**Natural Law, the Modeling Relation, and Two Roots of Perspectivism**

**1. Introduction**

Scientific perspectivism, or perspectival *realism*, is a position opposing both relativism and objectivist realism, holding roughly that the world studied by the sciences is “as it is”, mind-independently (contra relativism), while emphasizing that the truth of scientific knowledge claims nonetheless depends on the particular vantage point from which they are asserted (contra objectivism). Therefore, a central challenge of perspectivism is to ascertain how can “our scientific knowledge claims be *perspectival*, while also being about the world as *it is*” (Massimi 2016, emphasis original). Or more precisely, the challenge may be construed in two steps as follows. First, the perspectivist begins from acknowledging what Giere (2006) and Hacking (1999) have dubbed the “contingency thesis”, and which, in the words of Shapin (1975), states that “Reality seems capable of sustaining more than one account of it”. And second, the actual problem is then to elaborate an account of scientific knowledge containing both a “realist part”, specifying why “claims generated by scientific practice are claims about the world”, and a “perspectival part” justifying the view that “these claims are not unconditional but relative to a set of humanly constructed concepts” (Giere 2013). Several authors have engaged into the development of full-blown scientific perspectivism along these lines (e.g. Giere 2006, Massimi 2022, Teller 2018), while others have analysed its prospects somewhat more modestly (e.g. Ruyant 2020, Rueger 2016), and still others have stressed possible obstacles concerning its fertility in solving issues such as the problem of inconsistent models (e.g. Morrison 2011, Chakravartty 2010).

But while the perspectival nature of knowledge is primarily a concern of philosophers of science, it might be of quite direct relevance to a theoretical scientist as well. At least Robert Rosen, a theoretical biologist, apparently thought so; to him an essential problem in understanding a living organism as a natural system seemed to be the fact that there are always different *kinds* of information available for explaining its observed behaviours – at the very minimum, there are always the structural-physical and the relational-biological descriptions of one and the same system. This is well illustrated in “Note to the Reader” opening Rosen’s book *Life Itself*:

The trouble came when I tried to integrate relational and structural descriptions of the same biological systems. They did not seem to want to go together gracefully. Yet they *must* go together, being alternate descriptions of the same systems, the same material reality. Moreover, I needed both; biology seemed to require both. (1991, pp. xviii–xix. Emphasis original.)

While the resemblance of this to the perspectivist’s contingency thesis is evident, it is important to note such are by no means typical concerns of a biologist. Rosen was one of the past century pioneers in organicist theoretical biology, which in its basic attempt to conceptualize a living organism as a material system challenges conventional discipline boundaries: on the one hand, physics has traditionally been responsible for the formulation of general conceptualizations of material systems, while on the other, living organisms clearly belong to the province of biology. In the past century such an approach encountered much resistance (see e.g. Peterson 2016, Shmailov 2016), but in the present it seems to be gaining at least some new momentum (e.g. Moreno & Mossio 2015, Soto et al. 2015). In any event, a living organism is a natural system *par excellence* which in a valid sense is “one” in the world, and always “many” in our scientific descriptions, implying that a perspectivist might benefit from insights of theorists like Rosen working with parallel issues from within the sciences. And for exactly the same reason, it is conversely expectable that the current organism-centric movement in biology could benefit from a well-articulated account of scientific perspectivism.[[1]](#footnote-1) So against this general background, let us see how Rosen’s “Note to the Reader” continues:

They say that all science must start from experience. Mine was that relational models and mechanical models, drawn from physical analysis through reductionism, were not going together. That was a fact. My conclusion from that fact was that I was simply being stupid, or else there were some deep and essential things embodied in that fact. I was never able to rule out the first possibility, but the possibility of the second is what has led circuitously, in the course of time, to what is chronicled herein. (ibid.)

Thus Rosen took the epistemological questions of biology, and especially those related to the apparent plurality of available descriptions, as “the *primary* questions on which the resolution of all the other questions essentially depend” (Rosen 1978, emphasis original). The central instrument by which he addressed such questions was the concept of the modeling relation, employed actually in two distinct roles (Pattee 2007): both for conceptualizing our own knowledge, or epistemology, of organisms and of other natural systems (especially in *Life Itself*), and for conceptualizing the organism as a natural system perceiving its surroundings and manifesting model-governed behaviours (especially in *Anticipatory Systems*). This dual role of the modeling relation is an interesting observation as such, and I have studied its ramifications elsewhere (Weckström, forthcoming).

In the present paper, my aim is to show that the modeling relation in its former, epistemological role implies, or can be elaborated into, an account of scientific knowledge in which both a perspectival part and a realist part can be distinguished and defended. That is, my intention is not to say that Rosen himself was a perspectivist, but rather to employ his theoretical-epistemological framework for developing a position of perspectival realism. In doing so, I identify two distinct reasons, to be called two roots of perspectivism, why our scientific knowledge of natural systems cannot be divorced from the perspective of its production, even though the sciences can still be thought of as speaking of the world as it is. The first of these roots amounts to the dualism between a system and its environment, which a scientist necessarily imposes when focusing on the former, and which unavoidably results in perspectival inclusions and exclusions. However, the specification of the first root also provides the basis for defending the view that within a perspective, there are reasons to believe that such knowledge is about the world as it is. The second root amounts to the complexity of complex systems, and it renders the perspectival lessons of the first root remarkably more pressing. Especially here insights from biology become crucial. As I try to show besides developing the argument, perspectivism thus understood couples in interesting ways to a range of traditional issues in philosophy of science, and as I discuss towards the end of the paper, Rosen’s relational language exemplifies how perspectival epistemology might suggest novel ways of doing robust theoretical science of complex natural phenomena.

The structure of the paper is as follows. In Section 2, I elaborate the idea of the first root of perspectivism by describing how systems become extracted out of the external world by means of active imputation of relations between percepts and observables. I also comment briefly on the measurement problem of quantum mechanics from the point of view of the general system-environment dualism. In Section 3, I introduce Rosen’s concepts of Natural Law and the modeling relation, and apply the latter for generating a formal representation of the perspectivist’s contingency thesis “reality seems capable of sustaining more than one account of it”. This representation implies a relation between perspectivism and emergentism, which I explore in a preliminary manner therein. In Section 4, I apply the formal representation of the contingency thesis for advancing the idea of the second root of perspectivism which, as mentioned, is identified as the complexity of complex systems. In Section 5 I discuss the general prospects of perspectival science, and in Section 6 I summarize my conclusions.

**2. The First Root of Perspectivism**

The basic aim of this first section is to develop, beginning from epistemological considerations, a sufficiently nuanced general account of a *system*, and of its relation to an *environment*. This was more or less the starting point of each of the books comprising Rosen’s main “trilogy” (1978, 1985/2012, 1991); hence, what follows is largely interpretation and extrapolation of Rosen’s epistemology, which then develops successively towards more original and targeted articulation of scientific perspectivism. Another, more implicit aim here is to shift focus from percepts to *relations* between percepts, when human experience is concerned, and likewise from observables to relations between observables, when scientific observation is concerned. These can be seen as preparations for a corresponding shift from propositions to relations between propositions, when scientific reasoning is concerned, which on its part prepares for addressing questions such as whether it is true, false, or perspectival to say that a living organism consists of molecules, if the basic concept of a molecule does not quite imply how the molecules are related to one another in a living organism. Work lies ahead before flesh can be put on the bones of such ideas, but it is good to be aware of this implicit aim from the beginning; it for instance explains why certain aspects of experience and observation are emphasized instead of others, which in other contexts and for other purposes might be equally valid.

So, with these provisions, let us begin along Rosen (1991, 1985/2012) from perhaps the most basic of all questions: What is the point of departure for knowing anything about the world, for any knowing being? *Cogito, ergo sum*, said Descartes – it is the duality between the *self*, known and perceived directly, and the external world, or the *ambience*, accessible to the self only indirectly. The self’s interaction with the ambience produces *percepts* as the “basic units of experience”, and an intelligible picture of the world arises by positing relations between percepts; relations that apparently cannot be perceived directly as the percepts themselves, but which, when imputed, generate organized experience consisting of sets of percepts “hanging together”, i.e. of *systems* (Rosen 1985/2012, pp. 46-47). There are reasons to believe that the self must in some sense actively impute these relations between percepts; that nothing but unorganized chaos, or “hodgepodge of physical characteristics”, as Giere (2006) puts it, would result from passive and unmodulated receiving of, say, light and soundwaves originating from different angles and distances. Giere’s examples on colour vision are good illustrations of such organizing procedures, but also, for instance, thinking about the experience of a new-born human being seems to provide a way of seeing their function: by learning, little by little, to construct systems out of the messy sensory input, in essence by learning to impute relations between the received percepts, becomes successful navigation in the world possible, and the mind begins to act as a transducer between sensation and action.[[2]](#footnote-2)

This active role played by the self in organizing sensory experience has been much discussed, for instance, in relation to Kant’s philosophy, and it is well known in the field of neuroscience. Quite an illuminating example from the latter is the observation that even though the brain is, in general, capable of distinguishing timescales relevant to the difference between the propagation of sound and light waves, visual and auditory data are nonetheless perceived as simultaneous when they originate from a common source – in other words, a “correct” relation of simultaneity is established between percepts not received simultaneously by the sensory organs (Buonomano 2017). Hence, due to the imputed relation of simultaneity, visual and auditory signals are recorded as belonging to the same “state” of the same observed system, and this supposedly corresponds to the relations existing in the ambience, rather than reflecting the “raw” relation between signals entering the sensory system.

From these sorts of basic considerations on primitive experience, Rosen (1985/2012, p. 47) proceeds to the scientific context by “generalizing” the concept of a percept to the concept of an *observable*. That is, as organized experience imputes relations between perceived percepts, science imputes relations between observed observables. As a simple-minded example, the position of the Moon at *t*1 could be regarded as one observable and its position at *t*2 another, and the scientist, suspecting that these observables are not independent of one another, may construct a system out of them by imputing a (mathematical, say) relation between them. Or, in another context, depression could be taken as one observable and childhood trauma as another, and a psychological system could be constructed by imputing certain kinds of relations between these. Thus as an idealized account, the construction of a system could be conceived of for instance as follows. If there are two (or more) observations *A* and *B*, the self, or a scientist, suspecting that these might be related, i.e. suspecting that they might be observations of a common system, begins by an interrogative “If *A*, then *B*?”, and establishes perhaps by means of further observation that, indeed, “If *A*, then *B*”. Subsequently, a relation must be imputed which is able to indicate at least *how A* and *B* are related to one another, and preferably also *why* they are thus related, and the system is then essentially “made of” this relation. The nature of the relation may then allow to conjecture, for instance, what happens to *B* if *A* is varied, in the sense of “If δ*A*, then δ*B*?” (which is the case of prediction or anticipation; explanation is the converse case “If δ*B*, then what δ*A*?”; see Rosen 1985/2012, p. 372-376).

Thus from this point of view, it seems that scientific knowledge, and probably knowledge also more generally, is essentially about relations between observables, rather than about observables themselves, and instead of being in some sense given, or directly observable, they must be more or less actively or internally imputed. Hence a realist philosopher, and likewise a scientist, must next assume that the imputed relations between observables do, or may, reflect corresponding relations existing in the ambience as well (between *qualities* of the ambience corresponding to the observables of the self). Rosen himself concludes that while the existence of these imputed relations (or better, the existence of *corresponding* relations) in the ambience might always remain open to sceptical arguments, there would be little point in continuing doing science without believing in them in some sense, and hence “the question then becomes not whether, but when, such relations hold” (1991, p. 56). This should be quite an acceptable attitude for a naturalist philosopher as well.

However, even if there were good grounds for assuming that the imputed relations reflected relations existing in the ambience as well, constructing a system out of them in the proposed manner is not as innocent, or unproblematic, as it might first seem. And this is not only because the observables themselves are limited to and determined by the manner in which the self is interacting with the ambience. Irrespective of how “real” the imputed relations between the observables are, there is in general no reason to assume that the qualities of the ambience corresponding to the observables of the self were not, jointly or independently, engaged in all kinds of other relations in addition to those included into the system thus constructed. But once a system has been constructed, these “external relations” become thrusted into the *environment* of the system, and will henceforth be treated entirely differently from the relations constituting the system itself. In essence, the system becomes described in terms of its *states*, and the environment in terms of its *influence on states*; the environment does not get states of its own (Rosen 1991, pp. 41-42). And since this profound dualism arises within the inner world of the self, depending entirely on the system which must be picked up, or better, *extracted out* of the ambience, I propose that the inevitable act of imposing the dualism is what deserves to be regarded as the first root of perspectivism. These basic ideas and the applied terminology are illustrated schematically in Figure 1.



**Figure 1.** Perspectival extraction of a natural system out of the ambience.

So the situation seems to be this. Unless percepts, or more generally observables, are organized into systems, there will only be the “hodgepodge”, or an uncontrolled flood of unrelated data, or only the points of Fig. 1; hence systems must be constructed by imputing relations, and prior to the imputation, these relations are directly unobservable in themselves. Furthermore, since the “correct” relations must be *learned* (in this context, we may think of learning in a sufficiently general sense to include, for instance, associations arising due to evolution by natural selection), they can be conceived of as in some sense successful *generalizations*, which are then applied in more or less unique, particular situations. This reflects the diachronic nature of both knowledge and experience, in the sense that how we see the world now (i.e. what systems become extracted out) depends on how we have seen the world in the past, though the time scales of such learning processes evidently range from very small to very large. In any case, the imputation of relations is what generates systems, effectively by extracting them out of the ambience, and since neither every quality nor every relation of the ambience will enter into the system-description of the self, this can be thought of as a process of *abstraction* (see Rosen 1985/2012, pp. 205-206).[[3]](#footnote-3) Pulling together, then, a system may be thought of as a *generalized abstraction*, and such generalized abstractions seem to be, from the advanced vantage point, what our knowledge claims and the sciences are essentially about.

In this picture, then, the rest of the world not included into the system constitutes the environment, and what happens within the confines of the generalized abstraction appear as intelligible, entailed, and important, while the events of the environment appear as unintelligible, unentailed, and perhaps unimportant; the environment also becomes the source of randomness and noise. However, it is not difficult to see that random environmental influence from one point of view may well appear as intelligible and entailed dynamics from another; nothing said thus far entitles us to think of “random” as anything but a relation or a consequence of a relation not included into the generalized abstraction we happen to be employing. There are countless examples of situations in which the adopted perspective evokes an appearance of randomness and unimportance (it seems to me that *every* form of knowledge is associated with such appearances); below is an illustrative passage by Michel Foucault who, when investigating the history of the clinic and medicine’s path towards “objective medical gaze”, recognizes a historical moment at which the subjective facts of the patient became transformed into random disturbances of the “essence” of the disease (hence in our parlance, the disease is the system, and the rest of the patient constitutes the environment; think of this in the abstract sense of Fig. 1):

To the pure nosological essence, which fixes and exhausts its place in the order of the species without residue, the patient adds, in the form of so many disturbances, his predispositions, his age, his way of life, and a whole series of events that, *in relation to the essential nucleus, appear as accidents. In order to know the truth of the pathological fact,* *the doctor must abstract the patient* (…) Paradoxically, in relation to that which he is suffering from, the patient is only an external fact; the medical reading must take him into account only to place him in parentheses. (Foucault 1973, p. 8. Emphasis added.)

(…)

In the hospital, the patient is the subject of his disease, that is, he is a case; in the clinic, where one is dealing only with examples, the patient is the accident of his disease, the transitory object that it happens to have seized upon (ibid., p. 59).

Thus in a word, the price the self has to pay for its focus on certain causal relations is the ignorance and distorting of others; there is always much “more” in the particular real-world situations than can be captured by our generalized abstractions, and the appearances of “randomness” and “noise”, which are evident manifestations of this basic fact, depend on the abstraction we happen to be using for fractionating the world into intelligible fragments.[[4]](#footnote-4) In the medical example above, the world is fractionated into intelligible diseases, and it is thus from the point of view of the doctor (especially at the clinic) that the “subjective facts” of the patient, which may not be readily generalizable from the doctor’s vantage point and with which she may not be able to interact, appear as random disturbances with respect to the ideal conception of the disease. However, it is not difficult to imagine circumstances in which just such subjective facts can be decisively important concerning the onset, unfolding, and termination of the disease. Thus while the systems extracted out of the ambience and described by the self may well reflect causal relations existing in the ambience in the realist’s sense (we are not denying that there is some sense in which the classified diseases exist), the system-environment dualism as such is merely a consequence of perspectival exclusions and inclusions, and a reflection of the capacities and aims of the cognitive self (like those of a doctor who receives her information from a clinic, and uses that information for generating abstractions that are useful when many different patients come to her reception).[[5]](#footnote-5)

For further illustration, let us briefly consider the measurement problem of quantum mechanics; if the above basic considerations are on the right track, then also quantum mechanics should have its characteristic ways of establishing the system-environment boundaries, and I propose that the measurement problem provides a natural context for trying to comprehend how they might come about. However, while there are reasons to assign some specific importance to quantum mechanics from the point of view of perspectivism, [[6]](#footnote-6) my principal aim here is just to elucidate the system-environment terminology as such. Therefore, I will be concerned with a very simple image of quantum mechanics in order to illustrate how the system-environment language *could* be used therein; a more nuanced account with additional theoretical structure (on decoherence, say), or an alternative interpretation, might portray the actual boundary very differently, but that is not my point. Indeed, if I locate the system-environment boundary somewhere as an illustration, further discussion may locate it differently or try to evaporate it altogether; fertility of this sort I would regard as a positive side-effect.

Thus, Figure 2 portrays quite a basic picture of the formalism of quantum dynamics, familiar from many textbook situations, and without getting involved into any deeper nuances, I think there is a way to look at it such that the *measurement interaction is taken to belong to the environment of the conceptualized quantum system*.



**Figure 2.** The measurement problem of quantum mechanics.

That is, in Fig. 2 the quantum *system* is that what begins its time-evolution from some initial state, obeys the Schrödinger equation until observable *A* is measured, assumes then some eigenstate of *A*, after which it obeys again the Schrödinger equation until observable *B* is measured. Thus the system is characterized by the dynamical relations between (potentially measurable) quantum observables, and the Schrödinger equation applied to the wavefunction is an embodiment of these relations. The purpose of the measurement is to quantify such an “intrinsic” observable (e.g. spin), via interaction with the system; say by passing it through a magnetic field. This interaction does not, however, only move the meter but affects the quantum system as well, i.e. by forcing its state into an eigenstate of the measured observable. Consequently, and as above, the system here is that what is described in terms of states (of the wavefunction), while the environment (the measurement interaction) manifests itself only via its influence on states, without getting states of its own.

Thus the “problematic” part is the small gap (“collapse”) between the two segments of unitary time-evolution in Fig. 2 which, if the above wording is accepted, involves dynamics imposed on the conceptualized system by its environment. But what is important for the present purposes is that there seems to be no need to regard it as a *pressing* problem by the practicing physicists; it seems that what matters in actual quantum mechanics is the unitary time-evolution, and all the relevant inferences and applications follow from that (Healey, in press). Or, to put it differently: what is relevant and important to the practicing quantum physicists are the *characteristics of their system*, and not its less articulate interactions with the environment. Thus, at least as a vague metaphor (or perhaps even *mutatis mutandis*), it seems that the measurement interaction is related to the conceptualized quantum system as the subjectivities of the patient are related to an ideal nosological disease; in both cases, the extracted system does imply relevant things about realized “interaction” with the “excluded environment”, while being in some sense unable to conceptualize that interaction itself.

Thus it is interesting to observe how some authors, working for instance on the “Wigner’s friend” thought experiment of nested quantum mechanical descriptions, have taken quite a new look on the notion of interaction itself (e.g. Di Biagio & Rovelli 2022), and also on its relation to perspectivism (e.g. Dieks 2022). In a partly corresponding way, it seems to me quite rational to think that a single “wave of the world” could never be “like the world we know” (Bell 2004, p. 188), because the excluded interactions – measurements, if you like – are there in the world but not in the formal wavefunction of the world. However, at the same time I regard it as perfectly plausible to presume that a wave of more restricted situation probably tells quite relevant and true things about relations obtaining within *quantum* systems, defined via genuinely quantum mechanical observables – in this case, the extent to which interactions have been excluded from the description is reasonable and manageable, while concerning the wave of the world it certainly is not, and seems to render the whole description rather absurd. Be it as it may, on my view quantum mechanics *prima facie* discourages rather than encourages to believe in a single uniform master description of physical events, in the sense of “a view from nowhere”, which in the above case would amount to the wave of the world. And if so, there seems to be room for a somehow “perspectivalized” standpoint, for instance in the following sense of Rosen’s:

Our thrust will be that there is no one mode of analysis which is universally valid for all systems and for all interactions, but rather that each mode of interaction, and each set of meters chosen for observing it, determines a set of corresponding “natural” analytic units (1978, p. 95).

So in conclusion, the system-environment dualism, regarded as the first root of perspectivism, seems to imply that perhaps the relation between scientific knowledge claims and reality is quite analogous to the relation between closed and open systems, as they appear for instance in physics (see Rosen 1985/2012, pp. 277-283). To see this, let us think of, say, a heated gas container, which is initially strictly isolated and obeys accurately the principles of classical thermodynamics, but which is then opened more and more to environmental fluctuations and interactions, ultimately to a point at which it is never able to actually approach thermodynamical equilibrium. Roughly in the same sense, it seems legitimate to think that once a scientific claim is “opened” to the unaccounted relations, interactions, and entailments of the real world, the principles learned from its “closed form” still hold to some extent, but they become excessively constrained and modified, errors and inaccuracies begin to appear, and the objective appearance of the “closed form” is eventually lost. Thus, according to this view, knowledge claims do reflect aspects of reality, but only to the extent that the ignored entailments are kept at bay – this seems to align with the “piecewise approximations to reality” of William Wimsatt (2007).

To me, this appears as a largely plausible sub-conclusion. From the next section onwards my aim is to develop it a bit further; on the one hand by being more precise on the reasons why the “pieces” of knowledge indeed acquire their form from the world, and not the other way around, and on the other by arguing that especially when complex systems are concerned, it is crucial to acknowledge that an “extracted piece” generally behaves differently from an “embedded piece”. This latter observation has potentially far-reaching implications; for instance, it seems to imply that straightforward pasting of extracted pieces together might not be the best way of approximating intact complex systems.

**3. Natural Law and the Modeling Relation**

Now, if knowledge *consists of* actively imputed (generalized) relations between observables within the inner world of the self, and if this knowledge *is about* corresponding relations between qualities of the external world, or of the ambience, then what are the minimum presumptions on which any knowledge of the external world, or any science, must rest? What must there *be*, in order for such knowledge to be possible? According to Rosen, there must be two kinds of orderliness; orderliness within the ambience and orderliness within the inner world of the self. This is encapsulated in the following pair of assertions comprising his notion of Natural Law:

1. The succession of events or phenomena that we perceive in the ambience is not entirely arbitrary or whimsical; there are relations (e.g. causal relations) manifest in the world of phenomena.
2. The relations between phenomena that we have just posited are, at least in part, capable of being perceived and grasped by the human mind, i.e., by the cognitive self.

Science depends in equal parts on these two separate prongs of Natural Law. (…) In other words, the first part of Natural Law is what permits science to exist in the abstract. The second part of Natural Law is what allows scientists to exist. Clearly, concrete science requires both. (Rosen 1991, pp. 58-59)[[7]](#footnote-7)

Evidently, Natural Law thus formulated is something very different compared to the resembling notion of “laws of Nature”, which may cause some confusion – in what sense is Natural Law a *law*? The term “law” has two quite separate meanings; one related to commandments and norms of behaviour, and another to descriptions of the orderliness of natural phenomena. Interestingly, there are interpretations according to which ancient Greek did not separate these two meanings, even though from a contemporary standpoint they appear as very different and even unbridgeable (von Wright 1987). On my understanding, Natural Law can be thought of as a law partly in both of these two meanings – so perhaps it is best conceived as a law in the Greek sense – but for the present purposes, let us concentrate on the “normative” aspect of it. That is, rather than determining what will happen or how events must unfold as, say, Newton’s laws aim to do, Natural Law establishes the confines or norms within which science is “allowed”, or better, possible. If either of its assertions is given up, we step outside the pale of science; science becomes immediately inconceivable. On the other hand, any further addition into Natural Law would seem readily disputable. For example, we may say that within the confines of Newtonian science, future cannot affect the past, and as Laplace famously noticed, only one future can follow from a given past. Hence phenomena characterized by past-future relations more complicated than this (like anticipatory phenomena) are beyond the reach of Newtonian science; however, as, say, considerations on the relativity of time and on the ambiguity of the “now” seem to indicate, such phenomena probably should not fall beyond the reach of science in general, at least *a priori*. Thus in this sense, by expressing the minimum requirements of science and nothing more, Natural Law functions as a bedrock on which one may rely especially when new ways of seeing, or new perspectives, force the status of traditional and strong intuitions into reconsideration. Therefore, let us think of Natural Law as the constitutional law of natural science; as the last belief and commitment to be given up. And as such, it can well be regarded as a commitment to realism (see footnote 7).

But what do the assertions comprising Natural Law actually amount to? The first of them says that in order for science to be possible “in the abstract”, there must be *causal entailment* in the ambience, such that phenomena of the ambience may entail other phenomena of the ambience. Natural Law does not specifically require that every phenomenon should be causally entailed by other phenomena; it only says that if there were no such entailment relations at all, then science would be impossible. The second assertion tells us that for a concrete scientist doing science to be possible, there must also be *inferential entailment* within the inner world of the scientist, or the self, such that propositions referring to phenomena may entail other propositions referring to other phenomena. The practice of science is then about putting these two realms of entailment, the external realm of causal entailment and the internal realm of inferential entailment, into congruence by means of *encodings* from phenomena to propositions and by *decodings* from propositions to phenomena. This gives us the schematized picture of Figure 3, which is a representation of Rosen’s concept of the modeling relation, and which I will from now on adopt as the basic abstract picture of the science of natural systems.



**Figure 3.** The modeling relation. See Rosen (1991, p. 60; 1985/2012, p. 72).

The left box in Fig. 3 represents a natural system *N*, extracted out of the ambience. Arrow 1 represents causal entailment within *N*; thus how phenomena of *N* entail other phenomena of *N*. The right box represents a system of inferential entailments, or in short, a formalism *F*. A formalism is a structured fragment of language,[[8]](#footnote-8) within which it is possible to inferentially entail new propositions from given propositions without consulting anything outside the formalism. This flow from propositions to other propositions by means of inferential entailment is represented by Arrow 3. Arrows 2 and 4 represent encodings and decodings, respectively, connecting *N* and *F* to one another. Encoding is the process by which an aspect of *N* becomes a proposition of *F*; for example, the process by which a planet observed on the sky becomes transformed into a formal mass-point in a coordinate system. Obviously, it is on this formal object that the inferential machinery of *F* can act, rather than the planet on the sky. Decoding, on the other hand, is the process producing assertions about *N* based on *F*, for instance, a prediction where the planet will be observed a moment later.[[9]](#footnote-9) If the decoding coincides with what was causally entailed within *N*, that is, if the “natural path” consisting of Arrow 1 coincides with the “scientist’s path” consisting of Arrows 2,3, and 4, the modeling relation is said to *commute* (the idea of commuting approximately being fully intelligible).[[10]](#footnote-10) More detailed discussion on the modeling relation may be found, in addition to the original sources (Rosen 1991, 1985/2012), from for example Louie (2009) and Lennox (2020).

It is not difficult to see that as a general picture of science of natural systems, the modeling relation is a plausible concept; the elements it contains appear to be always present in the practice of science. Evidently there must always be some kind of encoding of phenomena (both measurements and linguistic or symbolic representations count as ways to encode; it is difficult to conceive of science without them), and indeed, it seems that both the advents of new ways of knowing, new sciences, and scientific revolutions in Kuhn’s (1962) sense are associated with the appearance of new encodings (for instance, the encoding of physical phenomena into the wave function, or the encoding of biological phenomena into evolving populations characterized by inheritance, variation, and selection, or the encoding of patients with symptoms into classified and conceptualized diseases). Moreover, these encodings are, of course, accompanied with their specific structures of inferential entailments; with their own, specific languages including some (implicit and explicit) auxiliary assumptions, that allow to “play the game” once a phenomenon has been suitably encoded. For instance, a biologist encoding a forest as an ecosystem immediately becomes able to make a range of inferences about it, and to pose a range of questions not available upon primitive encodings; similarly outside the confines of natural science, say a lawyer encoding a newspaper article as a defamation is able to make a range of inferences and pose a range of questions not available to a layperson simply reading what has been written. And finally, unless the inferences thus generated are allowed to act back on the natural system they try to talk about, i.e. unless there are the decodings as well (which can be verified), we are hardly speaking of science in any conventional sense; then the encodings and consequent inferences count as some sort of mysticism. Indeed, it is quite clear that if the decodings do not coincide sufficiently well with the appropriate phenomena of *N*, then either the encodings or the inferential entailments are to be replaced or modified. This is the basic sense, I propose, in which our pieces of knowledge acquire their character from the world, and not the other way around, at least once it has been decided what is the *N* with which one is supposed to engage into a commuting modeling relation. In sum, therefore, the modeling relation appears to align the science of natural systems quite well with the basic stance of realism. But what, if anything, does it imply about the perspectival nature of scientific knowledge?

There are, in my view, at least two things it implies rather directly about perspectivism; one strengthening the lessons of the first root, and another from which the idea of the second root will follow. Firstly, in the “normal use” of the modeling relation, a scientist starts with a givennatural system, and consults then the formalism for the whys and wherefores of it. For instance, a material system may be given to a physicist, and the physicist then invokes her encodings and formal systems for telling how the system is to be conceived and thought about; for telling what the system “actually” is, and why it behaves as it behaves. Or likewise, a collection of observations of a society may be given to an economist, and the economist then invokes his encodings and formal systems for telling how those observations are to be interpreted, and what are their underlying causes as well as their implications. Thus in Wilfrid Sellars’ (1962) terms, on this understanding we begin with the manifest image and seek to replace it by the scientific image to the extent possible. However, the converse is also possible: one can, in a way, turn the modeling relation around, and begin with a *given formalism*, and consult then the world *for asking how much of the world is the formalism able to talk about* (Rosen 2000, p. 156-170). This is a very illuminating exercise, and thinking over a couple of examples reveals the sense in which the first root of perspectivism, the picking up of a system out of the “environment”, always produces a perspectival picture. For instance, instead of saying that the functioning of a society is governed by monetary flows, we may ask: How much of the society are the monetary flows able to talk about? Or, instead of saying that the mind is an aspect of the brain, which is a physico-chemical system, we may ask: How much of the mind are the physics and the chemistry of the brain able to talk about? It is clear that we can (conceptually) extract a monetary system out of a society, or a physico-chemical system out of the brain-mind phenomenon, but it would be foolish to think that such ways of interacting with societies or with the brain-mind phenomenon are able to exhaust all the relevant relations there are “in the world”. And likewise, we may probe more general questions, such as: How much of the world is Newtonian physics able to talk about? Or quantum physics? Or thermodynamics, or the language of evolution, or the language of chemistry? Or, likewise, economics, sociology, jurisprudence? Furthermore, do the systems described in these languages exist in the world as objective layers in an objective hierarchy – or are they overlapping perspectival abstractions extracted out of the complexities of the real-world phenomena?[[11]](#footnote-11)

Secondly, the modeling relation allows to take a new and quite explicit look at the perspectivist’s contingency thesis formulated at the outset. The statement “Reality seems capable of sustaining more than one account of it” can now be interpreted as a situation in which a single natural system *N* is coupled, by means of encodings and decodings, to several *F*:s. The case of two formalisms and a single natural system, which is the simplest case, is represented in Figure 4.



**Figure 4.** One system, two formalisms. See Rosen (1991, p. 63; 1985/2012, p. 78).

In Fig. 4, there are two formalisms, *F1* and *F2*, into which *N* can be encoded, and both of the modeling relations thus established are assumed to commute (in some sense). If there is a *dictionary* $ψ$ mapping every proposition of *F2* into a corresponding proposition of *F1*, such that commutativity still holds, the former reduces to the latter. For example, if *N* is a heated gas container, *F2* is a formalism of classical thermodynamics, and *F1* is a formalism of statistical mechanics, then $ψ$ apparently exists and the objectivist realist will not be hard pressed (even though the perspectivist, in a looser sense than the one advocated in the present paper, might insist that *F1* and *F2* provide distinct perspectives on a single phenomenon nonetheless). But the truly interesting cases would be, of course, corresponding situations in which $ψ$ does not exist and, moreover, situations in which there are more than just two formalisms available. Then the different formalisms could clearly be seen as generating complementary images not only of the same reality, but of the same extracted system within that reality. This is the topic from which I will continue in the next section, and it will eventually take us to the notion of the second root of perspectivism. Before that, however, let us allow ourselves a brief excursion into the relation between perspectivism and *emergentism*, since Fig. 4 seems to suggest that such a relation might exist.

Namely, if Fig.4 is taken as a formal expression of the perspectivist’s contingency thesis, it then appears as if perspectivism was the opponent of reductionism: If *F2* reduces to *F1*, there will be no need to think in terms of distinct perspectives. And indeed, reductionism in its belief in the superiority of the reduced picture compared to any other is apparently an inherently objectivist position. But if this opposition to reductionism is at the heart of perspectivism, is perspectivism then coupled to, or even a form of, emergentism (or vice versa)? An obvious difference between perspectivism and emergentism is that the former is driven primarily by epistemological and the latter, at least quite often, by ontological concerns. In addition, if we take a look at some traditional claim of the emergentist, such as “Parts behave differently in wholes”, what the ongoing elaborations imply is that identifying parts in this sense is already a perspectival thing to do; it is but one way to establish the system-environment fractionation. This is the aspect of the reduction-emergence debate on which I would like to comment here, my central hypothesis being that *the debate itself is largely a consequence of the perspectival nature of knowledge.*

So, at the core of the traditional reduction-emergence debate is the notion of scientific composition (see e.g. Gillet 2016), and emergentist reasoning might proceed, for instance, as follows: a living cell is composed of molecules, but *these molecules* behave differently when they are embedded, or organized, into the cell. But what these molecules actually *are*? I think perspectivism encourages us not to forget that in the last analysis, a molecule is a theoretical term referring to a theoretical entity, i.e. an element of $F$ in terms of which something of *N* can be encoded, but which does not in itself belong to *N*. This means that whatever properties are associated with the concept of the molecule, these properties derive from certain ways of interaction, observation, and consequent conceptualization[[12]](#footnote-12) – they depend on a particular way of imposing and maintaining the system-environment dualism. A molecule in a test tube (or in a sample plate of an atomic force microscope) and a molecule embedded into a cell behave entirely differently – is this to be thought of such that the molecule in the test tube is the “fundamental”, or the “real” molecule, on which the cell as an accidental context, or as the environment in the terminology of the present paper, imposes new, interesting behaviours? Does the test tube situation reveal to us what the molecule *is*, and the cell situation what this molecule, under certain circumstances, *does*? Indeed, is the cell like the patient and the molecule like the ideal nosological disease, such that the former merely disturbs the ideal being of the latter? Is not this view of the molecule tied to the aims and capabilities of the physicist or the chemist, classifying molecules and studying their properties in isolation or in strictly controlled arrangements, precisely in the same sense as the view of an ideal, undisturbed disease is tied to the aims and capabilities of the doctor? Could we not say that from the point of view of the biologist, an isolated “ideal” molecule is an *unnatural*, disturbed entity?

Perhaps this is already too naïve; nonetheless, I seriously do maintain that it is utterly perspectival to say that a living cell is composed of molecules; a molecule being understood as an entity whose properties are defined in contexts very different from that of a living cell. To see this, let us imagine a process of decomposing the molecules out of a cell. In such an imaginary process, the material interaction in which molecules are materially extracted out of the cell is governed by a conceptual model of the molecule, and what comes out of the cell indeed corresponds to that model. However, what does not come out of the cell are the “biological” relations into which these “physical” molecules were engaged before the procedure of their extraction, and it is evidently perspectival, and probably severely misleading, to think that the cell is “more” or “primarily”, or even at all, “composed” of these physical molecules and not of the biological relations or of the “doings” of those molecules, which actually make the cell *a cell*; a natural system very different from a bunch of molecules. In this respect, perspectivism seems to align with the basic premises of process ontology (Nicholson & Dupré 2018, Seibt 2022), which aim to evaporate any absolute or fundamental *a priori* distinction between what something is and what something does, and perhaps emergentism has at least partly arisen as a response to problems rooted in the substance ontological tradition, in which the molecules’ and other parts’ objective “being there”, separately from their doings and relations, is not problematized. Indeed, it seems to me that any picture in which static “parts”, wholly portrayable *at* an instant of time, engage into ephemeral interactions must be a perspectival picture. Often such pictures serve well, of course, but for instance in biology they may sometimes do more harm than good, since in organisms any static, isolable entities, like molecules, tend to be transient visitors while the dynamic relations, which can neither be materially extracted nor visualized at an instant of time, seem to be what actually reign and persist. A living organism which no longer *does*, correspondingly no longer *is* (a *living* organism).

But to further clarify perspectivism’s possible contribution to the reduction-emergence debate, let us invoke a notion of the “surrogate world” (Rosen 1996), to be conceived of as a world populated by entities such as, say, elementary forces, particles, and fields. With this picture one can, for instance, either ask the ontological question of how genuine phenomena may emerge out of the surrogate world; i.e. how to travel *from elementary physics to the world*, or else the epistemological question of how genuine phenomena disappear out of sight (in addition to the obvious gains) when one travels in the opposite direction, i.e. *from the world to elementary physics*, by imposing successive system-environment dualisms. As an epistemology-first approach (Massimi 2022), perspectivism would be primarily concerned with the latter. What it seems to suggest is the possibility that the relations characterizing “emergent phenomena” have precisely been stripped away when generating the reduced picture, and thereby there should be no need, and probably no possibility, to account for such phenomena *within* the surrogate world, which in itself is a perspectival conceptualization; perhaps they should simply be captured (as they always are) by entirely different means.[[13]](#footnote-13)

But does this preclude a possibility to achieve in some sense unified scientific “worldview” – how to put everything together if not by proposing an objectively valid and “fundamental” reduced picture, from which all kinds of other phenomena may somehow emerge? As I argue in more detail in Section 5, an alternative for achieving unification is a picture whose basic elements are not isolated particles or anything of the sort, but generic concepts like *systems* in the original von Bertalanffy’s (1968) sense (see also Minati et al. 2016). Moreover, if such concepts can be formulated in a language which “by being about nothing is about everything” (Lennox 2020, p. 18; Yanofsky 2022); i.e. is a language of unspecified relations, like the language of category theory, then perhaps unification, to some extent at least, could be based on the language’s initial (interpretational) “openness”, such that from this initial openness one may proceed to more “closed” situations according to particular needs by imposing the required constraints and semantical interpretations (see Section 5 for further clarification). Obviously, this parallels with the above proposed “epistemological approach” to the surrogate world. While it is true that, when projected onto the material Nature, such mode of unification apparently takes us some distance away from materialism as traditionally conceived, it seems to me that such an appearance largely stems from conceiving matter primarily in static terms, which may not be the only fruitful perspectiveavailable. Indeed, if we become less interested in what matter *is*, when extracted and isolated in particular ways, and focus more on what matter *does* under various circumstances, then such a “global”, or “systemic”, or “open” thinking seems quite natural, and in sum the above considerations suggest that perspectivism, emergentism, and process ontology seem to go in interesting ways together; each being either direct or indirect reaction to problems apparently rooted in some traditional forms of objectivist realism.

**4. The Second Root of Perspectivism**

Let us then leave the problems with emergentism and processualism as they are, and return to Fig. 4 as a formal expression of the perspectivist’s contingency thesis. I will now take a position that *if* there are systems of causal entailments in the world which can sufficiently unproblematically be identified as natural systems, i.e. can be put into a modeling relation as *N*, but which nonetheless admit and require several non-reducible formalisms for their description, then this can be taken as a vindication of the contingency thesis in the strongest possible sense. In other words, I am looking for situations described in Fig. 4, possibly with more than two *F*, but without $ψ$. If there are such systems, I will call their characteristic property the second root of perspectivism.

Here it must be explicitly assumed that the first root of perspectivism has already been passed, meaning that the distinct formalisms are assumed to be talking about the same system, the same *N*, and not about systems defined in terms of their own specific encodings.[[14]](#footnote-14) For instance, if we put a human society into the left box of Fig. 4 as the *N*, it is immediately clear that there must be many, if not infinitely many, possible formalisms[[15]](#footnote-15) available for describing it. But since it is unclear what is actually meant by a society, it may appear that the distinct formalisms are not generating perspectives on the *same* thing – an economist admits that her formalisms are speaking of something else than those of a jurisprudent, a sociologist, a political scientist, a public health scientist, and so forth. However, since the actual *functioning* of the entailment structures described by these various perspectives are clearly not independent of one another, but closely tied together, a society as *N* might, in my view, already count as an important exemplification of the contingency thesis. In any case, for the present purposes something more concrete, or more *material*, is clearly needed. Shortly below, I will argue that a living organism is just the kind of a system we are looking for, but before that, let us turn the tables for a moment and consider why it has become quite conventional to regard the negation of the contingency thesis, i.e. objectivism, as the standard view. Indeed, on what grounds should we actually expect that there *are* natural systems in the world whose behaviours *can* be captured by a single formalism only? Are there such systems?

If we define *error* as the departure of system’s behaviour from that assumed by its model (Rosen 1985/2012, pp. 283-296), we can reframe the question as follows: Are there systems making no errors?[[16]](#footnote-16) Namely, if a system makes an error, this can be thought of as a consequence of entailments not captured by the applied model; thus arising beyond the reach of the adopted perspective. It is quite clear that such systems doexist, at least for limited (but yet significant) intervals of time. The Solar System, falling bodies, and the like constitute one category of error-free systems. Controlled experiments in scientific laboratories constitute another, and the products of technology, i.e. machines, a third category. But *why* are these types of systems describable by a single formalism? This is a crucial question because answering it might allow to identify systems whose behaviours can be captured from a single perspective only as a *special* category of natural systems, constituting the objectivist’s paradise, and to conclude that *in general*, i.e. outside the confines and constraints of this category, natural systems do admit different kinds of descriptions in the sense of Fig. 4.

So, machines *are* material realizations of (single) formal models, and if they make errors, these are tried to fix. Thus it is not surprising that a single perspective succeeds as a description of a machine; it merely reflects how the machine came into being as a realization of a model.[[17]](#footnote-17) Indeed, the modeling relation quite illuminatively portrays technology as science in reverse: science as being about generating models of systems, and technology as being about generating systems as realizations of models, and this reverse picture answers, in effect, the machine-part of our question. In laboratory experiments, on the other hand, the definition of the studied system, and all the arrangements, specifically aim to exclude influences and entailments not described by the model. Thus, although models have to conform systems in laboratories, rather than the other way around as with machines, laboratory practices precisely search for situations from which unaccounted entailments can be, and have been, intentionally cut off.[[18]](#footnote-18) But falling bodies and the Solar System certainly are *natural* systems, and for limited intervals of time, they make no errors. Since the Solar System (or rather some subsystem of it) as *Nsol* is, arguably, the grand origin of the objectivist ideals in Western post-Newtonian science, it is in order to consider it in particular. Indeed, the manner in which commuting modeling relations are searched for in laboratories derive to an important extent their nature from Newton’s treatment of celestial mechanics, and likewise the models realized as machines of technology belong to the pedigree of Newton’s *Fsol*. So, what is this inherited character of *Fsol*, and what is the aspect of *Nsol* it reflects?

The crucial aspect of *Nsol* is that it admits an encoding into a *fixed state space*, and within this space, states follow one another *recursively* (Rosen 1991, pp. 67-107). For the present purposes, it suffices to think of this in the following intuitive manner. If a scientist observes *Nsol* by, say, recording a planet’s phase at distinct intervals of time, the *chronicle* of observationsthus generated possesses certain kinds of identical relations between the recorded values; the *relations* between values do not change from value to value.[[19]](#footnote-19) In other words, because of the *physical constraints* characterizing *Nsol,* the chronicle of observations will manifest the *mathematical constraint* of being recursive (recursive in the sense that $f(n)$ entails $f(n+1)$ for every *n*). The coincidence of these constraints, one characterizing *N* and the other *F*, is one of the reasons why the respective modeling relations commute. Anyway, this mathematical constraint is then reflected as an *absolute distinction between system states and dynamical laws* in the corresponding formalism *Fsol*. That is, since the rule of state transition in recursion is always the same, the rule may be conceptually divorced from the states on which it operates; we can find a relation answering questions of the form “If δ*A*, then δ*B*?” once and for all, applicable to every possible state. Or, in still other words: The rules of state transitions do not evolve as the states evolve; the rules seem to be entirely independent of the system’s doings, and thus it appears as if the rules were in a sense “external” to the studied system and its organization. I believe this is one of the cornerstones of the objectivism characterizing post-Newtonian modern science.

Indeed, it seems to be here, in the separation of the dynamical laws from system states, where the classical idea of immutable, unexceptional, and eternal “laws of Nature” is rooted, as is Laplace’s demon and the classical conception of determinism, with obvious and enduring influences on discussions of free will, on the idea of an objective “God’s eye view”, on the organism-life and the brain-mind problems, and so forth. At the heart of each of these themes is the presupposition that a state can be assigned to a natural system, and that fixed laws coming from the “outside” of the system, like the fixed hardware rules of state transitions in the processing of an algorithm, will push this state “objectively” to the next state (the basic picture remains essentially the same even if states, or laws, or both are conceived in statistical terms). Furthermore, it is worth of a moment’s reflection to consider how closely this absolute state-law separation parallels the above-mentioned absolute being-doing separation in the substance ontological tradition.[[20]](#footnote-20)

There are many ways for elucidating the non-genericity of the state-law separation; perhaps the most straightforward is to merely unravel and acknowledge its historical situatedness. Another, more formal approach is elaborated in the Appendix, as a review of an argument according to which in activation-inhibition networks the separation of states from laws requires the exactness of certain differentials, which is a non-generic condition. But let us here try to build a more intuitive bridge from the state-law separation to complex systems and especially to the organism, and hence begin by considering a fragment of reasoning of the following form:

$$Ax=y$$

to be read such that operation $A$ takes value $x$ to value $y$ (see also Rosen 2000, p. 165). Now, if this is how we think of, say, the trajectory of a Newtonian particle, the question that generally interests us is “Why $y$?”, i.e. “Why is the particle now here?”, and the two answers immediately available are “Because $x$”, i.e. “Because it was previously there”, and “Because $A$”, i.e. “Because the dynamical law entails $y$ from $x$”. The questions that do *not* generally arise are “Why $A$?” and “What $y$ entails?”; the former may be ignored (“hypothesis non fingo”) since $A$ is always the same, and the latter may be ignored since all $y$ entails is a situation of exactly the same kind; i.e. $y$ becomes the new $x$ (Rosen 1991). Thus, if we can do well by ignoring these questions, then the state-law separation evidently provides a good framework in which to work; then we merely fix $x$ and let fixed $A$ to entail $y$ from it.

But suppose then that instead of a Newtonian particle, our $N$ is a living organism, and we are concerned with a process in which an enzyme catalyses substrate $x$ into product $y$, and this capability of the enzyme to entail is denoted by $A$. Can we still do well by ignoring the above questions? Here the answer is no: the question “Why $A$?” cannot be ignored because it is clear that something *else* of the organism, our $N$, must *entail* the enzyme entailing $A$. This can be thought of in such a way that there is a *set* of functions mapping $x$ to $y$, occupying a parameter-coordinated function space, and there is some process of $N$ (other than $Ax=y$) that “picks up” a certain function out of the function space by determining the corresponding parameters (in concrete terms, for instance, by determining the prevalent enzyme concentration). What this seems to imply is that the “law” of our original process, the $A$, can legitimately be interpreted in terms of “states” of another process.

Likewise, the question “What $y$ entails?” cannot be ignored either, since instead of entailing a new situation of the original kind, $y$ evidently must entail a difference, a stabilization, or something of the sort taking place within the organism. In other words, $y$ will not fly out of the process into nowhere; instead, it will directly or indirectly have eventually an effect on $A$ itself (either entirely within the organism, or else via its interaction with the ambience). In theoretical biology, loops or *closures* of this kind have been widely discussed as perhaps the most central feature of living organisms, and it was Rosen who originally introduced a language for discussing them by means of separating *efficient causation* from *material causation* (Moreno & Mossio 2015; causal categories will be discussed further below). But the main point is that also with respect to $y$, it seems legitimate to say that what is *entailed* in one process may (and generally will) *entail* in another process. Or, in other words, what is interpreted as a state of one process modifies or generates the laws of another.

With these ideas, let us again return to Fig. 4, an organism as the $N$. Suppose we have interacted with the organism in various ways, and thus generated a host of $F$:s each honestly describing some particular entailment structure of it. Is it possible to combine all this information into a single objective description; into the largest $F$? The reason why this now seems impossible is that while with the original $F$:s we may rather unproblematically discriminate between what happens (“state transition”) and why we think it happens (“law”), it appears that the hypothetical largest picture cannot inherit such a property from the quotient pictures (each in fact describing a *sub*system of $N$); thus it at least seems legitimate to propose that an idea of an objective state, on which a fixed and objective “law” could act on, is inconceivable when an intact complex system like an organism is concerned. In essence, what this implies is that if there is a largest picture, it may be an organization of the quotient pictures in some sense, but it cannot be just another picture *like them*, and it cannot make the quotient pictures to vanish. And if this much is accepted, then it indeed appears that “Reality seems capable of sustaining more than one account of it”, even when a single natural system extracted out of the ambience is concerned – if the system happens to be a complex system in which *entailments themselves are entailed by other entailments within the system*.

Obviously, this in no way contradicts the fact that there *are* natural systems, extractable out of the ambience, which seem to manifest only a single mode of causal entailment; systems with which it is fruitful to work without asking what entails the entailment, and what is entailed by the entailed. Rosen calls these kinds of systems *simple*, and they constitute especially the province of classical physics. When studying their behaviours, it is quite legitimate to forget about the first root of perspectivism; i.e. to forget that there may be entailed events in the environments of these systems – this does not affect how the simple systems *themselves* are to be conceived. But as we have seen, there also appears to be genuine natural systems, extractable as such out of the ambience, which consist of several different modes of entailments being intertwined together. These entailments can also be studied by selectively imposing system-environment dualisms, though now *within* the system, but here the effects of doing so cannot be so lightly ignored; here the questions like “Why $A$?” and “What $y$ entails?” are all-important, and directly affect our views *both* concerning the extracted subsystem as such, and concerning the intact complex system. This property is, in essence, what characterizes *complex systems* in Rosen’s sense, and it is what I call the second root of perspectivism because it is what actually renders the first root an acute *problem*.

Further discussion on the nature and evolution Rosen’s notion of complexity may be found, for instance, from Louie (2008); here I wish to merely emphasize two crucial aspects of it. Firstly, complexity is taken as a *qualitative* property in the sense that if a system is not simple, then it is complex. In other words, there is no quantitative threshold to be crossed after which a simple system becomes complex; rather, there are formal conditions a system must satisfy in order to be simple (which I do not expound here; the reader may consult Rosen 1991), and if it fails to satisfy them, it is complex. Thus what is perhaps more commonly understood by complexity is *complicatedness* in Rosen’s parlance and, indeed, a simple system may well be tremendously complicated. Secondly, since complexity is thus defined via the negation of simplicity, complexity takes the role of the generic, and simplicity that of the specific. This is a truly radical idea, since what it implies, amongst other things, is that extrapolating ideas of causality from “elementary” simple phenomena to complex is very likely to result in *artifacts*; when the conditions securing simplicity are successively loosened and discarded, we are likely to enter a range of possibilities as surprising as, say, that opened by quantum mechanics via its removal of the non-generic constraints characterizing classical physics.

As can readily be seen, a basic consequence of complexity in this understanding is that it is often possible to watch the *same effects* and explain them by *different causes*. This is intuitive in biological context; for instance, an organism may be simultaneously encoded in terms of its “molecular state”, or why not “quantum mechanical state”, or “physiological state”, “ecological state”, “life-cycle state”, “sense-informational state”, and so forth; each of these may capture some form of entailments of the organism, i.e. an aspect of it, but none can be regarded as an “objective” description of the organism because any one of them erases too much away of what the organism actually is. Furthermore, each of these encodings is clearly tied to a particular mode of interaction and conceptualization, constituting a specific system-environment dualism; this is what renders each encoding perspectival. But I think biology is hardly the only field where such views may flourish; for instance, it is easy to conceive of a situation in which a juridical law $A$ entails consequence $y$ from action $x$, and this entailment follows a particular kind of juridical logic. On the other hand, $A$ itself may here be entailed by “logic” of entirely different kind; say by that of politics and political institutions. And also here, $y$ may entail consequences quite unpredictable and apparently irrelevant from the standpoint of $A$, say societal segregation, which then, via further interactions, may in crucial ways become involved in the entailment of $A$. Thus again, we cannot expect that a single perspective succeeds as a description of the events that unfold, and I think this underpins the general observation that though it may be technically challenging to argue for perspectivism and complexity *against* objectivism and simplicity, the resulting ideas are, after all, intuitive and natural.

Finally, I would like to point out that just as the reduction-emergence debate was above argued to be partly a *consequence* of the perspectival nature of knowledge, as was the tension between process and substance ontology, the *ceteris paribus* talk ubiquitous in biology can, in my view, be interpreted as falling into the same category. This is because the subject matter of biology is complex, and thereby the second root of perspectivism says that the system-environment dualisms imposed for the purpose of generating particular knowledge claims can never be lightly ignored when doing biology; thus biological knowledge claims are always associated with *ceteris paribus* clauses of one sort or another. However, this is not exclusively a negative conclusion; rather it in itself tells something *about* biology and about the world. Amongst other things, it seems to imply that the lack of always valid and immutable laws *in our descriptions* does not imply lack of order *within the organism*; that the organism, in itself, can well be viewed as “the paragon of orderliness”, exhibiting order and regularity “unrivalled by anything we meet in inanimate matter” (Schrödinger 1967, p. 77), even if we as external observers are forced to impose all kins of boundary conditions, *ceteris paribus* clauses, changes in descriptions, statistical arguments, and the like, when making sense of its behaviours. In other words, it seems to be quite at the heart of complexity that order in Nature does not translate neatly into order in our descriptions. If this is so, I think the *ceteris paribus* talk need not be taken as a consequence of the finiteness of our brains or computers, but rather as a consequence of the fact that we are *external observers* subject to the laws of epistemology. Furthermore, is it not the case that the language of quantum mechanics is, albeit in a much more restricted sense, a *ceteris paribus* language too; is it not the case that the crown jewel of quantum mechanics is an equation telling us how a quantum state would have evolved had there not been a measurement?

But to summarize the main result of the present section: If a complex system like a living organism is put into the left box of Fig. 4 as the $N$, there will in general be many corresponding $F$:s available, each describing a subsystem of $N$ and corresponding to a particular mode of causal entailment. Each of these $F$:s is associated with a particular way of imposing the system-environment dualism. Since in the intact $N$ these entailment structures are tightly intertwined together, in ways not directly seen from $F$:s themselves, the effects of imposing perspectival system-environment dualisms can almost never be ignored when studying complex systems. Therefore, if the system-environment dualism as the first root entails perspectivism in principle, it seems to me that complexity as the second root entails perspectivism remarkably more strongly, and indeed with rather practical implications.

**5. Perspectival Science**

The picture I am thus proposing says that the basic epistemological reason why knowledge is perspectival relates to the system-environment dualism, and the reason why this can seldom be ignored is that we are in fact not surrounded by dynamics of weakly interacting simple systems, but rather we seem to be inhabitants of a complex world of strongly interacting complex systems. In this world, entailments themselves are entailed in non-trivial ways, which makes the dynamics of our world something much more interesting than progression from initial conditions towards a final state of equilibrium. Above I suggested that while the first root of perspectivism aligns well with Wimsatt’s “piecewise approximations to reality”, more could be gained by elaborating the idea of the second root. Let us now inspect exactly what, especially from the point of view of the sciences themselves.

The most important consequence of the second root is, in my view, that it encourages to reconsider the character of *natural systems we already think we know*. That is, if we only had the first root, we could accept that because of the “environment” the extent to which the truth of our claims hold will be limited, and that a “rainforest”, instead of a “desert”, of claims, ideas, and intuitions is required. But with the second root, we are equipped with the stronger idea that the behaviours of an intact $N$ can be expected to be *qualitatively* different from the behaviours of its isolated subsystems; we are likewise equipped with the idea that the behaviours of these subsystems may be qualitatively different depending on whether they are functioning in artificial isolation or as components of the intact system. This has both negative and positive implications, and to get hands on them, let us elaborate an example which is fictional and simple-minded, but not implausible, I think.

Thus, suppose there is a (pre-systems-biological) community of scientists that has invested much effort in studying how a ligand $L$ binds to a cell-surface receptor $R$, and how a sequence of events $E$ then unfolds within the cell. Hence their system, call it $N$, comprise the causal relations obtaining between $L$ and $E$. Suppose further that the “environment” of $N$ consists at least in the entailments responsible for the presence of $L$ and $R$, and in the further events entailed by the unfolding of $E$. By implication, then, to the environment belong also the ways in which the entailments of $E$ act back on $E$ itself, via their influence on $L$ and $R$. These kinds of influences are not included into the description of the mechanism, or the system; in practice, they are controlled in experimental setups and “averaged out” from observational data.

Now, what happens if the system-environment dualism is then suddenly “removed”; if $N$ becomes truly a subsystem embedded into a living cell, on its part embedded into a living organism? If we refer to the relations between $L$ and $E$ in this new situation by $N'$, then what is the relation between $N$ and $N'$? Are their causal structures *alike*? The basic lesson of systems biology, on my understanding, is that the assumption that they are sufficiently alike (which might be regarded as the objectivist’s assumption) is often not a good assumption at all, because when the excluded entailments enter the picture, the actual relations between $L$ and $E$ might depart quite drastically from the original appearance of $N$. Therefore, while it is clear that *something* has been learned by studying $N$, it is not at all obvious how this something relates to $N'$ and, importantly, there are good reasons to regard the difference between $N$ and $N'$ as an *entailed* difference, rather than something to be dismissed in the name of the stochasticity of Nature. I think this kind of a situation is far from peculiar to systems biology; essentially the same concerns arise in the contexts of ecosystems, societies, and all that. Anyway, what the second root seems to imply is that instead of straightforwardly building our picture piece by piece, it might be worthwhile to try to find a *novel* way of discussing the relations between these pieces; a way of generating legitimate perspectives on perspectives. Consider the following words of Rosen:

The category of simple systems is, however, still the only thing we know how to work with. But to study complex systems by means of approximating simple systems puts us in the position of early cartographers, who were attempting to map a sphere while armed only with pieces of planes. Locally, and temporally, they could do very well, but globally, the effects of topology of the sphere become progressively important. So it is with complexity; over short times and only a few informational levels, we can always make do with a simple (i.e. dynamical) picture. Otherwise, we cannot; we must continually replace our approximating dynamics by others as the old ones fail (1985/2012, p. 391).

I will in a moment close this section by introducing the manner in which Rosen sought to generate the “global topology” of complex systems. Before that, however, I would like to explicate what I mean by the mentioned negative and positive implications of the second root of perspectivism, and for that purpose, let us switch to psychology as our new exemplar. So, the second root implies that whatever is said about the associations between, say, such and such neurotransmitters and certain brain regions, or between such and such societal status and certain mental disorders, extrapolating this kind of information to any particular behaviour of any particular human being without thorough “semantic” judgement is uninformative at best, and severely misleading at worst – this seems to be a negative implication. Every sensible psychologist is aware of this, of course. But *how* negative an implication is this? I think it largely depends on what is thought about the aims and means of science more generally. On one extreme, one might conceive that the chief aim of science is to generate rigour in some quantitative sense, and that the language of statistics, large datasets, and carefully placed constraints provide means to generate such rigour even within a discipline like psychology. In this view, it may then be concluded that the particular behaviours in which everything intertwine in unpredictable ways together – which I would in fact be prepared to call the world as it is – is simply not what the sciences are *about*. On the other extreme, one might perceive it as the principal aim of the sciences to generate theoretical frameworks in which the semantical considerations and judgements could be insightfully performed and analysed; then the negative implication, if left as such, would clearly appear as pressingly negative. I am inclined to think that the modern techno-scientific world, at least in its most recent decades, has cultivated quite much the former view of science, while, say, the Greek conceptions were perhaps closer to the latter; on the other hand, it is not inconceivable that the increasing interest in biology *qua* biology, and in complex systems more generally, might be pulling us back towards the latter extreme.

But this takes us to the positive implication of the second root, which is, in essence, its suggestion that the entailment structures of complex systems are related to one another in a way that is not just another simple entailment structure; in other words, the second root suggests that the organization of these perspectival pictures might be conceptualizable in itself, thereby rendering the idea of a perspective on perspectives conceivable. Rosen’s relational system theory is an attempt to generate such a conceptualization, so let us consider briefly his ($M, R$) -model of the organism as a particular example (following Rosen 1991, see also e.g. Rosen 1972). I think the model nicely illustrates strategical choices that might be of quite general importance; i.e. valuable also outside the particular formalisms manifesting them below.

Thus, the basic component of a relational description is the following kind of a diagram:



which may also be thought of as a mapping $f\left(a\right)=b$. The solid-headed arrow indicates “efficient causation”, and the open-headed arrow indicates “material causation”, or “flow” from $A$ to $B$ (inspired by Aristotle’s causal categories). Thus if we ask within the diagram “Why $b$?”, the two answers immediately available are “Because $f$” and “Because $a$”, and these answers are of different nature; an intuitive understanding may be obtained by “perturbing” them in the examples given below. This is, of course, already familiar from above, only in a somewhat different notation. A crucial aspect of the relational language is that syntax does not fix semantics, and also the above diagram can be interpreted in many ways; for instance:

1. Enzyme $f$ catalyses product $bϵB$ from substrate $aϵA$
2. Metabolic system $f$ processes metabolic products $B$ from food inputs $A$
3. School system $f$ entails a set of educated citizens $B$ out of a set of uneducated children $A$

Thus evidently, this is a language of *system organization*; in each of the above interpretations a larger context is almost a requirement. But when proceeding towards such a context, a possibility arises that those which entail, i.e. the efficient causes, are themselves entailed by something else of the same system, which is the hallmark of complexity. Intuitively this means, as before, that something of the organism must entail the enzyme $f$ entailing $B$ from $A$ (the enzyme comes neither from nowhere nor from the outside of the system), just as something of a society must entail the school system entailing the education of its children. The ($M, R$) -model of the organism, represented below, is a complex diagram in this sense, and from the diagram we see that while it is open in terms of material causation ($A$ unentailed), everything that entails is entailed by something else within the diagram:



In biological terms, there are three things going on in the diagram: the *metabolic processor* $f$ is generating metabolic products $B$ from inputs (“food”) $A$, the *repair* *function* $Φ$ is entailing the repair of $f$ by using its own products $B$, and finally the *replication* *function*, in which an element $b$ of $B$ acts as a processor, is entailing $Φ$ from the elements of $f$.[[21]](#footnote-21) Thus, what the ($M, R$) model aims to describe are the relations between metabolism, repair, and replication that all living organisms must realize; what *else* the organisms might be, and *how* these relations are in fact realized, is left quite unconstrained by the model.

But interesting as it is, let us forget about the biology of the ($M, R$) model; let us not even care whether or not it succeeds in representing that what it aims to represent. For, if it is taken just as an exemplar of the relational strategy, it illustrates three aspects which are, in my view, quite relevant with respect to perspectival science in general. Firstly, the (*M, R*) model is precisely tailored for the purpose of bringing different *kinds* of entailment structures into a common representation. To get a better sense of this, it must be noted that a basic property of relational diagrams is that they can be composed and decomposed; in the simplest case this could mean the following:



Therefore, it is possible to begin from a component like the metabolic processing in general, playing a crucial role with respect to the studied complex system in one “global” perspective, and decompose it into arbitrarily complicated detail by employing lessons from other perspectives; thus “simple mechanisms” as subsystems can be incorporated into the description. And, perhaps more importantly, it is also possible to do the converse; i.e. to travel from the detail “upwards”. Consequently, an aspect of the organizational architecture may remain invariant even if the underlying “mechanisms” change to something else, which is very characteristic in biology but also elsewhere (for instance, the processing of food out of something is also a basic component of the organization of societies, which persists even though the actual “mechanisms” realizing it are constantly modified and replaced).

Secondly, the ($M, R$) model is, in itself, a very perspectival entity. This is because it does not even pretend to be a “mirror of Nature”; rather, it is a fragment of language, or an inferential structure, which of course can and must be studied purely as such, but which actually begins to “talk” only when connected to the world by suitable semantics, and the model is very open to many kinds of semantical interpretations (the number of ways in which the model can be realized is unlimited). In other words, the model is *interpretationally open*. It seems to me that interpretational openness in this sense could be thought of as the price to be paid for generating knowledge frameworks of complex systems in such a way that the lessons are not overwritten immediately by the contingencies of the real world. Indeed, if the ($M, R$) model succeeds in doing what it aims to do, then its main conceptual lessons should remain untouched, at least to a substantial extent, by the endless particularities of living organisms.

And thirdly, despite such interpretational openness, the ($M, R$) model nonetheless aims to say something very fundamental about the “here and now” behaviours of organisms of the real world. In particular, the relational structure it describes is not conceived as a mere consequence of putting $f, B$, and $Φ$ together, or as a sort of an epiphenomenon; rather, it is intended to portray an organizational context in which such subsystems can acquire a meaning in the first place; an organization which determines the very identities of these subsystems, guarantees the continuation of their existence, and which largely determines how, when, and where the events comprising them actually unfold.[[22]](#footnote-22) In other words, with suitable semantics it is intended to speak of fundamental and genuine relations of the world. And in this sense, the model is something like a “perspective on perspectives” to which I alluded above, and it seems conceivable that such a perspective might indeed yield substantial knowledge initially unseen from any of the original perspectives upon which it has been built. However, it must be stressed that, as is perhaps obvious, even as such it is certainly not the *only* perspective on perspectives possible. In any case, perhaps the most important lesson the (*M, R*) model demonstrates is that a picture of a tremendously complex system, like that of a living organism, can actually be quite neat, and yet fertile. That is, if it is acknowledged that the project of generating an exact and context-independent image of Nature rests on futile foundations, it is perhaps more easy to accept that a wisely chosen perspective often does better job than the maximum number of detail. And if so, then it seems that what is important concerning problems of complex systems like organisms, ecosystems, and societies is perhaps not the acquisition of every possible piece of data, but rather the semantical procedure of deciding how to include the relevant, and how to exclude the irrelevant.

**6. Conclusion**

My last question, which I would like to tie to the encapsulation of the conclusions, is this: how do the above considerations relate to the existing literature on scientific perspectivism? It seems to me that the relation is largely *complementary*. To see this, let us observe that for instance Massimi (2018) in her analysis of different kinds of perspectival truth repeatedly employs the phrase “science maps onto nature”, in this word order. This is of course the correct order in an analysis of truth, and to some extent it reflects the tradition in philosophy of science which has, with all legitimacy and importance, emphasized questions such as “Science says there are electrons, are there?” or “Science says water is viscous, is it?”.

But the problem faced by Rosen was the exact opposite: he was troubled of how well Nature maps onto science. In particular, his impression was that if a living organism is mapped onto the language of science, something very important does not come along (its relational organization due to which it is a *living* organism; see e.g. 1991, pp. 11-23). In the present paper, I have investigated perspectivism mainly from this inverse direction, beginning from natural systems and not from claims about them. Thus, as a complementary way of understanding perspectivism, such an approach might suggest something like the following: knowledge is perspectival because of that what it leaves to the world, and what it therefore cannot project back onto it. In this vein, I summarize my conclusions below as a system of two “axioms” of the acquisition of knowledge, each yielding both a “realist part” and a “perspectival part” as “theorems”. These are of course not axioms and theorems in the logician’s sense, but regarding them metaphorically in that way puts, it seems to me, the elements of the account into correct order and relations.

**1. The first root of perspectivism: “Axioms” of extraction**

Knowledge of natural systems is based on the extraction of systems out of the ambience. This procedure imposes a system-environment dualism, such that the entailment relations characterizing the system are included into the description (e.g. as conceptualized state transitions), while the entailment relations of the environment remain non-conceptualized and become in a typical case manifest as unaccounted or vaguely accounted influences on system states. With a genuine system extracted out of the ambience, it is possible to engage into a commuting modeling relation.

*1.1 REALIST PART*

As in the traditional realist’s argument, it would be miraculous if in a commuting modeling relation the “scientist’s path”, consisting of encoding, inferential entailment, and decoding, would coincide by accident with the “natural path”, consisting of causal entailments of the world. Moreover, whenever the paths do not coincide, the elements of the scientist’s path are to be replaced or modified, implying that at least when an already extracted system is concerned, it is the world from which the model acquires its form, and not the other way around.

*1.2 PERSPECTIVAL PART*

Where and how the system-environment boundary arises depend on the scientist’s aims and manner of interacting with the world, and is thereby perspectival. Knowledge obtained about a particular extracted system is valid only to the extent that the excluded environmental entailments remain absent or within appropriate limits.

**2. The second root of perspectivism: “Axioms” of complexity**

The characteristic property of complex systems is that no single family of observables, related to one another by a single mode of entailment, suffices as a description of a system. The reason for this is that in complex systems entailments themselves are entailed in non-trivial ways by other entailments within the same system. Therefore, what enters into a scientific description of a complex system is in the general case a subsystem of the original system. For the above reasons, a subsystem extracted out of a complex system behaves differently from a subsystem embedded into the intact total system.

*2.1 REALIST PART*

By adjusting experimental circumstances, and the scope and accuracy of the claims, it is possible to enter into commuting modeling relations with subsystems of complex systems. Therefore, realist knowledge about subsystems of complex systems is obtainable in the sense of 1.1.

*2.2 PERSPECTIVAL PART*

Claims about intact complex systems on the basis of subsystems are perspectival in the sense of 1.2, albeit remarkably more strongly so because the excluded “environment” generally consists in entailment relations upon which the character and integrity of the intact complex system, and hence also the character of the subsystem itself, essentially depend.

Thus, this scheme seems to imply that while *many things* can be said about the world (1.2) and about complex systems of the world (2.2), there is no need to allow that *anything* could be said about them (1.1 and 2.1), and this is indeed how I would like to encapsulate the basic spirit of scientific perspectivism.

**Competing interests**

The author has no competing interests to declare that are relevant to the content of this article.

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**Appendix**

It may be difficult to conceive what it means to say that system states and dynamical laws are inseparable, or that a natural system like an organism has no states, and at least partly because in the tradition of modern science, there are few *formal* examples of such systems. In this Appendix, I briefly review Rosen’s (2012, pp. 371-392) treatment of an *activation-inhibition network with inexact differentials*. This, I propose, may function as the Solar System of the scientific perspectivist; as a basic picture of a system of complex, intertwined entailments. Activation-inhibition networks are well-known and abundant in biology and chemistry, and their abstract representation might be quite universally applicable.

So, let us begin by thinking of a system of *n* interacting units $x\_{1},…,x\_{n}$. We assume that a numerical value can be assigned to each $x\_{i}$, and we call $x\_{j}$ and *activator* of $x\_{i}$ if the increment of $x\_{j}$ influence positively the rate of change of $x\_{i}$, that is,

$^{∂}/\_{∂x\_{j}}\left(\frac{dx\_{i}}{dt}\right)>0$ ,

and an *inhibitor* if the influence is negative. As is well-known, in these kind of systems there are, in addition to the activation-inhibition relations, the *agonist-antagonist* relations in the next “layer”. Hence, in addition to asking how a change of $x\_{j}$ affects the rate of change of $x\_{i}$, we may also ask how a change of $x\_{k}$ affects the $x\_{j}$:s influence on $x\_{i}$. Thus, if we describe the activation-inhibition relations by defining

$$u\_{ij}(x\_{1},…,x\_{n})=^{∂}/\_{∂x\_{j}}\left(\frac{dx\_{i}}{dt}\right)$$

then the agonist-antagonist relations can be described as

$$u\_{ijk}(x\_{1},…,x\_{n})=^{∂}/\_{∂x\_{k}}\left[^{∂}/\_{∂x\_{j}}\left(\frac{dx\_{i}}{dt}\right)\right]$$

and nothing prevents from iterating this procedure further, without limit. However, if the relations in this system are exactly symmetrical, such that, say, $x\_{j}$ acts as an activator for $x\_{i}$ exactly as $x\_{i}$ acts as an activator for $x\_{j}$, which means that exact differentials *do* exist for the system, then the iteration procedure adds nothing new; one can travel between the layers by straightforward integration and derivation. On the other hand, if the symmetry condition does not obtain, and exact differentials do not exist, which of course is the general case, then it is impossible to “see” one layer from another; the layers are, in an important way, independent from one another. A mathematical object describing the dynamics of such a system is, therefore, an infinite object.

So, presuming our network is of this general type, what can be known about it? It must be recalled that what we see is the family of observables $x\_{1},…,x\_{n}$. By just evaluating them and by collecting the observations into chronicles, we can find no laws; recursion does not apply here. Furthermore, two systems exactly identical in terms of $x\_{1},…,x\_{n}$ might, and will, behave differently if their activation-inhibition patterns or agonist-antagonist patterns (or patterns in any deeper layer) are different. In Kantian terms, the $x\_{1},…,x\_{n}$ are our *phenomena*, while the activation-inhibition etc. patterns are, in a sense, the *noumena*. In order to get a little closer to the latter, we must *dampen* most observables such that it becomes possible to probe how, say, an increment of $x\_{j}$ affects $x\_{i}$. In other words, we must extract a subsystem out of our network, and inspect how it functions in the absence of the intentionally excluded relations. Our network is thus a system in which everything is entailed, or “non-random”, but for which a state cannot be assigned. This is because a state defined in terms of $x\_{1},…,x\_{n}$ is useless in the absence of a general rule of state transition, on the one hand, and on the other, a notion of state into which all the activation-inhibition etc. patterns are included would lead to infinity which, in other words, implies that it is not a meaningful notion to begin with. Nonetheless, it is possible to generate approximations of system behaviours by focusing on some relations, and by ignoring the underlying patterns of activations and inhibitions, and it seems clear enough that this kind of a procedure is not producing independent and objective descriptions of the studied system, but rather something like a family of complementary perspectives.

1. It is worth mentioning that it has often been felt as the great achievement of modern biology to embed life into the *same* mechanical-material picture (or perspective) with inanimate phenomena. Consider, for instance, the following words of Daniel Dennett (1995): “In a single stroke, the idea of evolution by natural selection unifies the realm of life, meaning, and purpose with the realm of space and time, cause and effect, mechanism and physical law”. Organicists tend to portray things differently, for instance regarding evolution not as the explanation of life but rather as the “historical dimension of life” (Moreno & Mossio 2015). This is another, largely independent way of seeing a link between perspectivism and organicism. [↑](#footnote-ref-1)
2. The following passage by Kurismaa (2015) is instructive regarding this biological role of the mind as a transducer between sensation and action: “In this view, it is essentially the mind that enables the same animal to instantly transform itself from a crawling to a climbing, swimming or running organism – without any changes in its basic morphological constitution, and only by selectively realizing the various functional configurations which its increasingly complex body-plan has made available in the course of evolution”. [↑](#footnote-ref-2)
3. Illustrative of this understanding of abstraction, i.e. in terms of *forgetting*, is the idea that the measurement of a single observable is an act of “ultimate abstraction”, which substitutes for a natural system of the world a single number, while the theorist, positing relations between several observables, makes the description “less abstract” by incorporating “more” of the world into the description (ibid.). [↑](#footnote-ref-3)
4. As a sidenote, it is interesting to contrast the intense search for the most efficient way of fractionating the world into systems and environments (a search for “fundamental particles”, for instance), which may perhaps be seen as a characteristically Western enterprise, to the exactly opposite attempt to get rid of the natural need to fractionate the world altogether, as exemplified by, say, concepts such as *Śūnyatā*, “emptiness”, or *Anattā*, “non-self”, in Buddhism. There appears to be a sense in which the former provides means to discuss definitively about aspects of Nature but has troubles in putting them into a whole, while the latter provides means to “see” the whole without having precision on specific aspects of it. Perhaps this is one reason why several scientists perceiving it as problematic to put the pieces together have been seeking inspiration from the entirely opposite Eastern traditions of thought. [↑](#footnote-ref-4)
5. Massimi (2018) interprets Kant’s account on perspectival knowledge such that knowledge is both “from a vantage point” and “towards a vantage point”, such that the former reflects the limitations and capabilities of a human observer, while the latter reflects the regulative role of reason. It seems to me that both of these aspects can be thought of as being present in the first root of perspectivism; i.e. in the imposed dualism between systems and environments. “Where” the dualism is placed depends both on what we can see and what we need to see, as Foucault’s passage illustrates. [↑](#footnote-ref-5)
6. In the case of quantum mechanics, a question might arise on whether the system-environment boundary could be evaporated altogether, in the sense that behind the boundary of a quantum system there would be another quantum system, or in the sense that the whole world could be portrayed as a single quantum system. Such ideas have of course quite much to do with perspectivism; I say something about them below, but I wish to emphasize also here that the principal motivation is to illustrate system-environment language, and not to say anything too conclusive on such matters (while perhaps elucidating one potential way of approaching them). [↑](#footnote-ref-6)
7. Though this particular formulation of Natural Law is Rosen’s, the root ideas behind it were of course not original to him. To some extent they reflect rather directly the most basic premises of realism; i.e. the premise that a mind-independent (at least partly ordered) world exists, and the premise that knowledge of that world is obtainable. As Rosen (2012, p. 54) himself writes, the ideas comprising his epistemological stance were not as such novel, while their particular juxtapositions, and connections to various aspects of system analysis, in many ways were. [↑](#footnote-ref-7)
8. Rosen often emphasizes that a formalism nevertheless need not be, and generally is not, *formalizable* (in the sense of Gödel). A formalism neither needs to be a mathematical language, though thinking in terms of mathematical formalisms serves well for the abstract illustration of the general ideas involved. [↑](#footnote-ref-8)
9. Even though decoding is perhaps most intuitively thought of precisely as prediction, it may generally be an assertion of any kind (and need not be a simple inverse operation of encoding; see Rosen 1991 & 2012). [↑](#footnote-ref-9)
10. See Rosen (2012, p. 280). Essentially because of the environment, exact coincidence is not even the expectation apart from some specific categories of problems (such as perhaps those of traditional celestial mechanics). In practice, commutation must obtain “well enough”; when it ceases to do so a *bifurcation* has occurred. [↑](#footnote-ref-10)
11. See Cárdenas et al. (2018) for an argument of why Rosen’s epistemology does not support thinking in terms of hierarchies in the traditional sense. However, it is important to note that hierarchical structures and cycles *are* important and even central in Rosen’s theory, only in a sense somewhat different from the tradition (Louie 2009, Lennox 2020). [↑](#footnote-ref-11)
12. On my understanding, this is what Erwin Schrödinger (1964, p. 41) wants to emphasize by the following: “To begin with a purely factual statement: inorganic matter – the subject matter, by definition, of physics and chemistry – is an abstraction which, unless by special arrangement, we actually encounter scarcely anywhere, or at any rate extremely seldom.” [↑](#footnote-ref-12)
13. Of course, this is not intended to mean that the question of how “emergent phenomena” come into being is irrelevant or unapproachable. Using the terminology of footnote 17 below, I would say that, considering particles and a cell as an example, the “physiology” of particles can account neither for the “physiology” of a cell *nor* for its “fabrication”; these are three different problems each requiring a specific perspective to be addressed. [↑](#footnote-ref-13)
14. In MacFarlane’s (2007) terms, we hope to find a situation of *intra-conversational* rather than *inter-conversational* disagreement (disagreement about why *N* is doing what it does, rather than disagreement about what is *N*). [↑](#footnote-ref-14)
15. Formalism understood just as a fragment of language with some structure; it need not be a mathematical language. [↑](#footnote-ref-15)
16. Attributing error to the natural system and not to the model is perhaps unexpected, but should cause no confusion once adopted, and allows to illustrate certain aspects of the modelling relation. Moreover, doing so is not entirely unseen, especially in biology. For instance, mutation is conventionally described as an error in DNA replication; thus what *N* does “in the world” is described as erroneous with respect to the expectations of the model (see Rosen 2000, p. 247). [↑](#footnote-ref-16)
17. In Rosen’s (1991) terminology, the problems of “physiology” and “fabrication” coincide under such circumstances; e.g. the “physiology” of a clock essentially tells us how to build one. In biology, this is in general not the case, since one can have a detailed account of an organism’s physiology while remaining entirely unaware of how that physiology came into being. Likewise with other complex systems; for instance, a societal problem can have a rather definite and intelligible “physiology”, which may be very different from the interactions due to which the problem initially arose, and which may continue maintaining it (in this context, uncovering the “fabrication” is about uncovering the “root reasons” of the societal problem, which may not be at all visible in “physiological” considerations). [↑](#footnote-ref-17)
18. In the spirit of Cartwright (1983), Lange (2002), Wimsatt (2007) and others, we can well question the exclusively fundamental status of these arrangements: why should the causal relations stripped out of experiments be counted as less real aspects of our world? [↑](#footnote-ref-18)
19. More accurately, the states (phases) can be “made” to follow one another recursively; i.e. a position chronicle as such is not recursive, but together with velocity and acceleration chronicles, this *set* of chronicles becomes, under Newton’s Laws as constraints, recursive. This also involves the identification of “physical” velocity and acceleration with the first and the second “mathematical” derivatives of the position chronicle, which before Newton was not obvious in today’s sense (ibid.). [↑](#footnote-ref-19)
20. The state-law separation is also manifest in practically all forms of logic applied in modern science, as the absolute separation of *propositions* from *production rules* and, for instance, also quantum mechanics inherited this *formal* aspect of Newtonian physics; there are still the states (the wave function) and separate, recursive, dynamical laws (i.e. the Schrödinger equation). See Rosen 1991, pp. 103-107. This is an interesting view on quantum mechanics, whose central philosophical problems concern the interpretation of the state (the wave function), and the loss of recursion due to measurement (Lewis 2016) – in a way, it is the Newtonian state-law framework into which quantum mechanics was tried to fit, but into which it does not seem to fit completely unproblematically. [↑](#footnote-ref-20)
21. For instance in many bacteria, a protein encoded by the *FtsZ* gene (thus evidently an element of *B*) acts as the processor in cell division (Morris et al. 2013), thereby processing the regeneration of Φ from the activity of *f*. [↑](#footnote-ref-21)
22. It is worth mentioning that the organizational architectures captured by relational formalisms resemble to some extent the “non-causal explanations” of Marc Lange (2016). A non-causal explanation is a “because without cause” – instead of saying that *A* caused *B*, the explanans gives an account of the context of the explanandum, i.e. by specifying what is possible and what is impossible. Much in the same way, relational formalism describes the organizational-relational circumstances in which the particular, chronicled events (the nourishment of “simple approximations”) take place, instead of focusing on the events themselves. [↑](#footnote-ref-22)