenomena in a gravitational field*. Indeed, reportedly it predicts the (minute) differences between atomic clocks indications on the surface of the Earth and on a GPS satellite.

fundamental and very real possibility cannot be accounted for by the gravitation geometrization descriptive approach put forward by general relativity. Even more fundamentally, the *essence* of gravitation (and inertia for that matter) and its associated energy is completely beyond the reach of the general relativity approach for the reason that is epistemological (i.e. philosophical) in nature. Namely, general relativity is a phenomenological description that thinks it is a proper fundamental theory. Moreover, it is still widely believed to be the *final* theory of gravitation within the range of its applicability (i.e. on the macroscopic scale, sufficiently far from the "Big Bang" in time).

The other cornerstone of the new physics, quantum mechanics, goes back to M. Planck's 1900 discovery that the so called ultraviolet catastrophe in the problem of black body radiation could be avoided and a good fit with experimental data could be obtained by assuming the radiation consisting of discrete "quanta" with energy proportional to the frequency. This hypothesis received additional confirmation in the (near) independence of the stopping voltage of light intensity in the photoelectric effect, as elaborated by A. Einstein during his famous "annus mirabilis." A few years later, E. Rutherford's experiments on alpha particle scattering led to the planetary model of an atom in which electrons discovered earlier by J.J. Thomson were orbiting around a much smaller (compared to the size of the atom) positively charged nucleus. This model however led to contradictions with classical electrodynamics according to which the (centripetally) accelerating electrons would have to radiate electromagnetic waves and lose all their energy in a very short time making a stable atom impossible. In another couple of years, N. Bohr formally resolved the contradiction by introducing postulates stating that an electron does not emit radiation on a discrete set of "allowed" stationary orbits characterized by the angular momentum being a multiple of the (reduced) Planck's constant, and that radiation is only emitted upon electron's change of its orbit from one stationary one to another. The resulting frequency of the emitted radiation is then determined by the difference of the electron energy on the two stationary orbits. These postulates gave a very good agreement with experimentally observed frequency of radiation emitted by a hydrogen atom and other hydrogen-like atoms and ions.

Bohr's postulates did not perform nearly as well for larger atoms with multiple electrons. It took about another decade for a more general and successful descriptive scheme for atomic phenomena to emerge. Two versions of it were proposed almost at the same time: matrix mechanics by W. Heisenberg, M. Born and P. Jordan, and wave mechanics by E. Schrödinger. The former was the result of a formal modification of Bohr's postulates rejecting its original picture of electron's orbital motion and centered around the requirement of any frequency in a Fourier expansion of physical quantities being proportional to a difference of two stable energy levels. It was observed that the corresponding physical quantities (such as position and momentum) could then be represented by matrices, and their values could be identified with the corresponding eigenvalues. The latter used the recently proposed de Broglie matter waves and the implied similarities with optics for inspiration. Namely, the analogy between a massive particle action and a wave eikonal was exploited to arrive at the now famous Schrödinger equation. It was shown, in particular, that the equation allowed only a discrete set of solutions with negative energy for a charged particle in a Coulomb field which correctly reproduced the experimental results for a hydrogen atom including the ones (like fine and hyperfine structure of spectral lines) that had been found to be stumbling blocks of the Bohr-Rutherford planetary model.

The matrix mechanics, inspired by W. Heisenberg's original *Umdeutung* based on prior results on optical dispersion, is purely descriptive by design. Its explicit goal is a correct prediction of directly observable quantities such as emission frequencies. Correspondingly, it carefully avoids any discussion of space-time behaviour of electrons inside the atom. The original E. Schrödinger's article [72], however, states: "the charge of an electron is not concentrated in a point, but is spread out through the whole space, proportional to the quantity $\psi\bar{\psi}$." A bit later, it is further specified: "the real continuous partition of the charge is a sort of mean of the continuous multitude of all possible configurations of the corresponding point-charge mode, the mean being taken with the quantity $\psi\bar{\psi}$ as a sort of weight function in the configuration space." Thus the square of the absolute value of the wave function was originally interpreted by the author as a *real* density in the space inside the atom (around its nucleus). In the same year, E. Madelung showed [73] that the one-electron Schrödinger equation could be equivalently rewritten as that of hydrodynamics describing flow of some fluid, with the absolute value of the wave function playing the role of mass density and its phase that of velocity potential. These interpretations however did not receive much attention and were not developed significantly further as the Copenhagen interpretation of quantum mechanics took over shortly after.

The Copenhagen interpretation substantiated by W. Heisenberg's newly derived *uncertainty principle*, followed the already existing (by virtue of having been pioneered by the special relativity) easy purely descriptive route accompanied by a prompt objectivation and universalisation of the resulting economical (simple) subjective description. The proposed universalisation was rather profound in its nature and thus had to receive its philosophical registration – this time in the change of the *concept of reality* [70]:

> But the change in the concept of reality manifesting itself in quantum theory is not simply a continuation of the past; it seems to be a real break in the structure of modern science.

Specifically, as is widely known, the change consisted of a denial of the objective reality of any spatial motion of electrons inside an atom and other subatomic particles. Instead, the wave function itself (or its matrix mechanics equivalent) was pronounced to constitute the ultimate objective reality beyond which it is impossible to penetrate and make any rational statements. The interpretation assigned to the wave function became that of a *probability amplitude*, i.e. a complex-number valued quantity, the absolute value of which is equal to the probability density of finding the corresponding object (such as an electron) at the given point of – in general – an abstract phase space. Let us see how W. Heisenberg – one of the main originators of the Copenhagen interpretation – saw the situation about three decades later.

He begins with the observation that any experiment is accompanied by inaccuracies which is true in classical physics just as well [70]:

> In classical physics one should in a careful investigation also consider the error of the observation. As a result one would get a probability distribution for the initial values of the coordinates and velocities and therefore something very similar to the probability function in quantum mechanics. Only the **necessary uncertainty due to the uncertainty relations** is lacking in classical physics.

We see that, in W. Heisenberg's view, the only specifically quantum mechanical feature is the presence of some necessary unavoidable uncertainties expressed by the uncertainty relations. The latter are not present (or, rather, not noticeable) in the classical case due to the size of objects of study encountered there. The origin of the uncertainty relations is explained next by making use of a thought experiment on observing an electron inside an atom by using a microscope working on (imaginary) y-rays with wavelength shorter than the atom size. Clearly, the momentary position of the electron can be located with an uncertainty of the order of the wavelength of the y rays: $\Delta x \sim \lambda$. But the wavelength is related to the frequency ν via $\lambda = \frac{c}{\nu}$, while the frequency itself – according to Planck's formula – is proportional to energy of a y-ray quantum: $\nu = \frac{E}{h}$, where h is the Planck's constant. Finally, the energy E and momentum p of such (electromagnetic radiation) quantum are related as $E = pc$. Collecting all the pieces, one therefore obtains $\Delta x \sim \frac{h}{p}$, where p is the momentum of a single y-ray quantum that are used to observe the electron. This implies that a momentum of order p will be necessarily transferred to the electron in the process of observation creating the corresponding uncertainty in the momentum: $\Delta p \sim p \sim \frac{h}{\Delta x}$. The result of such an observation as described in [70] as follows:

> The momentum of light quantum of the y-ray is much bigger than the original momentum of the electron if the wave length of the y-ray is much smaller than

> the size of the atom. Therefore, the first light quantum is sufficient to knock the electron out of the atom and **one can never observe more than one point** in the orbit of the electron; therefore, there is **no orbit** in the ordinary sense.

This quotation is worth a brief comment. First, it deduces the *nonexistence* of an orbit from the *impossibility of observing* it, thus allowing a clear drift towards a radical subjective idealism of G. Berkeley's flavor. Second – and the key word here is "never" – it commits (just like special relativity) a clear act of absolutisation of the particular very specific (electromagnetic) form of matter (and the universal motion). What one should have said instead – at least anyone attempting to make a generally correct statement – is "one cannot observe more than one point in the orbit *using electromagnetic radiation for the observation purpose*."

In fact, the orbit of the electron in the atom might very well not exist, but not because it is impossible to observe given the currently available capabilities. It might not exist simply because the planetary model is far from accurate. What Rutherford's experiments showed is the very likely existence of a compact positively charged nucleus with size much smaller than that of the atom itself. The planetary model was just the first guess, based on an analogy with the solar system, for a mechanism that would keep electrons away from the nucleus. It was from the very beginning – simply by virtue of an atom stability – in an obvious contradiction with electrodynamics according to which an accelerating charged particle should constantly emit radiation. What sustained it for a bit longer was the success of Bohr's postulates in matching the frequencies of the observed spectral lines of hydrogen. Another piece of evidence in favor of the planetary model was the possibility of free electron emission by atoms. Free electrons behaved like particles (i.e. very compact objects) in experiments. That they would also do so inside atoms was just the simplest first guess that had no other reason of being correct. On the contrary, it was clear that macroscopic open space and the inside of an atom were two environments as different from each other as they come. So a significant transmutation (no less drastic than that from water to ice) on the part of an electron as it went between these environments would not have been totally unexpected. Also, when an electron moves in an open space, it is going to act like a point particle, no matter what its internal structure is. When the same electron is inside an atom, this internal structure is going to play a major role. There is nothing specifically quantum and capable of the concept of reality change in this simple observation. As we mentioned a bit earlier, Schrödinger equation itself contains a strong hint that an electron inside an atom is likely to be a dynamic structure comprised by collective motion of some material medium. Such a possibility presents no contradiction with electrons behaving like point particles under different circumstances (like, for instance, cathode rays experiments) when an electron is free to move in much larger space. An electron under such circumstances might as well still be a dynamic structure (possibly with somewhat different parameters), but no details of this structure would play a significant role in its motion. W. Heisenberg indirectly acknowledges such a possibility, but sees a potential contradiction which is avoided only thanks to the uncertainty relations [70]:

> Actually we need not **speak of particles** at all. For many experiments it is more convenient to **speak of matter waves**; for instance, of stationary matter waves around the atomic nucleus. Such a description would directly contradict the other description if one does not pay attention to the limitations given by the uncertainty relations. Through the limitations the contradiction is avoided.

One should note the form of expression used in this quotation. The emphasis is on what one should "speak" about, i.e. on a subjective description. A. Einstein's account on the degrees of freedom that have to be "assigned" to the ether immediately comes to mind. The corresponding contradiction between the point particle and wave descriptions is there only because no further step is taken along the way of establishing the *essence* of an electron, i.e. what remains unchanged throughout the electron's transmutations. Instead, the contradiction is allowed to stand and is only masked by the allegedly fundamental and unavoidable limitation of any possible subjective description – the uncertainty relations. This unresolved contradiction was later dubbed the "wave-particle duality" and is practically handled with the help of yet another principle – N. Bohr's *principle of complementarity* [70]:

> Therefore, Bohr advocated the use of both pictures, which he called 'complementary' to each other. The two pictures are of course mutually exclusive, because a certain thing cannot at the same time be a particle (i.e., substance confined to a very small volume) and a wave (i.e., a field spread out over a large space), but the two complement each other. By **playing with both pictures**, by going from the one picture to the other and back again, we finally **get the right impression** of the strange kind of reality behind our atomic experiments.

One can see that the emphasis is on "getting the right impression" by means of "playing with" mutually exclusive *pictures*, with no particular effort spent on moving beyond these pictures to understand the nature of the motion of the objective material reality "hiding" behind the term "electron" (and other terms atomic and nuclear physics operate with).

W. Heisenberg was a very intelligent classically educated person with a good background in the history of Greek philosophy in particular. So he understood all too well that such an interpretation of atomic and subatomic physics that explicitly rejected any possibility of describing the reality of the corresponding phenomena in its own terms (like those of spatial motion, for example) and concentrating exclusively on results of experiments (i.e. ultimately readings of some macroscopic devices) was going to invite accusations in excessive subjectivism. So he writes in [70]:

> Before discussing this problem of subjectivism it is necessary to explain quite clearly why one would **get into hopeless difficulties** if one tried to describe what happens between two consecutive observations.

A discussion of the famous double-slit experiment follows. A monochromatic light radiates a screen with two narrow slits in it resulting in an interference pattern on another screen behind the first one. Since light is known to behave like a collection of single quanta in emission and absorption processes, it should be possible to say, for each individual quantum, which of the two slits it's gone through. Then, for this particular quantum, it should not matter if the other slit is there at all, meaning the resulting picture on the second screen obtained after sufficient time of exposure to the light should look just like a sum of the two pictures obtained from individual slits. This would imply no interference, contrary to the experimental evidence. The conclusion W. Heisenberg reaches is as follows [70]:

> Therefore, the statement that any light quantum must have gone *either* through the first or through the second hole is problematic and leads to contradictions. **This example shows** clearly that the concept of the probability function **does not allow a description** of what happens between two observations. **Any attempt** to find such a description **would lead to contradictions**; this must mean that the term 'happens' is restricted to the observation.

Once again, one can see the same sin committed: the absolutisation of the subjective level of understanding *currently achieved*. Indeed, it was known then that light behaves like a collection of discrete quanta in emission and absorption processes which, by itself, in no way implies that it travels through space in the form of a collection of tiny mutually isolated balls which is pretty much what is tacitly implied in the example just described. The word combination "any attempt" highlighted in the quotation above should have logically read something like "our attempts so far," which would of course have changed the whole outlook. It is certain that light is some form of matter, some objective reality which moves in space in some particular way. Uncovering this way and the *essence* of light is the goal of physics. One would expect to initially get into *difficulties* while doing so. But a scientist should also refrain from considering these difficulties *hopeless*, especially while in the very beginning of the process of overcoming them.

The rejection of the very idea of understanding the essence of electromagnetic radiation and of subatomic particles like the electron led the adherents of the Copenhagen interpretation to the denial of reality of such objects thus resurrecting W. Ostwald's *energetics* in a slightly different more mathematically sophisticated guise [70]:

> In the experiments about atomic events we have to do with things and facts, with phenomena that are just as real as any phenomena in daily life. But the **atoms or the elementary particles themselves are not as real**; they form a world of potentialities or possibilities rather than one of things or facts.

As a matter of fact, the similarity with energetics goes even further and becomes virtually an identity as, for example, the following passage shows [70]:

> Since mass and energy are, according to the theory of relativity, essentially the same concepts, we may say that **all elementary particles consist of energy**. This could be interpreted as defining energy as the primary substance of the world.

The main point of the modern quantum physics as an expression of mathematical neoplatonism is expressed even more explicitly in the Introduction to one of the later editions of W. Heisenberg's "Physics and Philosophy" written by P. Davies:

> One cannot meaningfully talk about what an electron is doing between observations because **it is the observations alone that create the reality of the electron**. Thus a measurement of an electron's position creates an electron-with-a-position; a measurement of its momentum creates an electron-with-a-momentum. But neither entity can be considered already to be in existence prior to the measurement being made.
>
> What, then, is an electron, according to this point of view? It is **not so much a physical thing** as an **abstract encodement of a set of potentialities or possible outcomes of measurements**. It is a shorthand way of referring to a *means of connecting different observations* via the quantum mechanical formalism. But the **reality is in the observations, not in the electron**.

It should be pointed out that, in such extreme form, mathematical neoplatonism comes very close to the purely empirical descriptional Machism and the early (Vienna Circle) version of logical positivism. This is not very surprising since – as was noted long time ago – pure empiricism can be considered a form of subjective idealism as it relegates the universal to the status of a product of a thinking mind making the latter the sole source of all unity in the world.

One can say that mathematical neoplatonism of quantum mechanics takes its inspiration in the theories of relativity with their main recipe of *principle* invention followed by development of their mathematical consequences (i.e. what Hegel referred to as the "geometrical method"). It is in quantum mechanics, with its numerous predictive and explanatory (i.e. matching results of experimental observations) successes,[156] where mathematical neoplatonism became the philosophical method of choice of theoretical physics. W. Heisenberg, one of the creators and main ideologists of quantum mechanics, made no secrets about this fact as one of his widely known quotations attests:

> I think that **modern physics** has definitely **decided in favor of Plato**. In fact the **smallest units of matter are not physical objects** in the ordinary sense; **they are forms, ideas** which can be expressed unambiguously only in mathematical language.

We are going to take the above quotation by one of the founders of the modern theoretical physics as an authorization for us to use the name *mathematical neoplatonism* (in spite of its being significantly different from the original neoplatonism of late antiquity) as an "official" designator for the actual philosophy of the said science. Let us briefly review our logical path so far. At the level of being, we have, according to R.P. Feynman's testimony, a collection of ad hoc recipes for theoretical progress that have to be invented anew every time, by means of what the scientific philosophy expert B. Russell referred to as "direct philosophical vision." By looking at the genesis of this direction, we identified the essence of the method (i.e. its philosophy) as the *objectivation and universalization of subjective phenomenological descriptions* as the means of resolving the contradiction between the objective and subjective moments of rational cognition. Now we can go back to the surface and take a look at the appearance of our subject of study, i.e. the particular theories, but in the light of their known essence.

[156]The obvious question here is what these successes are due to. This question requires a much more extended answer, but, in a nutshell, it appears that the successes of quantum mechanics are largely due to the Shrödinger equation (with the mass density interpretation of the wave function absolute value square) capturing some of the essence of subatomic particles and its implicit use of Maximum Entropy (as shown in [14]) taking care of the relevant (for the given problem) information.

B.5 Logico-philosophical void and "crazy theories" as its fillers

Let us briefly summarize. When the *reduction to a known mechanism* approach favored by the classical tradition started encountering difficulties, special relativity set the proverbial *mathematically neoplatonic* ball rolling by performing a hitherto unprecedented act of a *universal objectivation* of a particular arbitrarily selected feature of a Machist style[157] *economical description.* The sheer boldness of this move with its wholesale revision of the fundamental – even though not explicitly logically articulated – notions of space and time played the role of an "ice breaker" of sorts for the ensuing developments in fundamental physics. W. Heisenberg describes its role in the following terms [70]:

> This was a change in the very foundations of physics; an unexpected and very radical change that **required all the courage of a young**[158] **and revolutionary genius**.

Then general relativity set a couple of additional examples to be emulated for the next century: the use of and reliance on the more and more "advanced" mathematics on one hand and geometrization of physics on the other. Both of these trends have received their fullest development so far in String Theory which we will briefly comment on a bit later. But perhaps most importantly, it helped to further instill in the minds of theoretical physicists the notion of a fundamental theory being a synonym of a *mathematical description*, with nothing else required once a suitable (according to some criterion) description is obtained. Recall that, in general relativity, gravitation is treated as a manifestation of space-time curvature which, in turn, is the result of the presence of mass (and energy). Thus, inducing space-time curvature is seen as an *inherent property* of mass (and energy), which not only does not receive further explanation, but such an explanation is pronounced impossible and the theory itself exact[159] and final (modulo possible quantum corrections that are unlikely to play a role on the macroscopic scale). The theory is still a phenomenological description,

[157]S. Weinberg, one of the key figures in the development of the fundamental physics in the second half of 20th century, is also one of the few physicists of the modern era in the narrower sense (i.e. fully and unquestionably quantum and relativistic) with a background and interest in philosophy. He notes in his popular book [47]: "Einstein's 1905 paper on special relativity **shows the obvious influence of Mach**; it is full of observers measuring distances and times with rulers, clocks, and rays of light." This is exactly right, but the said influence of Mach goes a lot further than S. Weinberg is willing to admit.

[158]As we mentioned several times earlier in this article, this particular adjective – young – is a key word here.

[159]Newton's law of gravitation, for example, is clearly phenomenological and as such is subject to future corrections. Indeed, more precise observations of solar system planets show this to be the case, as we reviewed earlier in this appendix.

but this description – due to its novelty, level of mathematical difficulty, and "elegance" – gets objectivised and proclaimed to have achieved the fundamental status. Mathematical neoplatonism in its inception – like any neoplatonism – thereby showed traits of agnosticism which, as we will see, were going to develop further.

When quantum mechanics came along, a brief history of which we reviewed in the previous section, the nature of objective reality came into question. Namely, the Copenhagen interpretation took a decidedly positivistic stance proclaiming – just like W. Ostwald's energetics a couple of decades before – atoms and elementary particles not fully real physical entities performing certain spatial motion, but rather elements of the "world of potentialities or possibilities" (according to W. Heisenberg) or even – in a more explicitly Machist fashion – "a shorthand way of referring to a means of connecting different observations" (according to P. Davies). The advent of quantum mechanics announced the maturation of the mathematical neoplatonism as the new "implicitly official" philosophy of fundamental physics and created a (necessary in any mature ideology) split in the ranks of its adepts. The two sides in this split, well-known in the history of physics, can be called – using the names of the main protagonists as labels – the line of Einstein and the line of Bohr and Heisenberg. On the surface of things, the split was initiated by A. Einstein himself and triggered by his unwillingness to accept the fundamental indeterminism[160] of the micro-world claimed by the Copenhagen interpretation. There is a popular opinion that, in his decades long debate with N. Bohr and the Copenhagen interpretation, A. Einstein was opposing the neoplatonic view advocated by the latter, while holding a fully materialistic position himself. There is some truth in this opinion: indeed, as we noted earlier, A. Einstein drifted towards the classical tradition in his later years, and especially in his polemics with the Copenhagen point of view. However, the divide between the two lines just mentioned was a divide *within* the mathematical version of neoplatonism, and not *between* the latter and a different direction. The distinction between them is *quantitative* (or rather quasi-quantitative) in nature, residing mainly in the *degree of objectivation* of the corresponding subjective phenomenological descriptions.

Indeed, the advocates of the Bohr-Heisenberg line of thought, given rise to by the development of quantum mechanics, were willing to admit the presence of a subjective element in the new physics theories. The uncertainty relations themselves, as we saw in the previous section, were interpreted as a consequence of the influence of the measuring procedures,

[160]According to physics folklore, A. Einstein used this now famous "God does not play dice with the universe" in a letter to M. Born, to which the latter replied that no one could know what games God likes to play.

relying on electromagnetic radiation.[161] The whole spirit of quantum mechanics, as we saw, is closer to the original Machism and logical positivism, with, for example, its denial of any intelligible sense that could be ascribed to any notion of an electron's trajectory or any other "classical style" description of its spatial motion inside the atom. Statements like "it is the observations alone that create the reality of the electron" are explicitly subjectivist in the spirit of Vienna Circle, except that were made by physicists (P. Davies in this particular case) in the end of 20th century. The line of Einstein, on the other hand, represents the "strictly objectivist" trend in mathematical platonism and therefore appears rather materialistic on the surface. This line has the relativity theories as its origin which, for obvious reasons, "cannot afford" any leeway in the interpretation of their main cornerstone – the miraculous absolute speed.

Once quantum mechanics got established and was shown to lead to accurate predictions of atomic phenomena, the problem of developing a relativistic version of quantum theory came to the fore of theoretical physics in 1930's. A good historical account – with some technical details – of this process that took about two decades until the modern formulation of quantum electrodynamics was obtained around 1950 is given in the first chapter of S. Weinberg's book [74] on quantum field theory. The one prominent problem that process was facing is that of infinities. This problem arises already in classical electromagnetism in which the total electrostatic energy of a single electron turns out to be inversely proportional to its radius and thus goes to infinity if the electron is treated as a point particle with zero radius. Clearly, the reason for this infinity is the very preliminary superficially descriptive notion of an electron in particular and electric charge in general. In the mature (i.e. treating electromagnetic field as an entity that "obeys" Maxwell's equations and does not require further analysis) classical electrodynamics, the latter was viewed as some inherent property of a certain form of matter which is otherwise mysterious. When it was discovered that any electric charge encountered so far was a multiple of an elementary one – that of an electron – the situation with the mystical nature of a charge did not change much. The mystery simply got shifted to the elementary charge. The quantum theory, by virtue of its chosen purely descriptive approach (recall A. Einstein's "entities that do not require further analysis"), could not change this situation. In the current version of quantum field theory (i.e. relativistic quantum theory), electric charge is understood as a generator of a $U(1)$ internal symmetry (i.e. not related to space-time transformations) of the Lagrangian describing electrons (or other charged particles). The electric charge value is then interpreted

[161] This feature, however, got promptly absolutised, in the true spirit of the mathematical neoplatonism, and the uncertainty relations (along with the Planck's constant) were elevated to the universal rank.

as an eigenvalue of this generator.[162] Thus the $U(1)$ symmetry – a mathematical construct – still plays the role of the sole explanation of the nature of electric charge.

The problem of infinities was eventually tackled using the idea of *renormalization*: absorbing the infinities into a redefinition of some constants of the theory, i.e. a mathematical descriptive scheme. Theories with finite numbers of such constants for which this was possible were given the name of *renormalizable* theories. Renormalization, which also sometimes takes the form of *regularization*, is essentially a way to *cancel one infinity by another one* to obtain a finite quantity which then can be set equal to the appropriate experimentally observed one. Even though the renormalization techniques led to many instances of a good fit to experimental data, such pioneers of the relativistic quantum physics as P. Dirac and R.P. Feynman, among others, still felt dissatisfied for many years. The latter, for example wrote in 1985 in his popular book about quantum electrodynamics [75]:

> Having to resort to such hocus-pocus has prevented us from proving that the theory of quantum electrodynamics is mathematically self-consistent. It's surprising that the theory still hasn't been proved self-consistent one way or the other by now; I suspect that renormalization is not mathematically legitimate.

Despite such criticism on the part of founding fathers, the larger (and younger) theoretical community still had believed for some time that renormalizable theories (like QED) were fundamental (and final for that matter). The main stumbling block impervious to the renormalization "hocus-pocus" however was gravity. Due to its field being equated – by general relativity – to second rank metric tensor, it was found to be fundamentally nonrenormalizable. This fact, together with the desire of obtaining a unified (in a mathematically descriptional sense) theory of all interactions and the unwavering belief in the universal validity of relativity and quantum postulates, in the end led the theoretical community to the notion of *effective theories*. S. Weinberg, for example, writes in the preface to Volume I of [74]:

> We have learned in recent years to think of our successful quantum field theories, including quantum electrodynamics, as 'effective field theories,' low energy approximations to a deeper theory that may not even be a field theory, but something different like a string theory.

Thus, in a very convoluted fashion, after several decades of collective valiant struggle with multiple integrals and anticommuting matrices, quantum field theories finally got relegated

[162] Photons as agents of electromagnetic interaction are obtained in the process of making the symmetry of the electrons Lagrangian local, i.e. space-time dependent.

to the more suited to them status of phenomenological descriptions. But what about that deeper theory to which quantum field theories are low energy approximations? What foundation can it be built on? Unfortunately – but at this stage practically unavoidably – the answer of the theoretical physics community turned out to be the same as in the beginning of 20th century: the foundation was to be mathematical. The proscriptions of relativity and Copenhagen interpretation were not to be lifted. It was still forbidden to think about spatial motion inside an atom, the nature of electric charge and, as we remember, to assign any degrees of freedom to the ether even though its existence was acknowledged by the the same person who reportedly had banished it from physics some 15 years prior to that (somewhat reluctant) acknowledgement.[163]

Thus the strategy has not changed. It was exactly what the founders of mathematical platonism direction in physics had in mind for the coming years. For example, in the introduction to his 1931 magnetic monopole article [76], P. Dirac foresaw the future of progress in physics in the following way:

> The most powerful method of advance that can be suggested at present is to **employ all the resources of pure mathematics** in attempts to perfect and generalize the mathematical formalism that forms the **existing basis of theoretical physics**, and *after* each success in this direction, to try to interpret the new mathematical features in terms of physical entities (by a process like Eddington's Principle of Identification).

This prescription is still being followed by theoretical physics to a proverbial "T": the mathematical formalism forming the existing (by 1931) basis – relativity and quantum mechanics – is extended in all possible directions (from Lie algebras to complex algebraic geometry and topology), and the new features are interpreted in terms of real or imaginary physical entities. The representative and founder of the other line inside the mathematical neoplatonism, A. Einstein, fully agrees to this assessment of his younger colleague [77]:

> Our experience hitherto justifies us in believing that **nature is the realization of the simplest conceivable mathematical ideas**. I am convinced that we can discover by means of **purely mathematical constructions** the concepts and the laws connecting them with each other, which furnish the key to

[163] Unfortunately, this acknowledgement was not sufficiently appreciated by the theoretical community. Even the critically inclined members of it like, for instance, the Information Physics group, kept referring to the original banishment as something self-obvious and carved in stone as late as 2012. See, for example, the quite unorthodox discussion of the foundations of quantum mechanics in [14].

> the understanding of natural phenomena. Experience may suggest the appropriate mathematical concepts, but they most certainly cannot be deduced from it. Experience remains, of course, the sole criterion of the physical utility of a mathematical construction. But the **creative principle resides in mathematics**.

For the sake of amusement if nothing else, let us contrast the last highlighted phrase in the quotation above with Hegel's view on the role of mathematics and quantitative relations in rational thought [1], p.32:

> In mathematics, **numbers have no conceptual content**, no meaning outside equality or inequality, that is, outside relations which are entirely external; **neither in themselves nor in connection are they a thought**.

Thus, holding fast to the miraculous absolute speed and unsurmountable Hilbert space formality as ultimate and undisputable truths, theoretical physicists embarked on the search of that more fundamental (and perhaps final) theory. The next candidate appeared in the form of String Theory. One of the main motivations behind this endeavor was the already mentioned unavoidable nonrenormalizability of a quantum field theory of gravity. According to the well-known textbook on String Theory by J. Polchinski [78], there are two possibilities of avoiding the related divergence of the quantum theory of gravity, with the second, more promising one, having to do with the existence of a different (not field) theory that "smears out the interaction in spacetime and softens the divergence." Then the beginning of the next paragraph of [78] reads:

> In fact, there is presently only one way known to spread out the gravitational interaction and cut off the divergence without spoiling the consistency of the theory. This is string theory. In this theory the graviton and all other elementary particles are one-dimensional objects, strings, rather than points as in quantum field theory.

It is interesting to note that the consistency of the theory mentioned in this quotation includes Lorentz invariance. The latter though, according to the author, makes it difficult to smear out interactions since "if we spread the interaction in space we spread it in time as well, with consequent loss of causality or unitarity." Even though a very exotic theory, most likely (according to the current views on fundamental interaction unification) not directly testable experimentally, is envisioned, the Lorentz invariance (implying the mystical absolute speed) is never relinquished. Also, even though all known physical objects without exception are three-dimensional, only one dimension is allowed to elementary particles. Thus the theory to be constructed is still a descriptional scheme (a curve fitting exercise) by design. But even if one is willing to be content with that, do we know that string theory is the only option? Not really. According to the author of [78]:

> Perhaps we merely suffer from a lack of imagination, and there are many other consistent theories of gravity with a short-distance cutoff. However, experience has shown that divergence problems in quantum field theory are not easily resolved, so if we have even one solution we should take it very seriously.

It is highly likely that the divergences in question occur in quantum field theory because it treats physical objects as mathematical points. As we see, allowing them just one spatial dimension apparently removes the problem. Why not give them the remaining two which they (the real particles) have anyway? "The answer is that as we spread out particles in more dimensions we reduce the spacetime divergences, but encounter new divergences coming from the increased number of *internal* degrees of freedom." What is the reason for these new divergences however? Could it be because the internal degrees of freedom are described by a quantum field theory of their own? But let us digress. It turns out that a string theory capable of describing fermions along with bosons has to possess supersymmetry (the hypothetical perfect symmetry between fermions and bosons) which can be only made consistent in *ten* space-time dimensions, i.e. in nine spatial dimensions. Would not this observation rule such a scheme out as a possible description of observed particles and their interactions? Not at all. On the contrary, it is taken as a plus. Prior to the discussion of strings, we read in [78] about extra (most definitely never ever observed) dimensions: "This is certainly a logical possibility, since spacetime geometry is dynamical in general relativity. What makes it attractive is that a single higher-dimensional field can give rise to many four-dimensional fields, differing in their polarization and in their dependence on the small dimensions." The extra dimensions are simply "so highly curved as to be undetectable at current energies."

String theory now, after more than three decades of intensive development, is a formidable mathematical edifice bringing together the branches of mathematics that were previously a lot further apart. In the words of R. Dijkgraaf, a leading expert in the field and a director of the IAS in Princeton, one of the main strongholds of String Theory in the world [79]: "Subjects like algebraic and differential geometry, topology, representation theory, infinite dimensional analysis and many others have been stimulated by new concepts such as mirror symmetry, quantum cohomology, and conformal field theory." To give just one example of a mathematical result that was beyond reach of pre-string theory methods, one could mention the calculation of the number of rational curves of degree d in a complex Calabi-

Yau manifold. P. Candelas and collaborators [80] were able to compute these numbers for the quintic in 4-dimensional complex projective space, for, in principle, arbitrary value of d whereas before the discovery of mirror symmetry within the string theory program, only the numbers up to $d = 3$ were known, with little hope of further progress. Speaking of the significance of String Theory for physics, R. Dijkgraaf writes in [79]: "In fact, one can argue that this stimulating influence in mathematics will be a lasting and rewarding impact of string theory in science, whatever its final role in fundamental physics." We can only add to this assessment that its ultimate role in physics will most likely be *entirely* due to advances in mathematics it has helped (and is going to help) to effect.

Now let us get to the main theme of this appendix: how the valiant struggle of B. Russell and other like-minded philosophers in early 20th century against metaphysics helped to bring about that said metaphysics to sciences and, in particular, fundamental physics. Is there a metaphysics conservation law according to which it simply migrated to physics after being banished from philosophy? Seriously though, to put it simply, the "amputation" of the main part of philosophical logic – the objective content of thought, in Hegel's words – left sciences without rational methodology just when it was needed the most. Physics got especially affected due to the relative simplicity of its subject matter and the accompanying this simplicity tradition – with an impressive history of success thereof – of reliance on mathematics. So when new problems occurred, the temptation to solve them quickly by purely formal means was expectedly especially strong. Objectively though, physics was entering the more mature stage of its development where the proper physical form of the universal motion became its center of attention. For the preceding two centuries, the focus had been on the mechanical form. When attempts at a direct reduction of the observed phenomena to the known instances of the mechanical form (constituting the so called *mechanistic* approach) failed, physicists had no methodology left to rely upon.

At this point in time, it was objectively the mission of philosophy – and especially logical part of it – to supply the "primary" natural science with a rational methodology that could logically "connect" the physical form to its progenitor – the mechanical one. Put slightly differently, what was needed is the subjective logical reproduction of the objective process of sublation of the mechanical form by the physical one during which the mechanical form "founders to the ground" forming the basis of the physical form with its characteristic (different from mechanical) laws at the same time without annulling its own. To the best of our present knowledge, the physical form, as the "second lowest," is especially closely related to its predecessor, and its laws cannot be rationally understood without following through with the corresponding sublation process. This closeness is reflected in the fact that (classical) mechanics was – and to a significant extent still is – considered a branch of physics. Unfortunately, philosophy of the time – as far as logic is concerned – decided to go backwards in time as the previous appendix discusses in some details. The result of this process of "clearing up metaphysical lumber" was that only the gussied up formal logic was left for physicists to avail themselves of. (Recall B. Russell's admission of the absence of any method to speak of, besides examples, and L. Wittgenstein's description of philosophy as an activity consisting of... showing that classical philosophy is senseless.) Of course, physicists knew the formal logic better than most philosophers and therefore had nothing to learn from them. S. Weinberg expresses this typical for physicists of 20th century (especially its later part) sentiment in the following words [47]:

> I know of no one who has participated actively in the advance of physics in the postwar period whose research has been significantly helped by the work of philosophers. I raised in the previous chapter the problem of what Wigner calls the "unreasonable effectiveness" of mathematics; here I want to take up another equally puzzling phenomenon, the **unreasonable ineffectiveness of philosophy**.

In fact, what most philosophers writing on physics related topics were doing in the period mentioned by S. Weinberg was simply repeating and "generalizing" what physicists had already said. One can easily find multiple books and articles extolling the unfathomable (and not yet fully appreciated) depths of *philosophical* discoveries of the universal geniuses such as Einstein, Bohr and – to a bit lesser degree – some other prominent figurants of 20th century fundamental physics. Naturally, physicists themselves showed little interest in learning about their own product from nonspecialists.

Thus having nothing to learn about the logic of future rational inquiry from philosophers, physicists were left to their own devices. That meant that they had to come up with that logic themselves. In the beginning of 20th century, the level of philosophical awareness was higher among scientists than it is today, but it still was not sufficient for an adequate resolution of the logical challenge fundamental physics was facing. So, to put it simply, the physicists who happened to take up that challenge (not necessarily being fully aware what they were doing at the time) chose the *path of least resistance*. Due to the relative simplicity of physics subject matter, precise quantitative measurements of phenomena were possible, and mathematics was a rather well developed sophisticated tool that many physicists had good mastery of – and knew that more was available. So the way of "utilization" of yet untapped mathematics was implicitly suggesting itself (recall Eddington's *principle of identification* explicitly proposed by P. Dirac as a future program a couple of decades later). Therefore it should not come as a great surprise that the first decisive step was taken by a physicist whose favorite (and only) philosophy was E. Mach's purely descriptive "economy of thought."[164] And that philosophy was treacherous. Taken to its logical end, it goes over to subjective idealism since pronouncing an economical description the alpha and omega of science essentially *denies the objective side* of nature laws and equates them entirely with economical subjective descriptions. Such a philosophical stance would have undermined the very idea of science as it was known by then and thus was felt to be unacceptable in its unadulterated form. So what was the *easiest* way out of such a potential predicament? Clearly, *objectivising some features* of the corresponding subjective phenomenological description. But which features should one objectivise (and call them *principles* or *postulates*, depending on the mood)? This is largely up to the scientist in question as the pioneer of this approach in fundamental physics attests almost three decades after the original breakthrough [77]:

> The structure of the system is the work of reason; the empirical contents and their mutual relations must find their representation in the conclusions of the theory. In the possibility of such a representation lie the sole value and justification of the whole system, and especially of the **concepts and fundamental principles** which underlie it. Apart from that, these latter are **free inventions of the human intellect**, which cannot be justified either by the nature of that intellect or in any other fashion a priori.

Thus the approach physicists were able to come up with can be likened to an especially complicated version of regression curve fitting. The goal of a theoretical physicist is seen as finding the shape of a curve which would correctly predict observations. The difference is that the usual random error term that always accompanies regression curve fitting in various practical applications was assumed (before the advent of quantum mechanics) to be absent (or due entirely to experimental errors). Also the shape of the curve found was assigned the status of a fundamental law of nature as opposed to that of the usual purely data driven "best fit." When quantum mechanics came along, the random error was reinstated but was assigned a fundamental status of its own. The latter innovation caused the opposition of the original inventor of physics mathematical neoplatonism, A. Einstein, which led to his polemics with N. Bohr causing his further gradual drift towards the classical tradition.[165] As more phenomena needed to be fit, more parameters of the model were introduced. It was

[164] It is also useful to note that the favorite philosopher of the other main ideologist of 20th century physics, N. Bohr, was, according to [81], S. Kierkegaard, who is widely considered to be the first existentialist philosopher.

[165] One would be justified though in stating that the opposition was logically not fully consistent: indeed, if God could create something as miraculous as a time machine in a pocket (an ordinary flashlight capable of emitting a light ray chasing which only makes one younger not helping one bit in the actual chase), then why wouldn't he engage in something as ordinary as dice rolling.

indeed a formidable task, helped by using analogies with classical physics, by mathematical talents and laudable inventiveness of theoretical physicists, and – it has to be added – by planning and interpretation of experiments that reflected the already constructed theory.

Mathematics was seen more and more as the only tool that could ensure future progress. Even the physicists that were known to give priority to "physical meaning" and "physical intuition" compared to mathematical sophistication, like, for example, R.P. Feynman, referred to mathematics as "the language nature speaks in," as can be seen in the quotation given in [79]. But just mathematics on its own could not serve in this role. There had to be some link between it and physical reality. The mechanical form of the universal motion – by virtue of being the sublated ground of the physical form – could play the role of the natural "gateway" to a rational comprehension of the latter. Due to the mentioned before "disconnect" between the best philosophy could in principle offer and physics, that possibility was not realized, and physicists were left with the necessity of producing the corresponding philosophy (logic) on their own. Given their very limited background thereof and the lack of time due to... having to do physics research, it was impossible for them to perform that task in a satisfactory fashion. As we discussed in the previous section of this appendix, physicists got caught between subjective descriptions and objective laws, and, being intimidated by the newly opening depths, took the easy way out towards objectivation (and universalization) of the simple and elegant descriptions whenever such descriptions could be found. There still was the need for finding such descriptions, in the absence – as B. Russell attested – of any general method. The limitations on the otherwise freestyle construction came not only from the need to obtain a fit to experimental data, but also from that to comply to the previously designed universal principles – such as Lorentz invariance. That, as R.P. Feynman noted, was a far from trivial task.

Thus the place of the missing (objective-subjective dialectical) logic as the proper link between physical reality and mathematics was taken by what was aptly called *"crazy theories."*[166] by N. Bohr. These were nothing else than what was referred to as "fundamental principles that are free inventions of the human intellect" by A. Einstein in 1933, and that were, objectively, the main features of the shape of the very complicated "curve" that physicist were busy drawing to be able to fit experimental measurements of observed phenomena. The degree of "craziness" of different components thereof was understandably variable, but – as N. Bohr noticed over half a century of active observation – it had to be present.

This brings us again to the physicist who started this revolution in physics and is rightly considered – all past, present and future criticism notwithstanding – the greatest physi-

[166]The physics folklore has it that N. Bohr said to one of his younger colleagues something along the lines: "Your theory is not crazy enough to be correct," some time in late 1950's.

cist of the new (quantum relativistic) epoch, the one who embodied all its achievements and downfalls. His *principle of speed of light constancy* – understood not as a hypothetical temporary assumption intended just to explore its consequences, but as a *postulate about physical reality* – got the whole "crazy ideas" ball rolling. Logically, it was a resolution of the contradiction between the known laws of mechanics and those of electromagnetism in the form of Maxwell's equations. Since the proper dialectical resolution by sublation (and the likely further refinement and correction of the latter) could not be thought of due to circumstances just described, the other (neoplatonic) possibility of an existing phenomenological (with the essence thereof still unknown) description absolutisation was chosen. The official pronouncement of electromagnetic field an "entity that requires no further analysis" marked an impending era of the over a century long search for a *formal* (neoplatonic in spirit) unity of the physical world instead of the real (unavoidably dialectical) one. The experimental evidence in favor of such a radical postulate about *physical reality* (which knows no absolutes in finite forms) was rather inconclusive at best.[167] It later turned out that this "crazy theory" (or, more precisely, crazy postulate) number 1 became the progenitor of nearly all "crazy theories" to follow. At first, it made physics look (a lot) simpler by banishing the elusive ether with its still puzzling properties and allowing for a simple derivation of several well-known experimental results (like those of the Fizeau famous experiment), but the ensuing removal of the only basis for the development of a unified rational ideal reproduction of the physical form of the universal motion was thereby lost which "backfired" several decades later.

The original "crazy" postulate essentially gave light supernatural status. In particular, it followed that light quanta in free space were exempt from any form of "aging" since the *physical* time (and not just some auxiliary formal parameter, like in H. Lorentz's original version of his namesake transformations) for them was literally standing still. A couple of decades later, this belief closed the door for a simple rational (and dialectical) explanation of the newly discovered red shift in the spectrum of other galactics in terms of the universally present energy transmutation, which would in this case lead to a gradual loss of photons energy and the respective increase of their wavelength. Instead, the monumental "crazy theory" of an expanding universe (and the preceding "Big Bang") was put forward. Incidentally, the other reason for the adapted Doppler interpretation of the red shift was the

[167]For the sake of historic authenticity, it has to be mentioned that matters were not helped by the article [82] of E.W. Morley and D.C. Miller (the same D.C. Miller who was finally able to reliably measure the parameters of the ether drift in Earth's cosmic neighborhood a quarter of a century later) containing a repetition of the Michelson-Morley experiment that came out in 1904 and beginning with the words "A NULL result was obtained in 1887," even though that was incorrect. The results reported by the authors about the repeated experiment were again inconclusive, with future plans of repeating the experiment in a more open location announced.

"crazy theory" of general relativity. The latter, as we discussed in some details earlier in the appendix, was the direct result of bringing together the "crazy principle" No.1 with the (not crazy but requiring a rational explanation and pointing in the correct direction) equivalence principle. As we saw earlier, without the "mixing" of space and time that follows from the speed of light constancy postulate, one does not obtain non-Euclidean geometry, but only an equivalent description of any potential field in terms of an effective (fictitious) time metric. The general relativity thereby obtained was rather promptly assigned the status of an "exact" (as opposed to phenomenological) theory thereby "finalizing" the story of (classical, non-quantum) gravity, so that the future research in the latter almost entirely concentrated on finding solutions of Einstein's equations (which could keep physicists occupied for their whole careers due to the nonlinear character of these equations). In particular, it essentially postulated the "frictionless" idealized nature of the gravitational field (just like it did with light in "empty space") which implied the inverse square law at large distances from gravitating masses and led to the gravitational paradox in an infinite universe. This turned out to be very convenient for the "experimental proof" of the theory by pointing out the match with the observed difference (with the Newton's law prediction) in the Mercury perihelion precession. As we already mentioned, the latter could be otherwise explained (as shown by A. Hall in [71] two decades prior to general relativity) by the non-exactness of the inverse square law that was a rather clear sign of the presence of energy transmutation from the gravitational to other forms.

In retrospect, it appears that quantum mechanics itself, in spite of its dramatic history and A. Einstein's rather stern opposition, was actually relatively low on the "craziness" scale. If one discounts the radical phraseology of some of its founders[168] then the (nonrelativistic) quantum mechanics can be only considered guilty of some absolutisation of the subjective knowledge of micro-objects dynamics achievable *at the present level* of theory and experimental techniques, and of some lingering early positivistic identification of objective existence with present observability (justly criticized, for example, by S. Weinberg in [47]). The nonrelativistic Schrodinger equation actually provided a hint at the possible true nature of an electron inside an atom as a collective motion of some medium (most likely the same ubiquitous ether), which could also shed some light on the nature of electric charge. Only the advent of the Copenhagen interpretation – along with the already established belief (in spite of A. Einstein's partial backtracking since 1920) in the non-existence of ether – prevented further developments in that direction. Still, the notion of "electron clouds," often understood as physical as opposed to purely probability clouds, proved to have valuable

[168]For example, W. Heisenberg, is known to have claimed the "evaporation of the conception of *objective reality* of elementary particles into the transparent clarity of mathematics that represents our knowledge of this behavior."

heuristic content in molecular chemistry. One can say that the Copenhagen interpretation brought some agnosticism in quantum mechanics that could be most likely relatively easily remedied without changing most of its existing results. In other words, it appears to be a valid phenomenological description that can be used almost unchanged as a useful tool for the future progress on a more adequate logical platform.

The relativistic quantum theory is higher on the "craziness" (and agnosticism) scale than its nonrelativistic predecessor. As argued in S. Weinberg's textbook [74], "quantum field theory is the way it is because (with certain qualifications) this is the only way to reconcile quantum mechanics with special relativity." One of the qualifications mentioned in this reference is the *cluster decomposition principle* "which says in effect that distant experiments yield uncorrelated results." In quantum field theory, all particle interactions take place at space-time *points*, which is a direct consequence of Lorentz invariance that "mixes" space and time making for a violation of causality (or unitarity) if an interaction is considered to take place at a set of higher dimension. (String theory can be considered as an embedding of sorts of two quantum field theories – on the string worldsheet and on spacetime.) Such point interactions lead to infinities that, as we already mentioned, have to be subtracted from other infinities to obtain finite values. Since this was found to be impossible to do for gravity with a finite number of such subtractions (renormalizations), String Theory was proposed to incorporate the gravitational interaction into the quantum relativistic picture. The latter was found to be consistent either in 26 or 10 (depending on the presence of postulated *supersymmetry* in the theory) spacetime dimensions. This was actually considered to be a welcome feature since, according to general relativity, "spacetime geometry is dynamical," and a "single higher dimensional field can give rise to many four-dimensional fields" ([78]) opening some new possibilities for a formal unification of gravity and gauge interactions of the Standard Model. String Theory, with its extra "curled" dimensions present *at every point* of the three-dimensional space, has to rank very high indeed on the "crazy theories" scale rivaling the "Big Bang" hypothesis. (In fact, both of them are closely related, as the first fractions of a second after the Big Bang are supposed to be the time when the "compactification" of the extra dimensions took place.)

As we see, the consequences of just one "crazy" postulate are thus truly remarkable. With some help from the Copenhagen interpretation positivistic flavor of agnosticism (the fundamental impossibility of a rational description of elementary particles' spatial motion), it gave rise to the full spectrum of "crazy theories" of 20th century fundamental physics. The only other idea that was not directly related to the original "crazy" postulate was that of *fundamental symmetries* that was originally generated in response to the crisis in particle physics taking place in the early second half of 20th century and lasting until 1970's.

That crisis was triggered by the proliferation of different short lived particles in accelerator experiments and was aptly dubbed the "particle zoo." W. Heisenberg actually proposed the following approach to solving this particular puzzle [70]:

> The elementary particles are certainly not eternal and indestructible units of matter, they can actually be transformed into each other. As a matter of fact, if two such particles, moving through space with a very high kinetic energy, collide, then many new elementary particles may be created from the available energy and the old particles may have disappeared in the collision. Such events have been frequently observed and offer the best proof that **all particles are made of the same substance**: energy.[169]

In spite of this insight by W. Heisenberg, the mainstream theoretical physics did not try to take advantage of it (it was most likely impossible at this point of its development). Instead, it took the route of classification of all the short lived particles trying to find some patterns in their multitude. The result was the view according to which the particle species formed *various representations of groups of symmetry* characterized with continuous parameters (known in mathematics as Lie groups). The first example of such symmetry was the *isospin* approximate symmetry proposed by W. Heisenberg in early 1930's to express a high degree of similarity between proton and the newly discovered neutron. The continuous symmetry group, whose representation the "doublet" of proton and neutron formed, was $SU(2)$ – the group of unitary 2×2 matrices with unit determinant. Later in the "particle zoo" times, when classification of the proliferating particle species was undertaken, the $SU(2)$ approximate *global* (i.e. with parameters of the the transformation constant in spacetime) symmetry group was enlarged to $SU(3)$ containing the original $SU(2)$ as a subgroup. The resulting allocation of the observed strongly interacting particles – *hadrons* – into various representations – *multiplets* – of that $SU(3)$ global symmetry group suggested a further step: postulating of constituent particles, the *quarks*. In the resulting picture, each hadron consisted of either two or three quarks or anti-quarks. In the original model, the number of different types – *flavors* – of quarks was equal to three, but later it grew to six. To explain the details of particle composition and to model quark interaction within hadrons, further

[169]If one disregards the name he attaches to *the same substance* all particles are made of, a view that is most likely the correct one is presented. That substance all particles are made of is not energy, but rather the same universal medium (historically known as the ether) that is the seat of all fundamental interactions, the latter being some specific forms of its collective motion. This point of view sounds even more promising if one remembers that only four particles in the whole "zoo" – proton, electron, neutrino, and photon – are stable on their own, the neutron being stable inside a nucleus, and transmuting into proton (along with electron and neutrino) in about 10 minutes outside of it.

classification of quarks – into three *colors* – was suggested. The color symmetry group – another $SU(3)$ different from $SU(3)$ of flavor transformations – was a *local* symmetry, the parameters of which were allowed to depend on spacetime. To preserve such enhanced symmetry – called *gauge symmetry* – additional fields had to be introduced in the theory. These fields were interpreted as mediators of the corresponding interactions. For the case of interactions between quarks, quanta of these fields were given the name *gluons*. This was the first example of a directly relevant to physics nonabelian (i.e. based on a Lie group with noncommuting generators) gauge theory. Even though free quarks (and gluons) could not be detected in experiments, an explanation for this phenomenon was given in terms of *asymptotic freedom* – the property (mathematically derived of course) of the corresponding theory to produce an *increased* interaction strength at larger distances which resulted in the fundamental *quark confinement* within hadrons.

Another fruitful idea was that of *spontaneous symmetry breaking* according to which a symmetry present in the Lagrangian of a theory might not be manifest in the corresponding particle spectrum due to its breaking via a nonzero vacuum mean value of some scalar field – dubbed the *Higgs mechanism*. This idea made for a lot better flexibility of various symmetry related theoretical constructs by making it possible to postulate higher *internal* (i.e. not related to spacetime) symmetries not immediately borne out by experimental data. The first successful fundamental interaction formal unification theory – the *electroweak* one – was based on this idea. Even larger symmetry hypotheses, the goal of which to achieve a formal unification of the color $SU(3)$ of strong interactions with the (spontaneously broken) $SU(2)\times U(1)$ of the electroweak theory followed. The smallest Lie group which contains these two as subgroups is $SU(5)$ suggested as the first GUT (grand unification theory) in 1974.

All symmetries we have just reviewed are internal. In early 1970's, when taming of the particle zoo with the help of these symmetries was making decisive steps, physicists discovered that the spacetime symmetry transformations Poincaré group (that includes translations, space rotations and Lorentz "boosts") could be extended by considering anticommutation (instead of the usual commutation) relations between group generators. The new generators happened to transform boson particle states into fermion and vice versa. And the new symmetry was called the *supersymmetry*. The main advantage enjoyed by quantum field theories with supersymmetry present was the much better behavior with respect to infinities. The reason is in the cancelation of contributions of bosons and fermions which now come in pairs. Thereby supersymmetry – a somewhat "crazily" extended version of the Poicaré group which incorporates the "crazy" postulate No.1 – was shown to be able to make some amends for the consequences of point-like interactions enforced by that postulate.

Overall, speaking about the idea of fundamental symmetries underlying the development of fundamental physics since the second half of 20th century, one can say that it is not so much of the especially "crazy" variety, as it is of a textbook neoplatonic flavor. Indeed, the notion of some fundamental ideal forms underlying and preceding their imperfect material manifestations is quintessential (neo)platonism. In the practice of 20th century theoretical physics, these neoplatonic ideas received a sophisticated mathematical form that was the result of very hard work of several generations of exceptionally mathematically gifted individuals. The overall logic of this process was just what A. Einstein had foreseen in 1930's [83]:

> The hypotheses with which is starts become steadily **more abstract and remote from experience**... The theoretical scientist is compelled in an increasing degree to be guided by **purely mathematical, formal considerations** in his search for a theory, because the physical experience of the experimenter cannot lift him into the regions of highest abstraction... Here too the observed fact is undoubtedly the supreme arbiter; but it cannot pronounce sentence until the wide chasm separating the axioms from the verifiable consequences has been bridged by much intense, hard thinking. The theorist has to set about this **Herculean task** in the clear consciousness that his efforts may only be destined to deal the death blow to his theory. The theorist who undertakes such a labor should not be carped as "fanciful"; on the contrary, he should be encouraged to given **free reign to his fancy**, for there is no other way to the goal. His is no idle daydreaming, but a search for the **logically simplest possibilities** and their consequences.

The logic of the process of scientific inquiry as seen by the originator of 20th century theoretical physics methodology is clear: an ad hoc abstract hypothesis is formulated and then its consequences are painstakingly worked out to be compared only much later with observed facts. The goal is to get the fit of the consequences to facts by assuming as little as possible as far as the original hypotheses are concerned. The hypotheses themselves are expected to take the form of axioms, and their motivation can be as arbitrary as possible (As A. Einstein says in the talk just quoted [83]: "The hypotheses with which it [the theoretical science] starts become steadily more abstract and remote from experience.") as the only justification for them lies in the match between their consequences and "the observed fact." Such an approach naturally invites "crazy," paradoxical, unexpected hypotheses. The reason is simply that the *large* variety of *different* observed facts are to be derived from relatively *few* hypotheses. This implies that the hypotheses in question cannot closely resemble any of the facts to be derived and hence are likely to look unusual, i.e. "crazy." What we see here is a *mathematical rendition of a neoplatonic metamorphosis of the dialectical essence* – the unity behind the phenomenological multitude.

The notion of the objective unity never left physics: in this regard the modern neoplatonic tradition (we can call it a tradition since it is already over a century old – dating from the "annus mirabilis" 1905) preserved the continuity with the spontaneous dialectics of the classical one. This was the reason physicists could never fully accept E. Mach's view of a subjective "economical description" being all that was needed. Where physics stumbled was the *origin* of that unity for the phenomena belonging to the proper physical form of the universal motion. Attempts to find this unity in the *mechanism*, i.e. in the mechanical form did not bring the desired results since the *general logic of a lower form giving rise to the higher one* via resolution of its own contradiction and the resulting sublation, "foundering to the ground" of the higher form was not known to or understood well enough by the physicist of the time or philosophers aware of physics' problems. The inability to find a satisfactory mechanical essence of electromagnetic and optical phenomena gradually led physicists to (in A. Einstein's words from [58], "to get accustomed to considering the electric and magnetic fields as entities whose mechanical interpretation is superfluous" and "as special states of the ether that do not require an analysis in greater depth." It was at this critical point where the seeds of mathematical neoplatonism with its "crazy theories" in place of the missing essence were sown.

As we have already mentioned several times, the actual birth of the mathematical neoplatonism as the main ideology of theoretical physics for the next century can be rather firmly associated with the original work of A. Einstein [63] on special relativity. With one elegant castling move and in a gross violation of the laws of objective logic, he stripped their status of universal abstractions (and absoluteness accompanying their abstractness) and pure quantities from space and time and moved that universality and absoluteness (detached from the not needed any more abstractness) to a parameter of a particular real process – the speed of light. Thereby was created the first – and central for the future development – *material eidos* of mathematical neoplatonism. Light in vacuum got endowed with ideal characteristics no real object or process had ever been known to possess. Time for any ray of light or any quantum of it from then on stood still making these quanta exempt from having their own "age" and "history," thus bestowing on them an absolute status hitherto not associated with anything of finite nature. On the other side of the castling move in question, space and time, by virtue of losing their universal abstractions status, became not just dependent of the new absolute for their measure but also acquired the right to dynamics of their own, just like any finite material entities.

The creation of *material eide* which we previously referred to as objectivation (followed by absolutisation) of subjective descriptions *of particular phenomena* is the main philosophical innovation of the 20th century mathematical neoplatonism in general and special relativity in particular. This is what distinguishes it from the original Plato philosophy and other versions of neoplatonism. Slightly more precisely, the modern mathematical neoplatonism has *both traditional ideal and innovative material eide* in its philosophical arsenal. All internal symmetries expressed by Lie groups are examples of the former type of *eide*. As far as we can tell, all material eide of 20th century theoretical physics are descendants of the main one created by the "crazy" postulate No.1. Augmented with the axiom of discreteness of electromagnetic radiation, with the energy of a single quantum being proportional to the frequency ν and the coefficient being the Planck's constant h, that postulate formed the basis for all newest physics theory and its underlying philosophy.

Somewhat metaphorically, one could say that the said philosophy can be regarded as a *cult of electromagnetism*. Indeed, the set of phenomena of electromagnetism and optics was the first to resist rational explanation in terms of a *mechanism*. At the same time, Maxwell's phenomenological equations (derived with the help of a hydrodynamic analogy model) proved to be successful in providing a reasonably accurate quantitative description of a range of electromagnetic phenomena and even predicted the existence of transverse electromagnetic waves propagating in space with the speed of light, which were experimentally discovered by H. Hertz a couple of decades later. These equations were still a bit later used to construct a satisfactory descriptive theory of optics phenomena by H.A. Lorentz, among others. Such successes, in the absence of general rational methodology of finding unity in multitude (which could have been provided by the dialectical objective logic), created a temptation in the minds of some physicists to consider electromagnetic field a kind of special form of matter not just (approximately) *described* but almost (or even fully) *defined* by these beautiful equations which would thereby acquire the status of exact and utterly fundamental, the electromagnetic field itself becoming something that *obeys* the equations. This canonization of Maxwell's equations had to be taken just a step – but a very *bold* step indeed – further to arrive at the primordial *material eidos* (the magical ray of light) that set the modern mathematical neoplatonism in motion. The postulates developed in the process of finding an economical description of electromagnetic and optical phenomena were given the universal status and applied without hesitation to the description of gravitational and nuclear (and subnuclear a bit later) ones. The parameters c and h (the speed of light and Planck's constant) characteristic of electromagnetism (and optics) were successively bestowed with the status of *universal constants*.[170] Thus some particular, "freely" chosen features of a

[170] In many popular introductions to the modern physics and its main ideas, one can find claims along the lines of "the classical physics considered (or acted as if it were) the speed of light infinite." This is not quite

mystified (i.e. not rationally understood on the basis of unity of its own) mathematical description of electromagnetism was made the basis, the source of unity – but a formal, mathematical, *external* one at that – of all descriptions to follow.

Historically, the second material eidos was that of gravitation, created directly on the basis of the primordial one. As was mentioned earlier, the resulting description of gravitation as a manifestation of spacetime curvature would have been impossible without the creative rendition – with their necessary "mixing" – of space and time following directly from the postulates of special relativity. The "eidos-like" character of spacetime curvature in general relativity manifests itself in its being seen as an attribute of *empty spacetime* (A. Einstein's later comments about the ether not allowed any degrees of freedom notwithstanding), which is caused in some further inexplicable way by matter (and energy), and in its resulting exactly "friction-free" character excluding any transmutations of the gravitational energy. Two major consequences of the second material eidos formed the basis of later foundational developments. One was the general idea of geometrization (i.e. an explication in terms of spacetime geometry) of matter and its dynamics. The other was the direct consequence of the essentially *eidēticos* (i.e. exact and not subject to any corrections, derived from the most fundamental and also eidēticos "first principles") nature of the resulting description of gravity, which made an application of it to the *Universe as a whole* legitimate. The first idea led to String Theory, and the second to that of the Universe expanding[171] following the Big Bang. The particularly welcome feature of this pairing was that the compactification of the unobserved extra dimensions required by a consistent string theory could be relegated to the first tiny moments right after the Bang.

One might be tempted to say that the classical physics could also be considered as a *cult of a mechanism*, with its belief in all physical phenomena being explicable by some kind of underlying – possibly very complicated – mechanical motion. There are indeed reasons to say that, and the classical tradition also showed some signs of neoplatonism with, for instance, Newton's law of gravitation considered exact and final by some physicists of the time. The spontaneous dialectics being its underlying philosophy and with mathematical methods playing an increasingly prominent role in it, it held the seeds of both the proper dialectics (by virtue of its being spontaneous *dialectics*) on one hand, and the mathematical neoplatonism (by virtue of its being *spontaneous* dialectics) on the other. Its belief in the

accurate. For the classical physics, the speed of light might have as well been a few orders of magnitude less than its actual value. What the classical physics did not think about doing was setting all clocks with light signals in the assumption that the speed of the latter was impervious to all relative motions and using such clock readings to *define* time.

[171]Recall that the primordial material eidos prevented the explanation of the red shift via the energy loss by photons.

phenomena of physics possessing a mechanical essence – even though rather naively construed – was closer to the truth than that of the modern physics which put electromagnetism in place of mechanics. To the best of our present knowledge, electromagnetic, gravitational, and nuclear (including subnuclear) phenomena all form the *same* typological unity which has the mechanical one as its (sublated) ground. Thus it would not be possible to provide a rational exposition of the gravitational and nuclear phenomena using electromagnetism as the basis. Such a relation can only be formally descriptional (external) in nature which is what we see – although in an implicit, not explicitly admitted fashion – in the modern theoretical physics.

The naivete of the classical physics mechanistic beliefs played a significant role of the modern physics eventually taking the neoplatonic route. For instance, the discovery of light polarization was interpreted as light being a manifestation of transversal oscillations of some universal medium from which it was concluded that the medium itself had to be some kind of a solid body, which led to paradoxes. The knowledge of vortex motion was very rudimentary at the time (as it is still lacking now), but such conclusions were not necessary, and ultimately had the inherent to physics (as the most "basic" science) belief that the universe is simple in its roots, and the *current* generation of physicists is already close to uncovering its basic mysteries.[172] The frustration resulting from the failure of naively mechanical reductionist approaches contributed greatly to the physicists taking the seemingly easier mathematically neoplatonic direction. One could make the argument though for the ease being deceptive as the going was getting increasingly harder as more phenomena needed to be made to "fit" the "regression curve" physicists were busy drawing. The "particle zoo" period was especially trying, according to some accounts.

The modern theoretical physics is an impressive mathematical edifice constructed by some of the best mathematical talents of the past century. One cannot help wondering if that extraordinary level of talent possessed by all the main figurants of 20th (and early 21st) century theoretical physics was not only a blessing, but also somewhat of a curse to the subject of physics. The reason is that, if that level of mathematical "brute strength"[173] had not been available to, figuratively speaking, pull the carriage of theoretical physics through

[172]It is amusing to observe that such beliefs are still alive and well and get activated after new (almost entirely mathematical nowadays) breakthroughs. One can recall, for example, the excitement that swept through the global String Theory community during the second (dualities related) revolution in the middle of 1990's.

[173]According to theoretical physics folklore, one of the leading specialists in quantum gravity, which was especially notorious for its mathematical difficulty, was running a summer school some time in 1980's. The story has it that the attendants, mostly graduate students, who were not all so extremely talented as the leading theoretical physicists, had to spend the whole weekend lying in bed to have a chance to somewhat recover from the unusual intellectual strain of the week.

the logico-philosophical mud, the physicists might have been forced to step back, pause, and make attempts to build some drainage system. In other words, they could try to learn a bit more seriously what philosophy already had to offer instead of trying to design the required – according to their mostly philosophically innocuous views – bits on the back of the proverbial envelope while waiting for a dental appointment.

To wrap up the story of "crazy theories" as the main methodology of the modern theoretical physics, let us point out that the level of mastery of the rather sophisticated mathematics used by the modern day theoretical physics does not seem to play any role in one's ability to rationally think about logical problems. Speaking of problems fundamental physics is facing now in trying to come up – in a truly neoplatonic fashion – with the "final" and "elegant" theory of "everything" (all the while not knowing what electric charge is), the author of this article had for a number of years generally shared the view articulated by L. Smolin in his book [84] with a telling title. In a few words, this view has it that, during the formative years of the new physics in the first few decades of 20th century, the very imaginative physicists like A. Einstein, N. Bohr and some others had the courage and the general type ("philosophical") sophistication to come up with a few truly groundbreaking "crazy," seemingly irrational, but in reality highly and deeply rational ideas. These ideas were so fruitful as to keep a few following generations busy just working out their mathematical consequences (i.e. performing A. Einstein's "Herculean" task). But – inevitably – time has come when the original "crazy" ideas ran out of gnoseological steam, and new – even "crazier" – ideas were needed. Unfortunately, in the course of these quiet, mostly "technical" years, physicists got conditioned to be too specialized, too "technical," too rational in the older sense (that was cutting edge "crazy" in its time), that they had trouble generating even "crazier" ideas that were required for further progress. String Theory, for example, might not be sufficiently crazy as what it did was just to increase the number of dimensions of the "elementary" object by one which required increasing the number of spacetime dimensions by six. Just a mere quantitative change? That's it? Might it not be the time to do something more radical with space and time (the primary candidates for a revision ever since the famous "crazy postulate" No.1)?

But, however surprising it might sound, maybe one does not need the further increase of the degree of "craziness." Perhaps, what is needed is simply *rationality*. "Craziness," on the other hand, can most likely be dialed down all the way to zero. Rationality, however, is not trivial, does in no way boil down to the rules of mathematical logic, and has a content of its own that had taken at least two millennia to develop to a decent degree (by no means fully) and that needs to be studied appropriately. Hegel liked the classical definition of truth according to which truth is the agreement between concept and its subject matter. But for such an agreement to take place, the concept – and therefore essence as the necessary step – has to be present in it. Otherwise, the cognition would just have some content which, being alien to concept, would not have a chance of representing truth. This is where one has to look to eventually resolve the troubles with physics so vividly depicted in L. Smolin's book.

B.6 Physicists and philosophy

As we have seen so far, the gap that formed by the end of 19th century between physics and philosophy caused physicists to take the "easy" (as it originally seemed) route of mathematical prowess following a few "exact, fundamental and final" postulates and principles later aptly dubbed "crazy" by N. Bohr, one of the most insightful physicists of 20th century. Here we want to very briefly discuss the attitude of physicists themselves towards philosophy as they see it, and also try to sketch – in a very preliminary fashion – the objective reasons for physics to have taken the turn it did.

The general attitude of physicists nowadays towards philosophy as an academic discipline could be briefly summarized by S. Weinberg's phrase about the "unreasonable ineffectiveness of philosophy," which we quoted a bit earlier in this appendix. The attitude is mostly that of dismissal mixed with a bit of contempt whenever it comes to philosophers expressing their views on the matters of physics. This was not quite the case in the beginning of 20th century. Physicists in general were more attentive to philosophy, even though their knowledge of it was not sufficient for a rational solution of the problems fundamental physics was facing at the time. The most conspicuous philosophical direction that was not indifferent to the current problems of natural sciences was that of *logical positivism*, which officially dates back to the works of A. Comte, but which received further development and acquired its mature form following the efforts of E. Mach, B. Russell, L. Wittgenstein, the members of Vienna Circle and some others. So, whenever physicists turned to philosophy for help in their problems, they naturally encountered some flavour of positivism first. Such cross-fertilization between physics and logical positivism that took place rather actively during the first several decades of 20th century was helped by the simplicity of the latter's content and its characteristic manner of making wide use of formal ("rigorous") notation to which physicists were already very well used.

But, as already B. Russell admitted, positivism (aka logical atomism) had no method to speak of. In fact, in its essential logical content, as we discussed in Appendix A, it did not go much further than Humean scepticism. Thus, in purely philosophical terms, it was at a pre-Kantian level. As far as logical problems of physics and their resolution go, the philosophers working in this direction gradually began repeating what physicists had already said in a different way. The expected result was the growing scepticism of physicists towards philosophy, the synopsis of which S. Weinberg summarized so concisely. In particular, W. Heisenberg, one of the founders of quantum mechanics, expressed his attitude towards the early logical positivism and its obsession with language and its precision in the following words [70]:

> Insistence on the postulate of complete logical clarification would make science impossible. We are reminded here by modern physics of the old wisdom that the one who insists on **never uttering an error must remain silent**.

A clear hint at L. Wittgenstein's famous phrase can be seen in the last sentence of this quotation. But, as we will see again, 20th century theoretical physicists are never consistent in their criticism of logical positivism. W. Heisenberg, for example, in the same book on modern physics and philosophy, writes on the subject of language:

> With regard to the language, on the other hand, one has gradually recognized that one should perhaps not insist too much on certain principles. It is always difficult to find general convincing criteria for which terms should be used in the language and how they should be used. One should simply wait for the development of the language, which adjusts itself after some time to the new situation. Actually in the theory of special relativity this adjustment has already taken place to a large extent during the past fifty years. The distinction between 'real' and 'apparent' contraction, for instance, has simply disappeared.[174]

[174] The dilemma between real and apparent contraction mentioned in this quotation can be illustrated by a thought experiment in which two friends in possession of the same exact model personal spacecraft, the length of which is 10 meters (according to the technical documentation), speed past each other at the relative speed of, say, $0.85c$. When they pass each other, each takes a measurement of the other's spaceship length. According to special relativity, each of them would obtain about 5 meters as a result. Since they fly through empty space at a constant speed, it is impossible not to admit that both spaceships are exactly the same as they were when they left the factory. Therefore both measurements of 5 meters have to be considered just "apparent," and not "real," an illusion of sorts, similar to a cow in the field *appearing* to be smaller than a dog next to you. But, since the subject matter of fundamental physics is not optical illusions, such an admission would undermine the whole theory. Hence the contraction to 5 meters from 10 has to be considered "real." One could also add that this dilemma of "real" vs "apparent" is very similar to that arising in the case of a spoon sticking out of a glass of water. Is the spoon "breakage" at the air-water boundary real or apparent? It is not just a subjective illusion as, for instance, a photograph taken would clearly show the breakage. Any outside observer using light rays for the spoon observation (measurement) would confirm the same breakage. So the relativistic contraction appears to be just as real as the spoon breakage. The customer then can decide if that's real enough for him/her.

Here we see the typically positivistic language-centric resolution of logical questions, reminiscent of L. Wittgenstein's interpretation of philosophy and thought in general in terms of "language games." According to W. Heisenberg in this passage, to answer the question on the true nature of relativistic contraction, one needs... to stop asking[175] the question, or, as L. Wittgenstein would put it in a way apparently unacceptable to W. Heisenberg, "remain silent" about it. One can also recall one more time the Copenhagen interpretation, of which W. Heisenberg was one of the main originators. It revolves around the *uncertainty relations* that are not only considered fundamental, but are also used as grounds of the impossibility of a rational discussion of spatial motion forms of micro-objects confined to micro-volume (like, for instance, electrons inside an atom). So the objective *non-existence* of such motion and its forms is derived from its being *unobservable*, in a typical manner of logical positivism.

Critique of positivism, with its "concentration on observables" also stands prominently in S. Weinberg's account of the role of philosophy in physics in [47]. However he finds at least one merit in it:

> After the First World War, positivism was further developed by Rudolf Carnap and the members of the Vienna Circle of philosophers, who aimed at a reconstruction of science along philosophically satisfactory lines, and did succeed in **clearing away much metaphysical rubbish**.

Unfortunately, as we discussed relatively extensively in Appendix A, some of the rubbish the developers and followers of logical positivism (aka logical atomism) succeeded in clearing (or, more precisely, helping to block its access to science just when it was desperately needed) was nothing else but the *objective thought content*, or, equivalently, the type of *rationality* required for further progress of thought in general and theoretical physics in particular. As we also discussed in Appendix A, at about the time referred to by S. Weinberg in the quotation just given, some contemporary philosophers were busy struggling to come to terms with the best of the classical tradition including Hegel's dialectical logic. Unfortunately, this struggle ended in defeat, and the academic philosophy of the period ended up taking a major step back in exactly the wrong direction as far as the needs of physics were concerned. In short, after clearing away that "metaphysical rubbish," some of which consisted of various bits of dialectics that, for the positivists, looked like Ancient Egyptian inscriptions before the Rosetta stone, there was nothing left of logic. Physicists, respectively, found themselves officially on their own in this regard.

S. Weinberg also provides a very illuminating personal recollection going back to the time when he was an undergraduate student who was apparently majoring (or at least very much

[175]In this particular case, this would indeed be the best strategy.

interested) in philosophy before getting disenchanted with it and switching to physics [47]:

> The insights of the philosophers I studied seemed murky and inconsequential compared with the dazzling successes of physics and mathematics. From time to time since then I have tried to read current work on the philosophy of science. Some of it I found to be written in a jargon so impenetrable that I can only think that it aimed at impressing those who confound obscurity with profundity. Some of it was good reading and even witty, like the writings of Wittgenstein and Paul Feyerabend.

It is ironic that the deeper acquaintance of the young S. Weinberg with philosophy apparently began with the writings of L. Wittgenstein, the self-made philosophical *tabula rasa* and self-professed *terminator* of philosophy as a theoretical discipline with its own specific subject matter. One could easily recall that, for L. Wittgenstein, philosophy was an "activity" consisting of pointing out (from the logical vantage point of an undergraduate student), why certain phrases of classical philosophers were "senseless." Thus, the rather sceptical view on philosophy (for which we cannot say we can blame him) that S. Weinberg expounded upon in [47] was likely helped by this peculiarity of his personal intellectual history.

Another outstanding physicist of 20th century with an interest in logic and philosophy, E.T. Jaynes, shares largely sceptical views on the usefulness of philosophy for physics [85]:

> The injection of philosophical considerations into science has **usually proved fruitless**, in the sense that it does not, of itself, lead to any advances in the science. But there is one extremely important exception to this. At the stage of development of a theory where we already have a formalism successful in one domain, and we are trying to extend it to wider one, some kind of philosophy about what the formalism "means" is absolutely essential to provide us with a sense of direction.
>
> In the construction of theories, philosophy plays somewhat the same role as scaffolding does in the construction of buildings; you need it desperately in certain phase of the operation, but when the construction is completed you can remove it if you wish; and the structure will stand on its own accord.

This quotation is important for proper understanding of the view on philosophy of those physicists who are at least aware of its existence and more appreciative of it than what is typical today. We see that, for E.T. Jaynes, philosophy is some kind of auxiliary means for helping physicists in construction of their theories "in certain phases" of the latter. In other words, a physics theory on one hand and philosophy (logic) on the other are separate intellectual constructs, a useful relation between which could be found only under certain circumstances when what the *formalism* "means" becomes important. The implication is that otherwise the "meaning" (i.e. the logic) of the "successful formalism" might not matter that much.[176] For Hegel, on the contrary, any science is nothing else but an *applied logic*, and logic shows its full strength only when used in such an applied quality. Thus any particular science and logic are inseparable, and no science can be developed satisfactorily and be learned, used etc. in separation from logic, "on its own accord" [1], p.37:

> Thus logic receives full appreciation of its value only when it comes as the result of the experience of the sciences; then it displays itself to spirit as the universal truth, not as a *particular* cognition *alongside* another material and other realities, but as the essence rather of this further content.

Such "theory on the right, (highly optional) philosophy on the left" view on the relation between physics and philosophy is still wide spread among even the more philosophy appreciating physicists, and is one of the main reasons – along with the developments in academic philosophy itself – for physicists' underappreciation of philosophy and the loss of direction and rationality in fundamental physics.

Still, as we know, just like anybody who speaks does so – with rare exceptions – in prose, anybody who thinks uses some philosophy, regardless of the conscious admission of the fact on behalf of the thinker. And so do physicists, whatever their attitude towards "official" academic philosophy might be. S. Weinberg fully agrees with such – rather obvious upon a little reflection – statement [47]:

> Physicists do of course carry around with them a working philosophy. For most of us, it is a **rough-and-ready realism**, a belief in the objective reality of the ingredients of our scientific theories. But this has been learned through the experience of scientific research and rarely from the teachings of philosophers.

We see that, according to one of the leading theoretical physicists of the second half of 20th century, such basic "working" philosophy for most currently practicing physicists is *realism* additionally characterized by S. Weinberg as "rough-and-ready," i.e. basic, simple, unsophisticated. We see the same belief at work here as well: that the philosophy needed

[176]It is fair to say that any dedicated classical tradition physicist would find such an admittance rather surprising if not downright appalling. But E.T. Jaynes, all his personal brilliance notwithstanding, was a physics student in 1940's when mathematical neoplatonism was already fully established.

in a (theoretical) physicists' work is a very simple, obvious one. Namely, according to S. Weinberg, it boils down to the belief in the presence of objective content of theories the physicist in question is either studying or developing. Any more developed philosophy, as we have seen, is considered "unreasonably ineffective." For E.T. Jaynes as well, as we have just reviewed, it "proves fruitless," the softening qualifier "usually" notwithstanding.

Let us pause for a moment to take a longer look at S. Weinberg's characterization of physicists' "working" philosophy, i.e. the philosophy underlying their day-to-day work. He describes that philosophy as a realism which is a very broad "umbrella" term encompassing virtually all philosophical directions except an outright subjective idealism. In particular, all materialistic directions and all flavors of objective idealism would qualify for that name. As S. Weinberg himself explained, that particular realism is very minimal consisting just of the belief that physics theories are not entirely subjective, but rather reflect some subject-independent objective reality. He also emphasized that such minimal realism most physicists imply in their work is learned from research experience, i.e. from other physicists rather than philosophers. As far as the actual methodology of constructing new theories go, that rough-and-ready realism apparently "remains silent" about it. R.P. Feynman, as we can remember, said a bit more about methodology of modern theoretical physics. According to him, the approach consisting of "seeing how the other guys did it" could not be effective since, if it had worked, the problem in question would have been solved already. Thus, a new ad hoc approach had to be invented, subject to some known constraints. He also at one point likened theoretical physics to safe cracking, i.e. *numbers puzzle solving* which appears to be a good metaphor for the actual methodology of theoretical physics from early decades of 20th century. This view also agrees well with A. Einstein's "concepts and fundamental principles" that are "free inventions of the human intellect." As we have argued in this appendix, the actual philosophy of the modern theoretical physics is the *mathematical neoplatonism*, and its main methodology is indeed an invention of (neoplatonic by nature) fundamental principles followed by the "Herculean" task of computing their consequences. Since mathematical neoplatonism can be most closely classified as objective idealism, we would have to agree with S. Weinberg's qualification of the working philosophy of physics as a "basic realism."

But what about the relation of the modern physics' mathematical neoplatonism to the logical positivism and postpositivism, the main directions of contemporary academic philosophy with an immediate interest in the problems of natural sciences? As we have seen, the leading physicists themselves, while admitting some merits of these directions, tend to disassociate theoretical physics and its working philosophy with logical positivism. S. Weinberg, for example, writes in [47]:

> The positivist concentration on observables like particle positions and momenta

has stood in the way of a "realist" interpretation of quantum mechanics, in which the wave function is the representation of physical reality.

In fact, the wave function with its fundamentally probabilistic interpretation adapted by the Copenhagen interpretation of quantum mechanics is the representation of information about physical reality that an observer using classical (macroscopic) observation tools can only possess. As we mentioned a bit earlier, this interpretation is directly based on the impossibility of making rational sense and, hence, *non-existence* of spatial motion of micro-objects under the conditions of the uncertainty relation not allowing the determination of position and velocity with high enough precision. Since the uncertainty relation is a direct consequence of *measuring* the corresponding quantities with electromagnetic quanta, the conclusion of the *impossibility* of spatial motion (or at least its rational comprehension) on the basis of the lack of its measure *observability* is an example of logical positivism *par excellence*. Thus the "realist" (with quotation marks) interpretation S. Weinberg refers to is certainly a product of application of the logic of positivism to scientific inquiry about atomic phenomena.

Another feature of mathematical neoplatonism that, in S. Weinberg's view, creates a logical chasm of sorts separating if from positivism is its insistence on the material existence of some of its constructs that not only have not been directly observed yet, but are unlikely to ever be observed in relative isolation. One of the primary examples of such entities are hypothetical ingredients of the hadron type elementary particles – quarks, and the corresponding "carriers" of strong interactions – gluons. We read in [47]:

> The idea that quarks and gluons can in principle never be observed in isolation has become part of the accepted wisdom of modern elementary particle physics, but it does not stop us from describing neutrons and protons and mesons as composed of quarks. I cannot imagine anything that Ernst Mach would like less.

Recall that E. Mach's main idea was that the goal of any science was just an "economical description" of observed phenomena, and therefore there was no need to assign any objective reality status to any ingredients of such description. He indeed might not have liked the quark model of hadrons. Would he have disliked it as strongly as S. Weinberg suggests in the quotation above though? Let us try to find out using the closest analogy we can find. For E. Mach's times, such an analogy is furnished by, in his own words from [53] (p.314), "the artificial hypothetical atoms and molecules of physics and chemistry." E. Mach then goes on to state the following:

> **The value of these implements** for their special, limited purposes **is not one**

> **whit destroyed**. As before, they remain economical ways of symbolizing experience. But we have as little right to expect from them, as from the symbols of algebra, more than we have put into them, and certainly not more enlightenment and revelation than from experience itself.

As we can see, E. Mach readily admits the *heuristic explanatory potential* of atoms and molecules. The only thing he warns against is expecting from them "more than we have put into them," just like the case is with mathematical symbols (and calculations) that are routinely used in physics for the *description* of quantitative aspects of various phenomena. According to S. Weinberg, physicists of his day "*described* neutrons and protons and mesons as composed of quarks." Indeed, if one consults any book on the Standard Model, one will find quarks and gluons as mathematical constructs (spinor and vector fields, respectively) making up terms in the Lagrangian. On the other hand, any real physical object that possesses a moment of self-equality (i.e. an own existence that is relatively independent on other such) necessarily resides (and performs some motion) in space. No modern theories involving quarks offer any consistent model of their spatial motion (due to the uncertainty relations if nothing else). We can thus conclude that E. Mach might actually like the modern style description of protons and neutrons as composed of quarks significantly better than S. Weinberg was willing to admit.

Logical positivism which, as we have seen, is rather closely related to the modern physics' mathematical neoplatonism had gradually lost some of its obsession with direct observation and its "precision and rigour" zeal over several decades of its own development. It was forced to admit the unavoidable "mediation" of (often very tentative) theories between empirical data and new knowledge, and, in general, the subjective moment present in any scientific inquiry. Also, it had to admit to the impossibility of clearing the language of science of imprecisions of various sorts and to sticking to the rules of mathematical logic only. According to J. Passmore's widely known 1967 phrase: "Logical positivism, then, is dead, or as dead as a philosophical movement ever becomes." So positivism had mostly gone over into *postpositivism*. Even though in the latest half a century physicists have been aware of philosophy noticeably less than philosophers have been aware of physics, this evolution of positivism had some effect on the mathematical neoplatonism of the modern fundamental physics. We have just seen both S. Weinberg's and later W. Heisenberg's (his book [70] on physics and philosophy was originally published in 1958) renouncement of positivism for its excessive demands of formal rigour and obsession with observability. To illustrate the related evolution of the ideology of theoretical physics, let us compare two statements on its ultimate goal as it was seen by the leading experts in 1930's and about half a century later. A. Einstein on in his 1934 talk "The Problem of Space, Ether and the Field in Physics" [83] claims:

> The hypotheses with which it [the theoretical physics] starts become steadily more abstract and remote from experience. On the other hand it gets nearer to the **grand aim of all science**, which is to cover **the greatest possible number** of empirical facts by logical deduction from the **smallest possible number** of hypotheses or axioms.

Here, as we see, "the grand aim of all science" takes almost the form of a mathematical optimization problem: *maximizing the number* of empirical facts while *minimizing the number* of hypotheses or axioms from which they can be deduced. One is almost tempted to ask about the weights of the two objectives or the form of the proposed penalty function. About six decades later, we can read in the Preface to Volume I of S. Weinberg's textbook on quantum field theory [74]:

> Why should we believe in the rules of canonical quantization or path integration? Why should we adopt the simple field equations and Lagrangians that are found in the literature? For that matter, why have fields at all? It does not seem satisfactory to me to appeal to experience; after all, **our purpose in theoretical physics** is not just to describe the world as we find it, but to **explain – in terms of a few fundamental principles** – why the world is the way it is.

While the purpose of theoretical physics (also somewhat softened from "the grand aim of all science") stays largely the same, the formulation is decidedly more reserved: just "a few" fundamental principles instead of the "smallest possible number," and the number of empirical facts to be covered is not even mentioned. Also, the categorical "coverage by logical deduction" got replaced by the broader "explanation," which can in principle mean something more rational than just (formal) logical deduction. We see that the ideology of the new theoretical physics, while staying fundamentally the same during most of 20th century, was subject to gradual evolution which mostly mirrored the evolution of positivism from which – without fully coinciding with it – it largely derived.

No review – however brief – of philosophical views of 20th century physicists can be complete without a mention of one particular physicist who dedicated arguably the most significant time and effort to specifically philosophical problems and who came the closest to rational dialectics. This physicist is N. Bohr, one of the main founders of quantum mechanics physics and – after A. Einstein – the most influential theoretical physicist of the new (quantum and relativistic) era. The main philosophical idea of N. Bohr is that of *complementarity*, which is referred to in [81] as “the pinnacle of Bohr’s dialectics.” For the first time, N. Bohr formulated his principle of complementarity at around 1927, following prior heated discussions with other founders of quantum mechanics such as W. Heisenberg, E. Schrodinger, and others. Apparently, at the same time W. Heisenberg came up with his derivation of the uncertainty relations which could be seen as an illustration of the principle of complementarity. For N. Bohr, however, complementarity went much beyond quantum mechanics, and was rather a general logical principle of rational inquiry. The essence of this principle is that any phenomenon can be analysed from two directly incompatible mutually contradicting points of view, and its true nature can only be correctly comprehended if both points of view are taken into account. The primary example of complementarity from physics is the famous *corpuscular wave dualism* according to which micro-objects display both particle and wave properties, and cannot be correctly understood as either *only* waves or particles. Continuity and discreteness, randomness and determinism were also complementary notion for N. Bohr, and reality had to be analysed while keeping both members of the pair of opposites in mind. The different typological unities of the universal motion forms, like physico-chemical on one hand and biological on the other, were also complementary in the sense that, in order to understand the laws of the higher form properly, one needed to take into account both *causa efficiens* of physics and chemistry and *causa finalis* of biology proper, in spite of a formal contradiction between them.

N. Bohr also, according to his long time assistant S. Rosental [86], made multiple attempts to involve professional philosophers of the period in the development of fundamental ideas of natural sciences. But the results of his numerous conversations with both Danish and foreign philosophers did not satisfy him. He believed that the development of philosophical problems of particular sciences had to be undertaken by the specialists since professional philosophers did not possess sufficient knowledge of the particular subject matter and clear enough understanding of the details of the current methodology. In this regard, N. Bohr lamented the insufficient level of interest on the part of physicists in developing of the philosophical aspect of physics.

From the logico-philosophical standpoint, it can be said that N. Bohr’s philosophical level was ahead of that of the contemporary theoretical physics in general. While the latter, as we discussed at some length in this appendix, was rather firmly entrenched in the specific mathematical version of neoplatonism closely related to logical positivism, N. Bohr was fairly close to the rational dialectics of the type expounded in Hegel’s “The Science of Logic” in that he was already at or even somewhat past the stage of *negative dialectics* in the style of I. Kant. His complementarity is essentially the modern edition of Kant’s antinomies of reason. Just like in Kant’s philosophy, the validity of the opposite points of view is admitted, but the contradiction is left standing and not yet resolved. Kant's conclusion, the critique of which is one of the central points of Hegel's rational dialectics, was the existence of a fundamental limitation to theoretical ("pure") reason which had to necessarily be supplemented by its not fully rational, intuitive ("practical") counterpart. N. Bohr's conclusion was similar in that he had not been able to rediscover the notion of a contradiction resolution and sublation of the opposites in something new.

Given all that, it is hard not to express regret about N. Bohr's not being able to move further all the way to at least the philosophical level that had been achieved already. Indeed, Kant's and Hegel's writings had been available for more than a century at the time N. Bohr was developing his philosophical ideas. At this time, one can only speculate what prevented N. Bohr from taking time to seriously study the works of the classics 18th and 19th century. It certainly looks like that a person of his intellectual ability, interest in philosophy, and just general dedication to the cause of objective truth should have been able to successfully connect rational dialectics to physics, especially because he himself had been on that path already. Perhaps it was his early fascination with the works of S. Kierkegaard who was known to be very sceptical of classical philosophy and Hegel. Perhaps the peculiar theoretical physicist's snobbishness – the tendency to consider anything making sense and not containing an excessive amount of complicated mathematical expressions easy to understand – was the party to be blamed. Or maybe the general level of contemporary philosophy that had undergone two major logical "reduction" stages – the neo-Kantian "back to Kant," followed by the advance of positivism which could be figuratively labeled as "back to Hume" – was bearing a bit too hard on anyone undertaking philosophical investigations. Now it is next to impossible to know. What remains is that, in N. Bohr, fundamental physics lost its best 20th century chance of "upgrading" its logic to the level fitting the problems it was trying to solve.

Another – less known – philosophical episode in the history of 20th century physics that is worth mentioning is the debate between W. Heisenberg and P. Dirac on the nature of fundamental theories. A rather detailed account of this debate is given in [87]. In short, the debate revolved around whether, in W. Heisenberg's own terminology, scientific theories should be "open" or "closed." For W. Heisenberg, a closed theory is "perfectly accurate within its domain" and "correct for all time." Such a theory, should it be found deficient, can only be replaced by another theory as a whole, not by parts. This was W. Heisenberg's notion of proper scientific theories. W. Heisenberg insisted on the existence of several different "coherent sets of concepts" ([70]) which may or may not be limiting cases of each other. According to him, by the end of 1950's, one could "distinguish four systems that have already attained their final form." These were, according to him, classical mechanics, statistical mechanics and thermodynamics, special relativity, electromagnetism and optics, and quantum mechanics. The fifth set, in his opinion, "of which one, three, and four are limiting cases," had not been found yet at the time of writing [70] and was, at that time, a task for the future. Finally, "the set of concepts connected with the theory of general relativity," was not included in that enumeration since it, in W. Heisenberg's view, had not yet reached its final form at the time. We see that W. Heisenberg's philosophical outlook is indeed that of an avowed neoplatonist,[177] as one would expect. His early education in a classical gymnasium with its curriculum revolving around the ancient Greek and Latin languages that are complete, beautiful and no longer evolving, possibly played some role. In fact, his autobiography begins with the teenaged Werner reading Plato's "Timaeus" while hiking in the Bavarian Alps.

P. Dirac, on the contrary, believed that proper theories could be further developed, modified and extended while keeping their original "identity." He also maintained, contrary to his friend W. Heisenberg, who favored the picture of several distinct "coherent sets of concepts," the idea of unity of all physics. Having been educated in a technical college and having obtained an undergraduate degree in engineering, he had kept that technical/engineering mentality throughout his later life as a theoretical physicist. In particular, he never believed in an existence of complete and finished theories and considered any theory "upgradeable" in small increments. Even though he shared in the very popular in the new physics notion of "beauty" inherent to a valid theory, he believed that even approximate theories could be beautiful [87]. The belief P. Dirac held in the continuity of all physics was at the root of his confidence in close connection between classical and quantum mechanics. In particular, he thought that classical mechanics was also an "open" theory and thus subject to further modifications and improvements. What appears to be the case that P. Dirac's double – technical/engineering and theoretical physics – background made him a relatively rare case of a physicist who – philosophically speaking – combined a rather pronounced spontaneous dialectics with the new physics' mathematical neoplatonism, of which he was one of the founders. The strong spontaneous dialectics moment of his general outlook combined with his belief in the possibility in improving valid theories in relatively small increments even led him to questioning the main pillar of all modern theoretical physics – the *primary material eidos* aka the "miracle postulate" of speed of light constancy. In the beginning of 1950's, he was working on improving the recently developed quantum electrodynamics in which he especially disliked the infinities that had to be dealt with in a very artificial manner. He began with trying to develop a version of classical electrodynamics which would have been easier to quantize. His proposed solution was to reintroduce the *ether* into the theory.

[177] W. Heisenberg is probably one of relatively few physicists who would not have objected to the "official" title of the modern theoretical physics' actual philosophy adapted in this article.

But would not that imply abandoning the "miracle postulate" (and possibly undermining the whole beautiful building that took about half a century to erect)? It certainly would. P. Dirac, the spontaneous dialectic, would have likely explored this option. But for P. Dirac, the mathematical neoplatonist, exploring this option apparently meant taking it too far. As we have just mentioned, P. Dirac, the engineer, preferred small improvement to the existing theories, and such improvement would have been too drastic. So what was his resolution of this contradiction? The *uncertainty relations* were coming to the rescue [88]:

> Quantum mechanics requires the velocity of the aether at a point in space time not to have a definite value in general, but to be subject to uncertainty relations, like all other dynamical variables.

Indeed, since in P. Dirac's own words, "the aether is presumably very light and tenuous," the uncertainty relations are likely to make the velocity of the ether *at the scale characteristic of the ether "quanta"* completely undetermined. Keeping in mind that light is likely to be some form of collective motion of the ether, and that the uncertainty relations are a direct result of "probing" microscopic motions with light quanta, trying to probe the motion of individual ether quanta (which can be reasonably assumed to exist) with photons would be akin to probing the motion of water molecules with tsunami waves. One would certainly obtain zero information thereof, i.e. an isotropic distribution. This is exactly what P. Dirac concludes in [88]:

> We can describe the vacuum state in a relativistic way by assuming that it corresponds to a wave function that makes all values for the aether velocity equally probable, in a Lorentz-invariant manner. There is then no longer any clash between the aether hypothesis and relativity.

So is the contradiction resolved? Yes and no. The ether is likely to be involved in a variety of motions at all scales: from the scale of elementary quanta all the way up to intergalactic and beyond. P. Dirac's was attempting to develop an improved version of classical electrodynamics. So the ether motion of most relevance would have been that on the laboratory scale, with coordinate uncertainty of the order of millimeters and centimeters, very similarly to what the Michelson interferometer experiments were attempting to measure (and reliably measured whenever due care was taken). In that case, the uncertainty relations are no help at all. For an illustration, a decent engineering-style analogy can be easily given. For a study of the flight of a model plane, the wind speed of the order of several meters per second is relevant, but the thermal motion of air molecules with typical speeds of hundreds of meters per second is not. Going back to the ether, the speed of ether drift near the Earth surface measured in D.C. Miller's (and actually even in the original Michelson-Morley's) experiments was of the order of several kilometers per second. Most likely, the chaotic motion of the ether quanta is multiple orders of magnitude higher. It is the former, not the latter, that would "clash with relativity." It is the latter whose distribution would be made isotropic by the uncertainty relations.

Having saved the *primary material eidos* from the ether, in spite of committing the act of assigning degrees of freedom to the latter which all "serious theorists" should have been on "their guard against," P. Dirac takes advantage of its newfound existence and introduces... the absolute time, whose absoluteness had been reassigned to "rays of light" almost half a century prior, in a very elegant fashion. But why does one of the founders of mathematical neoplatonism need to shake its foundations in such a vigorous fashion? As we have already mentioned a few times, the relativistic "mixing" of space and time, the cavalier swapping of the past with future depending on the frame of reference (all in egregious violation of basic laws of objective logic) has a side-effect of wreaking the proverbial havoc with casuality and thereby forcing physicists to point particles and point interactions to be able to save it. Expectedly, understanding the nature of an interaction while being forced to confine it to a mathematical point, is somewhat akin to laying out a tennis court plan with the help of a 5″ diameter globe. Thus what P. Dirac is looking for is just some additional freedom in constructing useful models of atomic phenomena [88]:

> The idea of an absolute time thus becomes a very attractive one, allowing a great increase in one's power of obtaining a Hamiltonian description of physical events involving high velocities. Present-day atomic theory, which works in a relativistic frame without absolute time, has ran into serious difficulties, and may well be that this increased power will help us out of them.

As we can see, it can be quite illuminating to observe a struggle between two philosophical directions in the head of a single physicist, and such a brilliant one to boot. One also has to admire the engineering savvy displayed by P. Dirac while trying to resolve the contradiction between a physical (and not simply a formal construct of a "language game") ether existence and The Postulate. The resolution turned out to be rather formal, but this was likely the best anybody could have done.

According to Hegel, *any* rational content can be expressed by means of a natural language adapted for philosophical ("speculative") goals. But, in the case of modern theoretical physics, that is not always true, according to one of its main ideologists (and P. Dirac's best friends) [70]:

> When this vague and unsystematic use of the language leads into difficulties, the physicist has to **withdraw into the mathematical scheme** and its unambiguous correlation with the experimental facts.

Any former or current student of theoretical physics can easily relate to these W. Heisenberg's words. Anybody who ever tried to honestly understand its logic can recall numerous little episodes of having to run to the safety of an equation that would always make everything clear, for as long as one can refrain from trying too hard to understand what it really means.

Given the lack of rationality and any logical method in the modern physics philosophy, it does not come as a great surprise that hopes for the future progress at any stage are set on intuition, sudden revelation of a genius etc. It is such hopes that are implied by the now common – following N. Bohr's famous adjective – high regard for "crazy theories." The "fundamental principles" being "free inventions of the human intellect," according to the main founder of the modern mathematical neoplatonism, the reliance on inexplicable, irrational "aha moments" becomes quite rational itself. A. Einstein himself, once he became "officially" given the status of a genius, was known to share his general views on the nature and main sources of scientific progress, including the especially valuable first-hand observations of one of the main effectors of the latter. At one point, for example, he remarked, in a rather categorical manner [89]:

> **All** great achievements of science **must** start from intuitive knowledge. I believe in intuition and inspiration... At times I feel certain I am right while not knowing the reason.

Thus genius intuition is really alpha and omega of all great achievements, without exception. The second sentence of the quotation above is especially believable, given the identity of its author. The thought process itself, on its articulated personal level, is also pictured as something largely irrational [90]:

> I have no doubt that our thinking goes on for the most part without the use of symbols, and, furthermore, **largely unconsciously**.

Such "largely unconscious" nature of thought in fundamental physics gives away rather clearly its strong irrational traits. Indeed, as we argued in this appendix, the main methodological problems of the modern fundamental (theoretical) physics have their roots precisely in that: its failure to find a proper rational methodology adequate for the problems it began facing in the second half of 19th century.

The deficit of rationality, and, more precisely, the absence of any method of rational synthesis to complement the analysis with, method of comprehending the whole in a fully rational way, made some physicists seek inspiration in the realm of arts that are holistic by their very nature. It is widely known that A. Einstein, for instance, was an accomplished amateur musician, and was known to claim to obtain a good deal of inspiration for his work from music. His reaction to the original work of N. Bohr on the planetary model of the hydrogen atom has become particularly well known ([90]): he referred to this work as "the highest form of musicality in the realm of thought." While such well-roundedness in an individual is unquestionably truly admirable, the direct reference to music in relation to specific problems of atomic physics is a clear sign of missing proper methodology of rational reproduction of nature's objective logic.

A little earlier in this section, we reviewed N. Bohr's deep interest in philosophy and his efforts to fill the existing gap in the logic of physics which he was keenly aware of. In a review article [81] dedicated to N. Bohr's centennial anniversary, A.B. Migdal, one of the leading theoretical physicists of the second half of 20th century and a personal acquaintance of N. Bohr, wrote:

> Bohr believed that the philosophy of physics had to be the job of professional physicists. And such concrete philosophy is absolutely indispensable for the development of science. It establishes the groundwork which breeds **unexpected flashes of intuition**.

The most characteristic feature of this quotation is the very typical for modern day physicists – even the ones more aware of importance of philosophy as logic of science – low regard for the kind of logic such philosophy is capable of providing. Its mission is just to set up the stage for the "flashes of intuition." Thus rationality, i.e. *reason*, gets relegated to an auxiliary position, with what is essentially a pre-reason form of intelligence playing the leading role.

Let us now try to briefly speculate on the objective and subjective reasons of such logico-philosophical deficiency that affected the fundamental physics at the time when just the opposite was needed for its further progressive development. The unfortunate part about this situation was that the required logic had been already developed and presented – albeit in a rather arcane fashion – in its "pure" form and was waiting to be filled with specific content. One cannot say that physicists of the period were totally unaware of the need for such logico-philosophical enhancement for physics to be able to cope adequately with the new, logically more complicated, subject matter: the proper physical form of the universal motion that came fully in the focus of physics. They were aware of that need and, understandably, were looking to the contemporary philosophy for the corresponding enlightenment (recall

A. Einstein's references to "powerful knowledge theory arguments"). Unfortunately, academic philosophy in the last third of 19th century, unable to further develop Hegel's rational dialectics, started the "back to Kant" reverse motion. At about the time the new physics was already in the process of active development, philosophy was busy taking one more backward step "from Kant to Hume" (see our review of B. Russell's philosophy in Appendix A for details). The resulting logical product[178] understandably left physicists less than thrilled and eventually resulted in their collective "unreasonable ineffectiveness of philosophy" view, explicitly expressed by S. Weinberg.

So physicists were not able to see how to link the physical form of the universal motion to the mechanical one properly. They had to resort to phenomenological descriptions for the time being. Such a situation is not unusual, and has to be expected in a fundamental science from time to time. The interesting question is what compelled them to begin the process of absolutisation and universalisation of such phenomenological descriptions. If a decent phenomenological description has been obtained, but a fundamental theory has not yet, why rush it? Why not take more time in the search for such a theory while refining and improving the phenomenological descriptions? First, with philosophy going the way it was, physicists likely had no idea whatsoever how a proper fundamental theory of the physical form of the universal motion should have been developed. Because of that, many physicists – especially the younger generation, but not only – really started thinking that laws of nature could be "freely invented." On top of this lack of a rational direction, there was the factor of "industrialization" of science and academia that was gaining speed at around the same time. Just like it was the case with (academic) philosophy, such industrialization practically meant that very young people in their early 20's (graduate students) had to begin producing and publishing supposedly *original work* in their field that was *fundamental physics* while being unavoidably *intellectually immature*, all at the time when the field was at a *conceptually* critical point. These factors created a situation where many theoretical physicists felt inclined to accept *any* proposal that would open up some development direction making successful novel work possible by at least the more gifted graduate students that could be considered work in *fundamental physics*. It is somewhat ironic that the original discoverer of this "easy" way out of the physics's conceptual predicament was (or at least became so a bit later) already fully aware of the "conveyor belt" type of pressure. About his patent office years (1902-09), A. Einstein later remarked [91]:

> A practical profession is a salvation for a man of my type; an **academic career compels a young man to scientific production**, and only strong characters

[178]The essential content of this product is very well exemplified by B. Russell's ratiocinations in [46] about the reality and true content of a table given to the observer as a collection of various sense-data.

can resist the **temptation of superficial analysis**.[179]

Given that physics deals with relatively simple phenomena, its extensive use of mathematics had been already common since the times of Newton. Thus the direction that ended up being accepted involved *trivializing the logical foundations* of the physical form reducing them to "freely invented" ad hoc style principles and *shifting the burden* of reproducing experimental results *to mathematics*. Practically, as we discussed at some length earlier in this appendix, this program boiled down to making some features of the previously existing phenomenological descriptions of *electromagnetic* (and optical) phenomena the chosen principles and proceeding mathematically from there. The specificity of mathematics as the discipline whose subject matter is comprised of external relations between abstract quantities makes it conceptually simple and potentially infinitely complicated at the same time. One of the consequences of these characteristics of mathematics is obviously the fact that it was historically the first well developed science (which caused multiple attempts of emulating the logical make-up of mathematics in philosophy and natural sciences, the fundamental nature of which is radically different). The other closely related consequence of that conceptual simplicity is the relatively easy mastery of mathematics by specifically gifted individuals, even very young ones. In this regard, it resembles chess or, say, Rubik's Cube speedsolving. So, given also the infinite richness of the world of formal possibilities in the realm of quantities that mathematics explores, the problem of professional productivity in the field of theoretical physics was thereby solved. Indeed, ever since the new mathematically neoplatonic physics was originally founded by the introduction of The Postulate in 1905 by a 26 year old, breakthrough contributions by very young people – who were all almost without exception mathematical child prodigies – became the norm.[180]

As for the objective reasons for such a turn in the course of physics, first, one needs to point out that any science as a particular form of human activity possesses both the progressive, future oriented, "eternal" moment and its "situational," "pragmatic," regressive counterpart. Put slightly differently, any science, including physics, is a particular form of

[179]As we mentioned a few times earlier, the young Albert could not be blamed for the superficialness of his own analysis leading to The Postulate that was destined to change the face of physics later. At that age, he simply could not have known any better, and this was not mathematics his analysis was dealing with.

[180]Let us take R.P. Feynman as a typical example. From the rather extensive Wikipedia article (more specific references can be found there), we learn that, for example: "**When Feynman was 15**, he taught himself trigonometry, advanced algebra, infinite series, analytic geometry, and both differential and integral calculus." About his Pn.D. thesis, we read: "This was Richard Feynman nearing the crest of his powers. **At twenty-three** ... there may now have been **no physicist on earth** who could match his **exuberant command** over the **native materials of theoretical science**." It is not hard to guess what (the corresponding reference being published in 1992) these "native materials" were: in the ninth decade of mathematical neoplatonism, they were mathematics, pure and simple.

activity of the human society in its particular social form. The current social form, as mentioned earlier, can be characterized as a transitional one – from the biological form of the universal motion to the proper intelligent one. Thus the current form can be called quasi-intelligent. One of the main defining characteristics of the whole quasi-intelligent transitional form is the lack of control of the society over its own development. This characteristic shows itself in the existence of impersonal (*alienated*, in Hegel's language) objective societal forces – specific to any particular societal subform – that dominate the development of the society. In different phases of the given subform, these forces can be more or less conducive to the overall progress. Typically, in later phases, the moment of *status quo* maintenance comes to the fore. In such times, progress in sciences may easily take a back seat to other goals. The corresponding science product would then have the "situational" moment gain some ground at the expense of the "eternal" one. Specifically, when the "industrialization" of science mentioned above became almost universal, career considerations for any individual scientist acquired primary importance. It would be fair to say that the importance of career considerations outweighs that of what can be called considerations of the objective truth pursuit in the majority of individual cases. The combination of such relation between various sources of motivation of an individual scientist with the "compulsion of a young man to scientific production by an academic career" (in the words of A. Einstein) can easily result in the science as a whole being largely indifferent to the cause of objective truth and overall progress, for as long as the outward criteria of career success are met for most or at least most leading scientists.

This likely is, generally speaking, what happened to fundamental physics in 20th century. When the last generation of physicists belonging to the classical tradition was struggling with the attempts to understand the phenomena of the physical form of the universal motion in terms of the mechanical form without any knowledge of the objective logic,[181] the whole societal form was going into the regime of the *status quo* maintenance from the preceding phase of more progressive development. This meant, in short, that further progress in fundamental physics was objectively not *needed* very much, or slightly more precisely, the limited progress which could be achieved by the adapted essentially phenomenologically descriptive approach was more than sufficient. Indeed, the objective needs of the transitional *homo economicus* form do not really include, say, interstellar travel (not that it would have been even remotely achievable by humanity in this form). So the knowledge of, for example, the essence of gravitation is not that necessary, and a descriptive scheme would do just as well, practically speaking. The interesting question is really that of the reasons for the

[181]Slightly more specifically, they believed that the physical form of the universal motion was just a more complicated version of the mechanical one, whereas, to the best of our knowledge, it has the mechanical form as its sublated ground.

strong tendency for making phenomenological descriptive schemes look like fundamental theories. What was the rush? Could physicists not be more patient and just keep working while using the phenomenological descriptions for more applied purposes in the meantime, refining them along the way? Subjectively, the "industrialization" of physics was likely the reason: *fundamental* physics could not afford to stop looking like one, even temporarily. It needed to keep "selling" its specific product to various sponsors, to keep funding coming to stay afloat and expand. Objectively, i.e. from the standpoint of the social form as a whole, one of the reasons for that "impatience" was probably the ideological role that science in general, and fundamental physics in particular, as the most basic, "foundational" science, plays in an industrial, secular society. Thus, being one of the means of cultural hegemony, especially over the more educated stratum holding key positions in such society, fundamental physics needed to look the part, so to speak. It needed to keep presenting the picture of the ever increasing mastery of the deepest secrets of the Universe, to maintain the faith of that educated stratum in the progressive potential of the social form even in the absence of such potential. An indirect sign of science acquiring such a role in 20th century was the increasing proliferation of various prizes, medals and other signs of personal distinction for scientists. Nobel Prize, for instance, was first given in 1901. One of the latest additions to this list is the Breakthrough Prize in Fundamental Physics, specifically targeted at the most *fascinating* aspects of physics, of the highest ideological impact that may not fit some criteria of the Nobel Prize. Also notable in this regard is the unprecedented "monetary" content of the newest prize, pointing fairly transparently to its ideological role.

Finally, let us engage in a little alternative history exercise, for the sake of diversion. Namely, let us briefly speculate what would have gone differently in fundamental theoretical (and experimental) physics if the physicists had been aware of the proper laws of logic to the extent available at the critical junction of early 20th century. Let us also assume nothing on top of being up to date with the developments in logic, i.e. let us refrain from any assumption of the possible – and very likely – consequences[182] of such logical awareness. What would have gone differently in fundamental physics under such minimal assumption? First, Maxwell's equations would have been treated as J.C. Maxwell himself originally intended: as a mathematical summary and a mild modification of the phenomenological laws of electromagnetism discovered empirically before. Nobody would have thought about making these equations into some kind of a fundamental exact law and proclaiming the (classical) electric and magnetic fields special stand-alone entities that *obey* Maxwell's equations and are defined by this obeyance. Next, Lorentz's theory of stationary ether offering a good fit to a number of experimental observations in optics would have never been taken for anything

[182]Such consequences might have included establishing the specific way of the mechanical form of the universal motion acting as sublated ground for the physical one.

more than a preliminary phenomenological description due to the hypothesis of stationary absolutely rigid ether alone. Indeed, this is the way H.A. Lorentz himself most likely viewed it, fully understanding that the available knowledge of the nature of ether did not allow for a more detailed realistic model. The Lorentz transformations leaving the form of Maxwell's equations invariant would have continued being treated as H.A. Lorentz originally intended: as transformations of phenomenological equations that might provide some hints in the future, both about the equations themselves (how they can be improved) and the nature of the reality behind the equations.

Speaking of special relativity, it would have still been an interesting proposal. Namely, if one decided to treat Lorentz's transformations as those involving *effective* space and time coordinates for the given reference frame that can be given *some* sensible interpretation (to be discovered later), then the speed of light would *appear* the same in every reference frame (thus allowing Maxwell's equations to keep the same form of course). The transformations of electric and magnetic fields under a reference frame change might have given an insight into their true nature, useful for the future search for the latter. The increase in the kinetic energy of a charged body (derived earlier by J.J. Thomson from Maxwell's equations) could have helped the search for the nature of electric charge. In general, the heuristic potential of any good (compact and giving a good fit to a relatively large number of experimental results, i.e. "economical" in E. Mach's sense) phenomenological description can only benefit from keeping its status clear. In such case, no one feels compelled to look for its "confirmation" at all costs, and to treat any lack of fit as an experimental error or a presence of some unaccounted for factor. On the contrary, such misfits become information sources for future improvements of the description and the search for a more fundamental theory. The maximality of the speed of light would have been interpreted as an impossibility to accelerate a particle by means of an electromagnetic field to speeds higher than that of electromagnetic interaction propagation. Also, it is possible, as J.J. Thomson noted, that a charged particle experiences an increase of its effective mass due to "ether drag" making it hard or impossible for such a particle to exceed the speed of light (with respect to the local mass of ether). There would have been no absolutisations, and no miracles claimed due to some mysterious properties of an empty spacetime.

General relativity, as we discussed earlier, relies in an essential way not only on the equivalence principle, but also on the speed of light constancy postulate. Without the latter in place, the equivalence principle alone leads only to an equivalent description of Newton's (or any other) law in terms of time metric component and auxiliary local time which, when the correct limit is taken, coincides with the standard (Newtonian) global one. Thus all the *fascinating* aspects of general relativity – gravity as manifestation of spacetime curvature and the related elegant constructions such as various solutions of the Einstein's equation for spacetime metric – owe their existence to The Postulate. In fact, as was mentioned before, more is true. Namely, the origins of *all most fascinating* results of today's theoretical physics can be traced back to the postulate stating real existence of a *finite absolute* in the form of light or any electromagnetic wave. As we argued earlier in this appendix, such a finite absolute is an objective logic impossibility, and hence can be logically classified as a *miracle*. Any internally consistent formal construct that takes a miracle as input can be expected to produce miraculous outputs. Indeed, the Universe expansion was obtained as a consequence of the Einstein's equation solution for the entire Universe and confirmed by observations of the remote galaxies spectrum red shift and cosmic background radiation. The red shift, in turn, was given the Doppler effect interpretation since the most obvious other (and a lot more prosaic and pedestrian) explanation of photon energy loss was ruled out by virtue of photons being quanta of the *real absolute* exempted (as any absolute) from the "power of time," i.e. the process of any change. The other fascinating theory is obviously the String Theory with its compactified extra dimensions and the observed particles in three flat space dimensions being just a manifestation of the geometry of the compactified dimensions. So the idea of spacetime having dynamics of its own – the consequence of the "real absolute" postulate – lies at the very core of String Theory as well.

Going back to our little alternative history exercise, assuming nothing else but physicists of the period being up to date with the progress in logic, one would have to say that no real absolute could be taken fully seriously. This implies that the general relativity and its various ramifications culminating in the expanding Universe and String Theory could have been only contemplated in the status of temporary phenomenological descriptions, "what-if" exercises of sorts. Under such conditions, given the amount of effort these theories required, they would have been unlikely to get developed to any extent comparable to their current state. On the other hand, the corresponding spared – very considerable – effort could have been used on, for instance, developing the theory of vortex motion which likely holds the "mystery" of the way the mechanical form of the universal motion gives rise to the physical one. Speaking specifically of mostly mathematical developments, E.T. Jaynes noted in [85]:

> *Unless the conceptual problems of a field have been clearly resolved, you cannot say which mathematical problems are the relevant ones worth working on; and your efforts are more than likely to be wasted.* I believe that in this century, thousands of man-years of our finest mathematical talent have been lost through failure to understand this main principle of methodology.

Indeed, while claiming all these man-years to have been totally lost is probably a bit of an exaggeration, they definitely could have been used with significantly greater effect on the progress of rational comprehension of the physical form of the universal motion.

Since the equivalence principle does not by itself lead to the notion of spacetime curvature as the essence of gravity, its rational content would have likely received a different explanation. As was correctly noted by A. Einstein, the fact that the phenomenon of gravity can be either locally "created" or "eliminated" by going to an accelerated reference frame, means that gravity on one hand and inertia on the other are just manifestations, or appearances, of the same essence. But what is that essence? This question was left without answer because, due to the same logical shortage in physicists' background, it was not even realized that the general relativity theory, regardless of its adequacy to reality, did not provide any answer to this question. It was – and still is – just a phenomenological description of gravity (and inertia) in terms of spacetime curvature. Neither the meaning of this curvature, nor the way massive bodies cause this curvature have received any further explanation. For the underlying mathematically neoplatonic philosophy, neither of these *require* further explanation. This implies that, had the objective (dialectical) logic been part of physicists' logical arsenal, further inquiry in the essence of gravity and inertia would have been undertaken. Given the amount of talent present in the theoretical physics of the period, such inquiry would have been unlikely to end in no progress.

Quantum mechanics is the second pillar of the new theoretical physics. On the other hand, as was pointed out earlier, from the logical point of view, and a bit contrary to the popular opinion,[183] it represents a less radical break – compared to relativity – from the classical tradition. The reason is simply that quantum mechanics logical underpinnings do not contain any *material eide* and thus no radical violations of of objective logic laws, i.e. no postulated "miracles." Logically speaking, the main faults of quantum mechanics include the absolutisation and universalization of the phenomenological laws of electromagnetism (which leads to assigning the fundamental character to uncertainty relations) and the claim of nonexistence of micro-objects spatial motion[184] due to its lack of observability. The latter claim goes back to the early radical (especially "simple-minded") days (in the spirit of Vienna Circle) of logical positivism but has endured in physics to this day.

[183]E.T. Jaynes, for example, was expressing major doubts about the logic of quantum mechanics while considering general relativity a gold standard of physics theories.

[184]The most widely known example of this claim relates to the trajectory of electron inside an atom. Such trajectory indeed, to the best of our knowledge, does not exist. But the reason for its nonexistence has nothing to do with reality being "created by observation" and classical concepts being invalid at the atomic scale. That reason is simply that the electron inside an atom is not a point particle (or even an object of a relatively negligible size), but rather a form of collective motion of certain material medium (the ether, most likely) described fairly adequately by the "electron cloud" metaphor widely used in chemistry.

Thus, speaking of alternative history possibilities, had physicists of early 20th century been aware of the full extent of contemporary logic, the content of quantum mechanics might not have changed that much. What would have changed is the attitude towards its current formulation and some interpretations. The uncertainty relations, in particular, while being accepted as a direct consequence of the use of light quanta radiation for observations, would have never been endowed with the fundamental absolute status they have been enjoying from inception to this day. There would have been neither the "existential" ban on attempts of theoretical inquiry into the mechanical motion of micro-objects confined to small volumes nor any beliefs in the finality of quantum mechanical descriptions in the sense of information. The quantum mechanical description of atomic and subatomic phenomena itself would have lost any "mystique" associated with the belief in its utterly fundamental nature and in the logically incomprehensible (and inexpressible in a natural language) nature of the whole quantum world that led to, in the words of W. Heisenberg, to "physicist having to withdraw into the mathematical scheme" whenever "this vague and unsystematic use of the language leads into difficulties." The heuristic potential of quantum mechanical phenomenological descriptions would have only improved by the open admission of their true status and their being divested of any "final theory" air.

B.7 A cursory look at the technical progress

The main point of this appendix is to illustrate the vital necessity of philosophy – in its logical aspect – to sciences, at least as long as they reach the stage in their development when the science specific unity has to be rationally comprehended in order to continue moving forward. The science we chose for the purpose of such illustration was physics that conveniently happened to reach such stage in late 19th century, but, for reasons indicated earlier, was unable to make timely use of the best philosophy had to offer. The academic philosophy of the period chose to go into the *logic truncation* mode ultimately making physicists acquire the belief in philosophy's "unreasonable ineffectiveness," which helped them get entrenched even more than before in the "unreasonably effective" – seemingly one and only – mathematical way. Mathematics though, as was known already two centuries ago, is unable to express the *thought content*, making it unsuitable as the basis for proper theory development. Physics therefore was unable to produce a proper theoretical treatment of the physical (meta)-form of the universal motion which unavoidably held up its overall development in 20th century. In the absence of objective logic, relegated to historical status – in large part due to the degree of its difficulty – by the early 20th century (positivistic, greatly "simplified") philosophy, physics resorted to ad hoc subjective descriptions objectivation (which lent it some mysterious flavor[185] later used successfully in the popular sphere).

The obvious refutation of all such claims would be just a gentle reminder of the amazing progress made by science and technology *precisely in the century* when the alleged slow-down of scientific development (at least in what concerns physics) took place. So to wrap up this appendix, we would like to briefly comment on these issues. Specifically, if physics development did indeed slow down, there surely have to be some consequences in the sphere of technology, especially the cutting edge one, much of which is based on recent advances in fundamental physics. Of course, if one thinks that something has not been done, it is hard to demonstrate conclusively, due to the absence of point of comparison. Indeed, the role of the latter point could only be played by alternative history which is just that, no matter what one can say in its defense. We can do a bit better though by taking some earlier, hopefully qualified, long term *prognosis* based on an extrapolation of the previous rate of progress and taking into account the projected science development. And a prognosis fitting this description is luckily available: it is contained in the book of one of the leading science fiction writers and futurologists of 20th century A.C. Clarke, perhaps best known to the general public as the author of the science fiction book "2001: The Space Odyssey" that was used as a basis for the namesake movie. The name of the book we are going to consult this time is "Profiles of the Future: An Inquiry into the Limits of the Possible" [92]. It was originally published in 1962 and went through many editions later. Now, more than half a century since its original publishing, we can compare what A.C. Clarke envisioned with what actually transpired, concentrating especially on his predictions of achievements directly related to the fundamental science of physics.

The task is made especially simple due the author of [92] having provided a summary table at the end of the book. The table of forecasted achievements is divided into five categories: transport, information and communications, materials and production, biology and chemistry, and physics. While the last category is most closely related to the science of physics (by virtue of coinciding with it), the predictions comprising it are rather vague sounding and not discussed in any detail in the main text. So we will mention them last. Let us begin with the first one – transport. Understandably, it focuses on the cutting edge of transport which has to do with the outer space. Incidentally, we should note that this is the only category of science/technology which contains a factual (not forecasted) outlier. Namely, it is the only category, where a cursory look at the *actual* progress that has taken place since the time [92] was published, reveals a clear *negative slope* interval

[185] Indeed, who hasn't been fascinated with things like the "twins paradox" and spacetime "hidden dimensions," and, respectively, slightly awed by the people who could uncover such mysteries in the real world.

on the corresponding imaginary graph. Normally, one would not expect any technological *regress* barring some kind of catastrophical developments, especially during the "science age." What can (and should) be expected is a *slower (or much slower) rate of progress, relative to objective needs and possibilities*, caused by conservative *status quo* preserving tendencies of the particular alienated (in Hegel's language) social form. In this case however, according to the official history, six successful manned Moon landings took place in late 1960's and early 1970's, with capacity to spare, so to speak: three people in each crew, and even an electric vehicle having been brought to the Moon surface during several later flights. Moreover, the technology proved to be incredibly robust, able to withstand even a liquid oxygen tank *explosion* (!) in space and still return safely to Earth. (Think about any instance of an explosion on a plane, for comparison.) Fast forward over half a century, and we can read the following passage in the United States Government Accountability Office (GAO) report to congressional committees GAO-16-610 [93]:

> While NASA intends for Orion to provide an important capability for planned human exploration missions, the agency's **attempts over the past two decades** at developing a **human transportation capability beyond low-Earth orbit** have ultimately been **unsuccessful**.

So what became almost a routine practice around 1970 proved to be *impossible* in *two decades* worth of efforts starting over a quarter century later, with all the not insignificant progress in materials, production technology, and especially computation.[186] But disregarding this single outlier and the corresponding regress, let us take a look at the *progress* in human space transport. The first low orbital flight took place in 1961. The first orbital station was launched and began its operations exactly a decade later, in 1971. It made extended stays on low orbit possible by virtue of increased inhabitable space. What is available in 2021, exactly half a century later? Very much the same orbital station with exactly the same means of shuttling its crews back and forth. Due to the progress in photographic, video imaging and communications technology however, the crew members can easily take better pictures, make better videos and share them with friends on social networks.

Now let us compare to A.C. Clarke's predictions. In the summary table from [92], we find the following forecasted dates. 1970-1980: Landing on the Moon, cosmic laboratories, rocket with nuclear propulsion. The first two prediction – counting the outlier we just discussed – were fulfilled, if one considers an orbital station a version of cosmic laboratory. Nuclear propulsion was actually discussed in 1950's in the course of the so-called "Project Orion"

[186] A glancing look at a microprocessor speed in 1970 and, say, 2010 should be sufficient to confirm the latter observation.

(in which F. Dyson, one of the founders – along with R.P. Feynman, J. Schwinger and S. Tomonaga – of the modern quantum electrodynamics, was an active participant). That project had actually a humorous side to it as the nuclear propulsion was supposed to take the form of a series of small size *fission bombs (i.e. A-bombs) explosions* within the confines of the ship. The projected size of a single bomb was in the range of 30 to 350 *tons* of TNT equivalent. Anybody remotely familiar with the effects of TNT would be able to see right away that such flight would have been over upon the very first turn of the "ignition key." Nuclear powered propulsion is most likely possible, but not in that form. Let us look further down the first column of the table. 1980: Landing on the (Solar system) planets; 2000: Planet colonization. Any comments here would really be redundant. Going still further down, we find automated *interstellar* probes by 2020, gravity control by 2050, near-light speed propulsion by 2070 and interstellar manned flight by 2080. While 2070 is still another half a century away, it is abundantly clear that science and technology at this time are not on the forecasted trajectory, to put it mildly.

Let us turn to the information and communication technology category. The actual state of progress looks a lot better there, in comparison with that of transport, relative to A.C. Clarke's predictions. In particular, World Library was projected in [92] by about 2005. While we do not have an official global library, the totality of web sites augmented by fast search engines can be said to more or less play its role for many practical purposes. Finding a book at will in a few minutes without leaving one's study has become possible to a significant extent (with exceptions). While satellite communication technologies are not in the table, they are mentioned in the text of [92], and his prognosis overall got fulfilled remarkably well. The table also has artificial intelligence by 2000 and robots by early 2020's. Here, one has to realize that the artificial intelligence that was hoped for in 1960's and the AI of our days are two very different notions. The artificial intelligence of the era of the original cybernetics was envisioned as having all main attributes of the natural intelligence: as "thinking machines" in the literal sense of the world "thinking." In the course of the ensuing attempts to understand and model the workings of the human mind (mostly in mathematical terms), cybernetics passed over into the much less ambitions modern "computer science," and the AI became associated with neural networks and machine learning. Still, the construction of a machine ("Deep Blue" for example) that – even though it could not break into the "thinking" category in the original cybernetic sense – made any human not a match to it in chess,[187] has to be mentioned here as an impressive achievement nevertheless.

The third category – materials and production – has efficient electric accumulators by

[187]At this point, one can recall Hegel's view on the relation of formal logic, mathematics (to which chess bears a lot of logical resemblance) to thought as such.

mid 1970's and *controlled fusion* by 1990. The latter has an interesting history which by now resulted in a joke that controlled fusion is always 30 years out and that is a (fundamental) constant. Given that A.C. Clarke was writing the original version of his book around 1960, it is possible that the joke was already going around at that time, perhaps not in the status of a joke yet. So where is it now, six decades later? You guessed it: 30 years out. Actually not quite: now it is more like 25, and this time – naturally – it is for real. 2010 has weather control in store, and 2030 – mining for minerals in the outer space (Moon and planets). The latter prediction is obviously conditioned on the respective transport, and is therefore of a somewhat derivative nature. A.C. Clarke positioned it 30 years after planet colonization (in the form of bases, most likely). It is hard to fault such choice.

As we already mentioned, A.C. Clarke's forecasts for the science of physics are of a somewhat vague variety. An interesting prediction – a discovery of nuclear catalysts – is dated around 2020. Such catalysts would make nuclear reactions – in particular that of fusion – possible at much lower temperatures making possible the so-called "cold fusion." A.C. Clarke places it 30 years after the standard "hot" controlled fusion. In our view, that could be a bit on the conservative side. If and when the controlled fusion is obtained, the necessary for it rational (i.e. not just superficially descriptive, and not relying on any postulates) understanding of the corresponding form of the universal motion would most likely make cold fusion possible soon after. By about 2060, A.C. Clarke predicts the advent of "space and time control," apparently referring to their now famous – and very fascinating – "structure" and "curvature" being manipulated in a laboratory. In this connection, it is interesting to observe the extent to which the *fascinating* (all stemming from the main *material eidos* of the mathematical neoplatonism, as we know) aspects of the modern theoretical physics got a hold over even the people consciously practicing the anti-conservative attitude, like the author of [92]. Indeed, the first two chapters of [92] are mostly devoted to a rather derisive style critique of various science and technology naysayers of the recent past, especially ones with some reputation, who managed to seriously underestimate the present potential for scientific and technological progress. Also, A.C. Clarke, as an enthusiast of science and progress, was certain that science and humanity as a whole are just in the very beginning of their knowledge and discovery journey (to which opinion of his we agree). Thus, for example, in the end of Chapter 8 of [92], one can read the following rather poetic passage:

> Despite the perils and problems of our times, we should be glad that we are living in this age. Every civilization is like a surf-rider, carried forward on the crest of a wave. The wave bearing us has scarcely started its run; those who thought it was already slackening, spoke centuries too soon. We are poised now, in the precarious but exhilarating balance that is the essence of real living, the

> antithesis of mere existence. Behind us roars the reef we have already passed; beneath us the great wave, as yet barely flecked with foam, lumps its back still higher from the sea.

At the same time, in the next chapter of the same book, the reader is presented with the view from which it transpires that our still feeble science that only makes its first steps on the road of knowledge had nevertheless already managed to get hold of the ultimate laws of nature. Thus one can read: "The velocity of light is the **ultimate speed limit**, being part of the **very structure of space and time**."[188] Speaking of the future interstellar travel in Chapter 10, A.C. Clarke again (justly) criticizes the overly conservative scientists who do not believe that it would ever be possible:

> Many conservative scientists, appalled by these cosmic gulfs, have denied that they can ever be crossed. Some people never learn; those who not long ago laughed at the idea of travel to the planets are now quite sure that the stars will always be beyond our reach. And again they are wrong, for they have failed to grasp the great lesson of our age – that if something is possible in theory, and no fundamental scientific laws oppose its realization, then sooner or later it will be achieved, granted a sufficiently purposeful incentive.

But still, even for purposefully progressive writer and futurologist A.C. Clarke, that interstellar travel is *absolutely and forever doomed* to remain – for its purpose – snail slow, taking about five years even to the *nearest* star:

> Every technical device is always developed to its limit (unless it is superseded by something better), and **the ultimate speed for spaceships is the velocity of light**. They will **never** reach that goal, but they will get very close to it. And then the nearest star will be less than five years' voyaging from Earth.

Several paragraphs later however, A.C. Clarke allows himself to relax that fundamental and final constraint and says: "Can we be *sure* that the velocity of light is indeed a limiting factor? So many 'impassable' barriers have been shattered in the past; perhaps this one may go the way of all the others." Indeed, just in the very beginning of our intellectual history, how can we now be *sure* of something that – as far as full-fledged practice (the ultimate

[188]We can recall at this point that the author of the idea of space and time "structure" realized by 1920 that the very presence of any structure there can be due only to some material "filler," that nevertheless had to be denied the said structure by all the "serious theorists," to avoid making the theory too difficult (and perhaps objective thought content too unavoidable).

criterion of truth) involving it is concerned – logically belongs to the future, home of *a lot* more intelligent humanity? A.C. Clarke, however, does not *really* think *that* particular barrier could possibly turn out to be passable, in spite of all others that have been shattered. So he backtracks right away: "We will not argue the point, or give the reasons why **scientists believe** that light can **never** be outraced by any form of radiation or any material object." What's ironic here is that A.C. Clarke just reproached "conservative scientists" a minute ago for being too conservative. Could it be possible that those scientists who believe that light can never be outraced belong to the conservative group? What about the scientists who (in spite of being in the *very* beginning of this science) established that "fundamental" law? Is it really that simple? What we want to point out here is that A.C. Clarke himself is not at all alien to the conservative attitude, which observation makes his prognosis we are reviewing here an even more reliable comparison point.

Let us summarize the results of our improvised comparative analysis of the *still rather conservatively*, but with the belief in the fundamental science being on the right track, prognosticated technological achievements with the actual ones. As we have seen, the situation with information and communications technology – discounting the "real" artificial intelligence – looks the best. On the other hand, that with outer space transport and the mastery of the physical (meta)-form of the universal motion (that is most likely required for controlled fusion) appears – even relative to the mildly conservative prognosis and discounting the regress-indicating outlier – to be on the rather appalling side. It is fair to say that the main obstacle on the path to space transport progress is the lack of the (significantly) more advanced means of propulsion. For instance, given its current state (virtually identical to that present half a century ago), it is relatively clear that, if a method of reliably lifting even several hundred tons to the low orbit had been available, the other challenges of Solar system manned travel (such as radiation protection) would have been overcome even at the current level of development. The same method would have likely had no trouble reaching the third cosmic velocity and beyond, making Solar system transport a lot more "Sun gravity independent." But, as A.C. Clarke correctly noted in his book, in order to really master the Solar system and to go beyond it, a fundamentally different propulsion mode would likely be needed. That mode could possibly be based on gravity, or rather quasi-gravity. Namely, if the same kind of ether motion that causes gravity could be properly understood and generated, virtually any acceleration could be sustained without any ill effects. Also, since the speed of gravity propagation is many orders of magnitude higher than that of light, speeds required for effective interstellar travel could be achieved. Preliminary estimations indicate that, in natural gravity, this particular mode of ether motion appears as an artefact of sorts which is the reason for its extreme (compared to electromagnetism, for instance) weakness. Thus, when the means of its purposeful generation are discovered, it will likely be just as universal (in particular, acting equally on all nucleons of all physical bodies in its range), but a lot stronger. A.C. Clarke in his book places gravity control around 2050. On the current science and society trajectory, this is highly unlikely, to put it very mildly. In particular, the descriptively mysterious "absolutely electromagnetic" relativity paradigm (which, while admitting the ether existence, stays on its guard against ascribing a state of motion to it at all costs) serves as a reliable insurance against any rational understanding thereof.

What are the main reasons for the information and communications technology having enjoyed an incomparably more significant progress to the extent of almost fulfilling some of A.C. Clarke's mildly conservative predictions? Given what we now know about philosophy (logic) and physics, this appears to be a relatively simple question. The progress in this area largely hinged on two developments: algorithms and software on one hand, and semiconductor/optical technology on the other. The former one is almost entirely applied mathematics (including mathematical logic) which is the area that – as opposed to philosophy – benefitted from the works of Frege, Peano and many others outstanding researchers in 20th century. Being the realm of external relations, it could do little for rational comprehension of natural intelligence, which explains the gradual near disappearance of the goal of producing a thinking machine from the technological landscape. The developments in semiconductor/optical technology that sustained the progress in computation and communications area – as far as physics is concerned – depended on quantum mechanics and also classical optics and electromagnetism. Quantum mechanics, as we mentioned earlier in this appendix, is the least "crazy" of the modern physics theories and is – in its current form – capable of good phenomenological descriptions of phenomena from the atomic scale up. Optics and electromagnetism phenomena enjoy the luxury of being easily accessible and producible in a laboratory,[189] which was the reason for an extensive scientific and practical experience physicists and engineers accumulated during the last two centuries. Such experience was able to go a long way towards filling in theory gaps, especially where applications were concerned. Information Theory, incidentally, which also played a major role in the development of these technologies, enjoyed similar advantages. Thus probability distribution – the universal form of (incomplete) specific information – was developed in the course of the analysis of games of chance by mathematicians of 16th to 19th centuries. Such games of chance can be thought of as a near-perfect "laboratory" case of incomplete specific information. Later, Shannon's entropy (along with related quantities) was obtained in the course of exploring the problem of optimal compression and transmission of messages, the setting which presented a good

[189] One might recall that is was that ease and "friendliness" of optics and electromagnetism that prompted some early 20th century physicists (primarily those labeled "serious theorists" by A. Einstein) looking for simple and elegant – while at the same time utterly fundamental and "final" – theories to use their phenomenology as a basis for such constructs.

opportunity to get hold of abstract information, as we described in the main part of this article.

Finally, let us remark on the main source of A.C. Clarke's conservatism (which, as we noted, actually made his forecasts a better comparison point). On the surface, the book [92] reads like one written by a great optimist and enthusiast of science and progress, which of course it is to a large extent. The conservatism in question is more difficult to spot. It can be seen, for instance, in the author's unshakable belief in an absolute and final status of some modern physics claims that were – at any rate – a result of a very early and raw attempt at finding the objective truth in that specific domain. The said conservatism has a philosophical (logical) origin. A.C. Clarke – much like B. Russell – is a philosophical pluralist (i.e empiricist and eclectic). And any pluralism (empiricism, eclecticism) unavoidably generates a conservative gnoseological position as it leads to some absolutisation of the currently existing transient forms of social practice, which is where cognition is rooted by virtue of being – in its totality – the ideal aspect thereof. A rather clear sign of such eclecticism in [92] is the author's casual mention of commercial information exchange between future humanity populated planets whereas, dialectically (i.e. "holistically") speaking, developed space travel and commerce belong together even less than GPS satellites and feudal corvée labor. At the same time, one has to admit that A.C. Clarke's progressive general attitude mitigates his (most likely not fully articulated, implicit) philosophical empiricism. Thus, for instance, he writes in Chapter 8 (devoted to the subject of outer space transport) of [92]:

> The whole structure of American society may well be unfitted for the effort that the conquest of space demands. No nation can afford to divert its ablest men into such essentially non-creative, and occasionally parasitic, occupations as law, advertising and banking.

If one replaced the adjective "American" in the quotation above by something like "quasi-intelligent" or "alienated" (qualities that have little to do with nationality), one would obtain a rather accurate, if a bit superficial, characterization of objective reasons for the proper space travel being most likely unachievable at the corresponding stage of societal development. Speaking of the immediate reasons for such incompatibility, one could also add that it is not just the waste of talent on non-creative endeavors noted by A.C. Clarke, but – even more importantly – the impossibility of developing such talents and putting them together in a sufficiently "synergistic" for such an advanced task way in what is an essentially *contentious* society still largely motivated by survival related considerations.

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