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THE CONCEPT OF NATURE, THE EPISTEMIC IDEAL, AND EXPERIMENT: WHY IS MODERN SCIENCE TECHNOLOGICALLY EXPLOITABLE?

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1. Introduction

This question this essay poses, and attempts, to some degree, to answer, is as follows: What features of modern natural science are responsible for the fact that, of all forms of science, this form is technologically exploitable? The three notions mentioned in my title, the concept of nature, the epistemic ideal, and experiment, suggest the most important components of my answer. I will argue, first, that only the peculiar interplay of the modern concept of nature with an epistemic ideal attuned to it can cast experiment in the specific, highly central role it plays in the pursuit of knowledge about nature. It will then become clear that the form of science in which experiment plays such a role will, necessarily, prove technologically exploitable.

So as to draw attention to the specificity of the modern concept of nature, I begin in section 2 with an exposition of the concept of nature characteristic of Aristotelian science. A discussion of the modern concept, in which both continuities and discontinuities with the Aristotelian concept will become apparent, follows in section 3. In section 4, I consider the divergent epistemic ideals of Aristotelian and modern science; the difference between them, which can be traced back to the differing concepts of nature, will explain why experiment can play its pivotal role only in modern science. Finally, section 5 will illustrate why such science, proceeding, as it does, by experiment, must necessarily be technologically exploitable. Section 6 recapitulates the line taken in this essay.

2. The concept of nature in Aristotelian natural science

Aristotelian natural science[1] concerns itself not with the set of all in principle perceptible things, but only with a particular subset: the set of objects that exist "by nature," or the set of natural objects. This set encompasses, above all, animals, plants, and their natural parts, as well as the Sun, the Moon, the Stars, and the "elements," earth, fire, water, and air. What all these have in common,

1. My primary source in this section is Aristotle's Physics, especially Book II. Layman's introductions may be found in Craemer-Ruegenberg (1980) and Solmsen (1960). Seeck (1975), Broadie (1982), and Judson (1991) offer important discussions of individual issues. All of these works include thorough bibliographies.

according to Aristotle, is that they contain the ground of change and motion peculiar to them (or their peculiar rest-states) within themselves, and instantiate such motion and change when given the appropriate impetus. This common feature seems quite plausible when the normal motion and change of such natural objects is contrasted with the motion and change of artifacts. Compare, for example, the growth of a tree with the growth of a high-rise. While the tree grows by itself, so long as certain conditions obtain, the growth of the high-rise depends on a persistent, external impetus: the activity of building. Similarly, massive bodies fall by themselves, fire rises by itself, the Sun, Moon, and stars circle the heavens by themselves, and people and animals can move or come to rest by themselves. Artifacts are thus excluded from the domain of natural science from the very outset by the fact that they don't become what they are by themselves. To be sure, they also undergo "natural" motion and change, as when a vase falls to the floor or a wooden beam rots, but such motion and change have to do not with their status as artifacts, but with the natural qualities of their component materials. Natural objects thus bear the grounds of their motion and change within themselves; these motions and changes are characteristic of them, or determined by their "nature." The word 'nature' must evidently be used in a second sense here; where, first, we used it to signify the totality of natural objects, we now use it to refer to the characteristics of natural objects. Or, to use a word that has now come to be despised, we might say that the grounds of motion and change peculiar to natural objects reside in their <u>essences</u>. Such essential or natural motions and changes include, for example, the orbits of heavenly bodies, the downward motion of massive bodies, and the growth of plants and animals to their full stature. The essence or nature of a natural object, as expressed in an essential definition given in response to the question, "<u>What</u> is this?" is something <u>universal</u>; it applies <u>in common</u> to all objects in the given class.

For Aristotle, natural motions must be understood teleologically, as directed at some goal (<u>télos</u>). This understanding is plausible when we consider the growth of animals and plants; their developmental processes may appear organized (up to a point) with a view toward their adult forms. It's less plausible for us when we recall the motions of stones or stars; for Aristotle, the motion of a stone is directed toward the stone's natural resting place, the location dictated by the stone's essence, which coincides with the center of the Earth. As for the <u>télos</u> of stellar motion, its explanation lies so deeply embedded in Aristotelian metaphysics that, for present purposes, we may disregard it. At any rate, we have now discovered the objective of Aristotelian natural science: Aristotelian natural science examines natural objects with a view toward their natural motions and changes. Implicit in this project is the suggestion that even natural objects may undergo certain kinds of motion and change whose study lies outside the realm of natural science. Such motions and changes are just those which aren't indicated by the essence of the natural object in question. While in explaining the growth of a tree, one has recourse to the tree's essence, in these cases, by contrast, one has no such recourse to the essence of the natural object, or to its teleological constitution, when enquiring into the cause of motion or change. Such processes must instead be ascribed to some "external force." Again, this ascription is easily understood given the Aristotelian conception of the natural motion of natural objects. A stone may undergo upward motion, but only when "forced" to do so, say by someone throwing it. This is an unnatural motion for the stone.

True natural science, in Aristotle's sense, doesn't investigate such unnatural motions and changes. To be sure, it doesn't deny them, either, though it excludes them from "nature," its proper area of study. For nature encompasses only the totality of natural objects, conceived in terms of their essential motions and changes. One might say that, in some sense, the task of "basic natural science" thus consists in finding the essences of natural objects; for the other features of natural objects may all be derived from their essential definitions.[2]

To summarize:
1. Aristotelian natural science aims at knowledge of universalities.
2. These universalities are one-place predicates, namely those which specify the essential attributes of the elements of a given class of natural objects.
More briefly still, Aristotelian natural science examines nature with a view toward predicative universalities.

3. The Concept of Nature in Modern Science

The modern understanding of nature (conceived as the set of all natural objects) is heralded by the appearance of a concept unknown to Aristotle, the concept of a natural law.[3] We have now come to take this notion completely for granted, along with the view that it's the job of natural science to determine the natural laws with whose help we engage in scientific explanation and prediction. The natural sciences (in opposition to the social and human sciences) have even been defined as the "nomothetic" sciences, the sciences which set up laws. Nonetheless, a long, heated debate has been carried on over the precise definition of the notion of a natural law, an issue on which there's still no consensus.[4] Two features of natural laws, however, have never been disputed: natural laws are both universal and relational. For our purposes, it will suffice to insist on these two features. The universality of natural laws asserts the constancy of nature at all places and times, in the following sense: ceteris paribus, nature will behave in the same way, irrespective of time or place. The relationality of natural laws asserts that such regularities hold between the elements of one class and the elements of another (not necessarily distinct) class of natural objects or properties of natural objects. The search for the essential attributes of natural objects (or for their "nature") is thus banished from the realm of scientific enquiry, either because it's unimportant by comparison to the search for natural laws, or because it's held to be unattainable within the bounds of natural science.[5]

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2. It should be noted, however, that Aristotle, in his scientific writings, seldom follows this axiomatic scheme.

3. See Zilsel (1942), Reich (1958), Schramm (1981), and Ruby (1986). Paul Feyerabend has objected to this claim, arguing that Aristotle did, in fact, recognize natural laws, most notably the famous statements of proportion in Physics VI.8 and VII.5. Even if I concede that these are lawlike statements, the central thesis of my last section, which claimed that Aristotelian natural science aims primarily at predicative universalities, remains untouched. To be sure, the statements of proportion may serve an auxiliary function.

4. See Stegmüller (1969), Ch. V, for a survey.

5. Consider, for example, the first sentence of Newton's Preface to the Principia: "... the ancients (as we are told by Pappus) esteemed the science of mechanics of greatest importance in the investigations of natural things, and the

With the introduction of the concept of a natural law, certain distinctions central to Aristotle's understanding of natural science become inconsequential.[6] First, the distinction between "that which is by nature" and artifacts loses its scientific relevance. The universality of natural laws makes it irrelevant whether objects came about with or without mediation by human agents. All that counts is whether the conditions under which a natural law predicts certain values for its dependent variables have been fulfilled; how they may have been fulfilled is of no importance. Secondly, the notion of unnatural motion and change becomes scientifically meaningless. In its new sense, on which nature is conceived as the arrangement of all physical things (including fields) in accordance with natural law, there can't, on purely logical grounds, be anything unnatural, for such would contradict the very idea of natural law. The notion of something's being unnatural in the old sense of nature, however, is irrelevant, for the same reasons as the distinction between natural and artifactual objects.

These consequences of the introduction of the concept of a natural law are illustrated quite well by the example of mechanics. For Aristotle, the natural motion of terrestrial bodies is always vertical; heavy bodies move toward the center of the Earth, and light bodies move away from it. Celestial bodies naturally move in orbits. When we look for the analogue of such natural motion in Newtonian mechanics, we find Newton's first law of motion, on which "every body continues in its state of rest, or uniform motion in a right line, unless it is compelled to change that state by forces impressed upon it."[7] "Natural" kinetic states would now appear to be rest and uniform, linear motion in an arbitrary direction, where such states certainly aren't normal, in the sense of frequently observable; in fact, strictly speaking, they never occur at all. Obviously, it would be absurd to restrict mechanics to the examination of such motions at the cost of denying it all objects of study. And so, under the new conception of nature, the distinctions constitutive of the Aristotelian conception lose all meaning.

To summarize:

1. Modern natural science aims at knowledge of universalities.
2. These universalities are relations, namely those which specify the lawful associations between elements of given classes of physical things (including fields) or aspects of them.

More briefly, modern natural science examines nature with a view toward relational universalities.

4. The concept of nature, the epistemic ideal, and the role of experiment

Up to know we have been considering what natural science takes as its topic (i.e. whatever one conceives as nature), without considering how this topic is to be approached. To view this latter question as asking only after the methods of science would be over-hasty; we must also ask

moderns, rejecting substantial forms and occult qualities, have endeavored to subject the phenomena of nature to the laws of mathematics ...".

6. On this issue, compare Heidegger (1968).

7. Newton (1687), Lex I.

which epistemic ideal guides the scientific tradition in question. For scientific methods are meaningful and warranted only relative both to an object domain conceptualized in a certain way, and to a corresponding epistemic ideal. The epistemic ideal and the conceptualization of the object domain are not mutually independent, since the epistemic ideal must be viewed as in principle attainable, if it is to provide any meaningful guidelines for scientific efforts. The epistemic ideal of modern natural science, for example, doesn't demand apodictic proofs (in the mathematical sense) for candidate natural laws, not because apodictic proofs are in any way despised, but because they are thought unattainable in the study of nature. Roughly speaking, one might say that the concept of nature determines which questions may be asked, while the epistemic ideal determines which answers are legitimate.

4.1. The Aristotelian epistemic ideal, like that of the axiomatically structured Euclidean geometry, is that of science-as-proof.[8] It demands "first principles," which include, in addition to general rules, the essential definitions of the given scientific field's objects of study. The essential definition of an object lists those attributes which necessarily pertain to the object, simply in virtue of its being what it is. Further propositions may then be logically deduced from these first principles. An acceptable proposition of science is thus one sufficiently warranted, or proved, from first principles. The first principles themselves cannot, of course, be justified in this way. We are persuaded of their necessary truth by a special process of induction, distinct both from complete, mathematical induction, and from modern science's generalizing induction. In this process, the intellect somehow distills what's essential out of a range of remembered individual perceptions, thus allowing us to determine the essential definition, a necessary truth.

To be sure, one might doubt whether this epistemic ideal can ever be attained, or whether the explanations it provided would satisfy us. These issues need not concern us here. For our present purposes, we must recall two features of this epistemic ideal. First, it corresponds to the Aristotelian concept of nature, in the sense that any enquiry which pursued it could legitimately explore all knowable features of Aristotelian nature. Secondly, while this project of enquiry demands some empirical effort in the sense of systematic observation, it does not call for experiment. Systematic observation might include, for example, the dissection of organisms, say for the purpose of determining certain differences between species. But the Aristotelian study of nature can't grant scientific experimentation any pride of place. This feature of Aristotelian science may be understood, first, as a consequence of the epistemic ideal of science-as-proof; by this standard, experiment per se can't make contribution to knowledge, since it lacks the rigorous authority of proof.[9] One is naturally prompted to ask why Aristotle failed to modify his epistemic ideal in such a way as to allow for the exploitation of what, for us, is an extremely important source of knowledge. It seems to me that the answer to this question is just that there is no possible epistemic ideal compatible with the Aristotelian concept of nature on which experiment, as

8. The most important source on this issue is Aristotle's so-called Posterior Analytics. For some useful commentary, see Barnes (1975) and Berti (1981).

9. This is the line taken, for example, in Dingler (1928), p. 214.

employed in modern science, can be relevant; experiment becomes scientifically relevant only given the modern concept of nature and its corresponding epistemic ideal. But before I can justify this claim, we must first direct our attention to the epistemic ideal of modern science.

4.2. The epistemic ideal of modern natural science is the "hypothetico-deductive" model.[10] In this model, the first principles are the (most general) natural laws, and from these, together with initial, boundary, and perhaps other conditions, particular claims may be (approximately) derived. If it were possible to confirm the natural laws directly, without reference to the particular claims deduced from them, then the certainty ascribed to first principles could be transferred, at least approximately, to derivative claims. But direct confirmation isn't possible; the truth of the natural laws must always remain hypothetical, since we know of no way to verify them directly and completely. At best, only the most particular claims derived from natural laws with the help of initial and boundary conditions can be confirmed quasi-directly, i.e. empirically (and even here, the validity of certain other theories must always be assumed). In this way the law-hypotheses may receive confirmation, albeit confirmation of a rather indirect and incomplete variety.

Three features of this epistemic ideal must be recalled. First, in this case, too, the epistemic ideal caters to the concept of nature, by doing justice to the central role of natural laws. Secondly, this epistemic ideal is clearly weaker than that of Aristotle, for it contents itself with hypothetical truth, where Aristotle required insight into the necessary truth of first principles. Thirdly, experiment now becomes relevant in addition to systematic observation, a circumstance we must consider more closely.

4.3. At first blush, the many goals in the name of which modern science undertakes experiments appear fairly heterogeneous. Experiment determines the properties of various materials and the values of natural constants, it decides between competing hypotheses by experimentum crucis, clarifies which variables are relevant for a given phenomenon, tests candidate hypotheses, produces the data needed for the quantitative formulation of functional dependencies by testing appropriate controls, demonstrates the possibility of certain phenomena, and so on. But when such uses of experiment are examined together, it quickly becomes clear that all of them aim at confirming law-hypotheses (or entire theoretical structures), or at making them more precise.[11] How and why does experimental activity further these aims, so fundamental to modern natural science? In the three interrelated points which follow, I will try to provide an answer to this question which, at the same time, also makes it clearer why experiment must remain irrelevant to the Aristotelian form of natural science.

First, I note that as far as the modern concept of nature is concerned, whether a given phenomenon occurs "by itself," in nature, or rather as a result of purposeful activity in the laboratory, is irrelevant to its status as a legitimate object of inquiry for natural science. This, we

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10. See e.g. Diemer (1970), 213.

11. Since this account of experimentation operates at a fairly abstract level, I see no need to confront the recent literature on this topic, e.g. Franklin (1986) and (1990), Galison (1987), Gooding (1990), Hacking (1983), and Tetens (1987). There are some parallels in Tetens' book to the present study which I discovered only after its completion.

recall, was a consequence of the introduction of the concept of a natural law (section 3). The collapse of this distinction in no way denies that between in vitro and in vivo experiments, nor does it deny the possibility of artifacts in animal (and human) behavior studies conducted under laboratory conditions. When such artifacts occur, it simply means that we either haven't identified all the relevant variables, or that we can't adequately control for them. On the Aristotelian conception of nature, by contrast, the idea of experimental intervention in the very processes which natural science is supposed to investigate is rather alien; for such intervention would disturb a natural object's motion or change in accordance with its essence.[12] For modern science, however (with the possible exception, in certain cases, of quantum mechanics), there can be no situations in which experimental intervention is fundamentally at odds with the epistemic goal, and not simply practically unfeasible.

Secondly, having shown that experimental, scientific intervention in the workings of nature is compatible with the modern concept of nature, we might reasonably ask what purpose it serves. Natural laws, as we saw earlier, establish relations. Their relata are the elements of certain classes of things (or of aspects of things), and are usually (though not always) described quantitatively. Familiar examples include, for example, Newton's universal law of gravitation, which asserts a relation between force, masses, and distances between them, or Maxwell's equations, which articulate a relation between electrical charges, their motions, and electric and magnetic field properties. From such relations, further, more specific relations may be derived (approximately, and with the help of other assumptions). In these latter relations "dependent" variables may be distinguished from "independent" variables, where this distinction may be undertaken in a variety of different ways. Those whose values can be fixed arbitrarily, and whose values in turn determine the values of the dependent variables, may be counted as independent variables. For purposes of quantitative description, the mathematical structure of the relation is represented by means of a function. If certain values for the independent variables are practically realizable (which implies the absence of disturbing conditions), and if the corresponding values for the dependent variables can be empirically determined (where theoretical assumptions and judgements may play a role that determination, one we cannot discuss here), then the specific relation, as gleaned from experiment, may be compared with that derived from the law-hypotheses. Antecedent law-hypotheses may thus be tested by data points--whether such testing is done with the intention to confirm or to falsify doesn't matter, here--or conversely, data points earned may be applied toward the projection of as-yet unknown laws. If the experiment is not reproducible, insight is at least gained into the missing control, or into the inadequacy of present knowledge of the relevant variables.

Even this rather schematic account of the relationship between theory formation, theory testing, and experiment, should suffice to show the decisive importance of the relational character of natural laws. This relational character is a necessary condition for the possibility of distinguishing dependent from independent variables, which is in turn a necessary condition for the discourse between theory and experiment. This dependence becomes even more obvious when

12. On this issue, compare Kuhn (1976), p. 55.

we ask whether experiments could prove informative in the Aristotelian study of nature. It's clear, trivially, that experiment must be irrelevant in the process of deduction from first principles (compare section 4.1), for this is the job of the logician. But even in the assembly and testing of the first principles characteristic of a given scientific field, i.e. the essential definitions of its object domain, experiment remains irrelevant, and not only because the epistemic ideal sets standards so high that experiment must be discounted for lacking the authority of proof. The essential definitions to be found (or tested) assert, for some attribute P, that it essentially pertains to some natural object S qua member of a certain class; they are statements of the form. "All S's are essentially P." Now in order to show that a given attribute P is essential, it's not enough to show that all S's have it. For example, all and only humans have earlobes, yet earlobes aren't what makes them what they are; they aren't an essential feature in the Aristotelian sense. The insight that a given feature of S is an essential feature is an accomplishment of the intellect, and so it's obvious that experiment can't aid in the immediate production of such insights.

But mightn't experiment make some mediated contribution to essential insight, offering the intellect a broader choice by revealing features of the object under study which might not otherwise be observable, but which are nonetheless candidate essential attributes? Consider, for example, the electrical conductivity of metals, which is most clearly exhibited in experiment, and seems a good candidate essential attribute. But from the perspective of Aristotelian natural science, it would most likely have to be objected that attributes exhibited primarily in the experimental context simply aren't candidate essential attributes. For it's precisely in the experimental context that a natural object fails to behave in accordance with its nature, since it's subject to external intervention.

To summarize this second point, we can say that the information gained from experiments is applicable to relational, universal law-hypotheses, but inapplicable to predicative, universal essential attributes.

Thirdly, we must assess the manner in which the epistemic ideal geared toward a given concept of nature co-determines the weight placed on experiment. As suggested above, modern natural science lends markedly less credence to its first principles (the natural laws) than does the epistemic ideal of Aristotelian science, for it contents itself with hypothetical, rather than necessary truth. This concession is of decisive importance for the role of experiment. If we demanded insight into the necessary truth of our natural laws, either by certain intuition or by rigorous proof from indubitable premises, then information gained by experiment would be, at most, of heuristic interest. Its status would be comparable to that of measurements showing that the average measured angular sum of a planar triangle, over several trials, is 179.8°∀0.6°; at best this result would motivate us to attempt a rigorous proof that the angular sum is precisely 180° for all planar triangles. But once mere hypothetical truth is set as the standard for natural laws, experiment may acquire the statues of ultimate authority it occupies in modern natural science.[13] And so yet another factor in the irrelevance of experiment to Aristotelian natural science emerges: given Aristotle's epistemic ideal, experiment could play, at best, a heuristic role.

13. See e.g. von Weizsäcker (1947), p. 5.

But mightn't Aristotle have weakened his epistemic ideal so as to allow a more meaningful place for experiment? I think not. For the status to be granted experimentation is decided by the concept of nature. In the modern conception of nature, only the notion of a natural law provides for a possible intersection between theory and experiment; when an epistemic ideal geared toward natural laws is adopted, this intersection becomes fundamental. By contrast, the Aristotelian concept of nature is hardly compatible with selective human intervention in the workings of nature for purposes of epistemic gain, and this incompatibility is not to be overcome by any qualification of the actual Aristotelian epistemic ideal.[14]

5. Technological Exploitability

In the discussion which follows, we shall be concerned with experiment as a means of testing law-hypotheses.[15] By section 4.3, such testing can occur when the following conditions have been met:

1. There is an antecedent law-hypothesis.
2. This law hypothesis may, for an imagined case, be instantiated in such a way that independent and dependent variables may be distinguished, and the values of the dependent variables theoretically deduced (at least approximately) from the values of the independent variables.
3. Within the prospective domain of testing, various possible values for the independent variables in the imagined case may, given the conditions (explicit and tacit) specified under 2., be realized with sufficient precision.
4. The values of the dependent variables may more or less directly be empirically determined with sufficient precision; for ease of exposition, I will call this process measurement, even for cases in which the dependent variables lack quantitative formulations.

In the performance of an experiment, then, a range of values for the independent variables are practically realized, and the corresponding values for the dependent variables measured. These realized or measured empirical values can be compared with the theoretical values yielded by the law-hypothesis. If both theoretical deduction (2.) and experimental implementation (3. and 4.) have been conducted without error, and if the experiment is reproducible, the correspondence of both sets of values, to within the limits of experimental error, constitutes a confirming instance of the law-hypothesis.

Action in the physical world is thus constitutive of one component of all experiments: the realization of certain target values for the independent variables. I shall call the realization of a particular set of values for the independent variables point-wise testing procedure. Experimental

14. Compare my analysis of the absence of experimentation in Aristotelian natural science with that of Dijksterhuis (1950), pp. 70-71, in which the conceptualization of nature plays no role.

15. My talk of "law-hypotheses" diverges from the common practice in the natural sciences, in which one usually talks of the experimental testing of "hypotheses," "theories," and "assumptions." All of these, however, are universal relations of the kind I have called "law-hypotheses." Testable "models" are usually idealizations of certain universal relations.

testing of a law-hypothesis thus consists in theoretical preparations, a series of point-wise testing procedures, the measurements of dependent variables which follow, and, finally, the interpretation of the experiment. Point-wise testing procedures have positive results when they bring about values of the dependent variables which reproducibly accord, within a given margin of error, to those deduced from the law-hypothesis.

Like all action (in the narrow sense, which presupposes agency), point-wise testing procedures have both "internal" and "external" aspects.[16] The internal aspect of an action includes the action's goal (that which the action is supposed to achieve), as well as an assessment in accordance with which the agent deems the goal of this particular action attainable. The external aspect of an action includes its physical parameters, such as the muscular activity of the agent's body, or the effects of such activity, insofar as they are conscious and willed (otherwise, they aren't an aspect of the action, but of the action's effects). The goal of a point-wise testing procedure is to test the law-hypothesis over a certain range of values for the independent variables. Accordingly, the tester makes the assessment that these values must be realized. The external aspect of a point-wise testing procedure includes, in addition to muscular activity, the agreement or disagreement of the measured values of the dependent variables with those predicted by the law-hypothesis.

We are now in a position to state the connection between the typical features of modern science and the possibility of technological exploitation.[17] Something is technologically exploitable if it expands the possibilities for technical action. Technical action is behavior "through which humans intelligently reshape natural substance and energy, so that they better serve our purposes."[18] Now, every point-wise testing procedure with positive results may be repeated. It follows that the external aspect of such actions may be carried out with a different goal, in particular the goal of attaining certain values for the dependent variables. Each point-wise testing procedure with positive results is thus also a potential technical action, as far as its external aspect is concerned; its goal becomes the intentional realization of certain values for the dependent variables, for whatever need or purpose they may serve. Examples which illustrate the identity of the external aspects of point-wise testing procedures with potential technical actions may be found throughout the natural sciences--consider the successful test of an hypothesis on the onset of superconductivity in a given material, or the successful clinical test of new medications. In such cases, the identity of external aspects is obvious.

But the mere fact of this identity fails to entirely capture the significance of modern science's technological exploitability. For up to now we have made use only of the reproducibility of point-wise testing procedures with positive results. The resulting exploitability is really shared by any sort of action whose external aspect is reproducible (e.g. reproducible point-wise testing procedures with negative results). So far, however, we've neglected the fact that a point-wise testing procedure is a component of an experiment in which some law-hypothesis is tested. Should

16. For this distinction, so fundamental to the theory of action, see e.g. von Wright (1971), sec. III.2.

17. On the discussion which follows, compare Storck (1977), p. 42, and Rapp (1978), p. 105.

18. Storck (1977), p. 1.

this experiment have positive results, then the law-hypothesis it confirms, assuming it similarly survives other experiments and theoretical investigations, warrants a range of technical actions which isn't confined to those whose external aspects have already been realized in point-wise testing procedures. Potentially successful technical actions are now warranted by instantiations of the hypothesis for all possible choices of independent and dependent variables, over all possible values within the scope of the hypothesis. The confirmation of the hypothesis also yields information on the effects of variation in the values of the independent variables on the values of the dependent variables, information of central importance to our ability to optimize technical action, or confine it to within physical tolerances. All told, the confirmation of a law-hypothesis makes a tremendous contribution to the theoretical control of technical action. The modern concept of nature also allows for technical actions to be combined in procedures of arbitrary complexity, for as far as any single step in such a procedure is concerned, it is irrelevant how the values of the independent variables, which result in a set of values for the dependent variables needed for the next step, come about. Such complex procedures include, for example, the operation of an engine, or the programmed functioning of a robot.

It remains to be shown what role the epistemic ideal plays in technological exploitability. Suppose we were capable of proving, without recourse to experiment, the truth of natural laws, and could in this way achieve epistemic progress. Such epistemic progress would not, despite the relational structure of natural laws, necessarily entail any technological progress. For though insight into natural laws alone permits us to derive the relations between independent and dependent variables, nothing in this hypothetical situation ensures that we may either attain any values for the independent variables, nor measure those of the dependent variables. Such knowledge would be, in principle, technologically exploitable, but not by us, since we would still lack the technological prerequisites for such exploitation. But when theoretical progress (however conceived) is, by virtue of its guiding epistemic ideal, inextricably linked to experimental testing, then at least some consequences of new, but tested, hypotheses, will prove technologically exploitable. And so the positive feedback between technological and scientific progress, an increasing source of distress to some these days, comes about.

6. Summary

I shall now attempt to recapitulate the argument of this essay. The modern concept of nature has been shaped by the notion of a natural law, conceived as a universal relation. Because the epistemic ideal of modern natural science doesn't demand the rigorous proof of natural laws, experiment becomes the central process in the testing of law-hypotheses. Now, the external aspects of the point-wise testing procedures typical of experiments are identical with the external aspects of potential technical actions. Thus every experimentally confirmed law-hypothesis sanctions a range of actual technical applications. The decision in favor of the technological exploitability of modern natural science has thus been taken once the modern concept of nature, and the epistemic ideal which, though not unavoidably determined by it, nonetheless corresponds to it, have been adopted. Why it is that these choices came out in just the way they did when they did is an extremely interesting question, but one which lies beyond the scope of this essay.[19]

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