

Emergent Evolutionism, Determinism and Unpredictability

Olivier Sartenaer

Department of Philosophy, Columbia University, 708 Philosophy Hall, 1150 Amsterdam Avenue, NY 10027, New York

Present address: Higher Institute of Philosophy, Catholic University of Louvain, Place du Cardinal Mercier, 14 bte L3.06.01, 1348 Louvain-la-Neuve, Belgium

*olivier.sartenaer@uclouvain.be
+32/473.58.04.06*

Abstract

The fact that there exist in nature thoroughly deterministic systems whose future behavior cannot be predicted, no matter how advanced or fine-tuned our cognitive and technical abilities turn out to be, has been well established over the last decades or so, essentially in the light of two different theoretical frameworks, namely chaos theory and (some deterministic interpretation of) quantum mechanics. The prime objective of this paper is to show that there actually exists an alternative strategy to ground the divorce between determinism and predictability, a way that is older than – and conceptually independent from – chaos theory and quantum mechanics, and which has not received much attention in the recent philosophical literature about determinism. This forgotten strategy – embedded in the doctrine called “emergent evolutionism” – is nonetheless far from being a mere historical curiosity that should only draw the attention of philosophers out of their concern for comprehensiveness. It has been indeed recently revived in the works of respected scientists.

Keywords: Emergent evolutionism – Determinism – Predictability – Chaos – Bohmian mechanics – Emergence

1. Introduction

If, during the dawn of modern science, it was once firmly believed that the behavior of deterministic systems was in principle predictable, things have now changed. In the light of the frameworks that are chaos theory and (some deterministic interpretation of) quantum theory, it has been extensively and convincingly shown over the past decades that some systems can be conceived of as deterministic, and yet be radically unpredictable.

The prime objective of this paper is to identify and describe an alternative strategy, embedded in the doctrine of “emergent evolutionism”, which is older than – and conceptually independent from – chaos theory and quantum mechanics, and which is also able to ground the divorce between determinism and predictability.

In section 2, I begin by setting the stage in a twofold movement. First, I propose a conceptual analysis of the notion of determinism through four different theses, namely “ontological determination”, “state determinateness”, “epistemic determination” and “state determinability”. On this basis, I then lay down the overall structure of what I will refer to as the “Laplacean argument”, according to which some minimal form of determinism necessarily entails predictability. This argument will be purposively framed in a way that renders explicit its dependence on three controversial inferences I_1 , I_2 and I_3 . In section 3, I concisely mention the way in which chaos theory and (some deterministic interpretation of) quantum mechanics constitute proper places to object to the Laplacean argument, namely through the idea of algorithmic incompressibility (to the effect that I_1 is denied) and the impossibility of performing non-disturbing (position) measurements (to the effect that I_2 is denied), respectively. Finally, in section 4, I turn to the original, older framework that is emergent evolutionism, which, as its name suggests, rejects the Laplacean picture by invoking the existence of “emergent” entities and laws through evolution (to the effect that I_3 is denied).

While the first two strategies have received much attention over the last decades in the philosophical literature, the third one is often overlooked as a

consistent – though metaphysically heavy – alternative way of grounding the idea that determinism and unpredictability can peacefully coexist. Emergent evolutionism is however more than just a historical curiosity. It has been recently revived in the works of respected scientists, coming essentially from the field of condensed matter physics, and this should constitute a sufficient clue that it deserves renewed attention from the community of philosophers of science.

2. The Laplacean Argument

In order to set the stage for the subsequent discussion, let us begin by analyzing the very general and somewhat ambiguous notion of determinism through four different theses¹. First:

(L_o) *Ontological determination*. There exists a uniform and univocal determinative relationship between successive states of a given system, to the effect that two similar systems in the same state and the same conditions at time t are in the same state at all times t^* .

Extended to the whole universe, L_o states that when two worlds agree at t , they agree at all t^* . Second:

(S_o) *State determinateness*. There is a fact about the state in which a given system is at each time t .

This second ingredient, which is seldom explicitly stated but often tacitly endorsed, is required for L_o to hold, insofar as for two systems (or two worlds) to be able to agree at any time t , there must at least be something to agree on at t .

¹The first one, L_o , corresponds to a metaphysical way of framing determinism that can be found, for example, in Boyd (1972), Schurz (1995) or Earman (2007) (under the name of “Laplacean determinism”). Adding the second thesis, S_o , to the picture is not an unusual move; see for instance Glymour (1971) or Bishop (2003).

Both theses L_o and S_o , which are primarily *ontological* claims about systems in the world and the way they evolve through time, can be given *epistemological* counterparts – L_e and S_e , respectively – which are claims about the access that cognitive beings can have to the states of these systems and the determinative relations between these states. Thus:

(L_e) *Epistemic determination.* The uniform and univocal determinative relationship that exists between successive states of a given system can be decrypted by a cognitive agent and captured under the form of a predictive algorithm. A predictive algorithm is a formal device (*e.g.* a set of equations) that allows in principle a cognitive agent to determine the state of the system at any time t^* from complete knowledge of its state at t (provided that, between t and t^* , nothing changes in the nature of the system that renders the algorithm obsolete).

(S_e) *State determinability.* The fact about the state in which a given system is at each time t can be known and specified by a cognitive agent.

If we now consider that a given system is *predictable in principle* (P) when its states at all times t^* can, as a matter of principle, be predicted by a cognitive agent at a previous time t , then we may lay down the structure of an argument that expresses a belief – *viz.* that deterministic systems are predictable in principle – that has been part of our scientific tradition since its advent in modernity. The argument – to which I will from now on refer as the “Laplacean argument” – runs like this (where theses P_i are the basic premises, I_i additional entailments traditionally taken for granted, and C the overall conclusion):

(P ₁)	L_o
(P ₂)	S_o
(I ₁)	$L_o \rightarrow L_e$
(I ₂)	$S_o \rightarrow S_e$
(I ₃)	$L_e \wedge S_e \rightarrow P$
(C)	P

In a nutshell, the argument expresses the idea that, given the assumptions that the state of a system at t^* is univocally determined by its state at t (P₁) and that the system has well-defined states at t^* and t (P₂), then an absolutely competent cognitive being (*e.g.* a Laplacean demon) should be able to capture the determinative relationship between these states under the form of a predictive algorithm (I₁), as well as specify precisely what the state of the system is at t and plug this specification into her algorithm (I₂). As a result, such a demonic calculator should be able to predict what the state of the system at t^* will turn out to be (I₃), and hence the system would be predictable in principle (C)².

It may be pointed out that $L_o \wedge S_o$ constitutes what can be referred to as “ontological determinism”, whereas $(L_e \wedge S_e) \wedge P$ rather constitutes “epistemological determinism”³. While the former consists of a claim about the determinative relations holding *in the world*, the latter pertains to the way in which cognitive agents can come to *know* these relations and exploit this knowledge to make predictions. According to the Laplacean argument presented above, ontological determinism entails epistemological determinism, and hence predictability.

²In what follows, I will regularly use the metaphor of the demon to capture the idea of a “perfectly competent cognitive being”. In order to be philosophically useful, such a metaphor should be understood in the following sense: a “Laplacean demon” is an idealized scientist whose cognitive and technological powers consist in infinite *extensions* of the powers of real human scientists. Accordingly, a “Laplacean demon” is *not* an omnipotent god that could overtly *transgress* what turns out to be physically possible according to our best scientific theories.

³For early uses of this distinction – albeit with slightly different terminologies –, see for instance Popper (1956), Hunt (1987) or Redhead (1987).

3. Around the Laplacean argument: contemporary strategies

That the Laplacean argument is mistaken – to the effect that there exist ontologically deterministic, yet unpredictable systems – has been massively vindicated over the last few decades from two different scientific perspectives, namely chaos theory and (some deterministic interpretation of) quantum mechanics. In this section, I briefly mention how these theories indeed provide adequate frameworks to argue against the Laplacean picture by rejecting either I_1 or I_2 , respectively. In section 4, I will turn to the real core of this paper by showing how a different, older framework – emergent evolutionism – is able to object to the Laplacean picture in yet another fashion, namely by denying the truth of I_3 ⁴.

But before turning to this, it is worth stressing the fact that chaos theory, (some deterministic interpretation of) quantum mechanics and emergent evolutionism have in common that they *object to* – rather than merely *circumvent* – the Laplacean argument. Accordingly, these approaches take the conclusion of the argument (P) as false while taking both its premises (L_o and S_o) as true. With that in mind, the obvious strategy one can adopt in order to argue for in-principle unpredictability through ontological *indeterminism*, defined as $\neg L_o \vee \neg S_o$, is not to be considered here⁵.

⁴I acknowledge the heterogeneity of the three frameworks envisioned here as strategies to object to the Laplacean argument (the first is something like a set of scientific models, the second some interpretation of a scientific theory and the third a philosophical doctrine). Nonetheless, this heterogeneity is not detrimental to the project of the present paper, insofar as identifying the possible options to oppose an argument doesn't *a priori* require these options to be related in a certain way. I thank an anonymous reviewer of this journal for having drawn my attention on this.

⁵Such a strategy is often put forward through an appeal to the so-called “orthodox” interpretation of quantum mechanics (see for instance Popper & Eccles (1977), p. 33). It ultimately rests on the two following facts (Maudlin (1998)): in some circumstances – typically when a “measurement” occurs, whatever that means –, the determinative relationship between successive quantum events – the “collapse” – is intrinsically chancy (denial of L_o), and/or quantum events themselves are not determinate (denial of S_o).

3.1. Denying I_1 through chaos

The way I framed the Laplacean argument in the previous section renders explicit a first strategy to invalidate it, namely denying the truth of I_1 , according to which ontological determination necessarily leads to epistemic determination ($L_o \rightarrow L_e$). Adopting such a strategy requires us to identify natural systems that are ontologically determined (so that L_o is true) and yet for which it is impossible to devise a predictive algorithm (to the effect that L_e is false).

Over the last decades or so, a wealth of literature has been devoted to convincingly showing that good candidates for such systems are chaotic systems. It has indeed been argued that the behavior of chaotic systems cannot be expressed in a closed-form solution, to the effect that there is no shorter algorithm to determine a future state of a chaotic system than the one that contains *complete* information about the system in question and its evolution (Stone (1989)). Surely, the latter claim implies that cognitive agents, no matter how competent, have to confine themselves to merely *inspect* – rather than *predict* – what a future state of a chaotic system will turn out to be, for there is no possible shortcut for knowing such state “ahead of time”, *i.e.* before the state in question actually obtains. Put differently, when it comes to chaotic systems, it happens that the best algorithm that a Laplacean demon can come up with is *incompressible*. All the demon can do in order to determine what a future state of the system will be is to “wait and see”. And surely enough, such a procedure doesn’t count as a prediction, insofar as an essential part of what prediction is is that there is a temporal antecedence between the moment when the prediction is performed and the moment when it is supposed to come true (or not)⁶.

⁶It is noteworthy that the notion of algorithmic incompressibility is not restricted to chaos theory. It is also used in the context of computational science as a way of vindicating in-principle unpredictability in spite of determination (see for instance Huneman (2012)). It also turns out that the fate for predictability in chaos is even direr, for it has also been argued that chaotic systems cannot be the objects of infinitely accurate measurements (Bishop (2003)), a fact that, when combined with the property of sensitivity to initial conditions, hinders predictability. This latter line of argument – which actually amounts to an objection to the

3.2. Denying I_2 through (Bohmian) quantum mechanics

Another strategy to object to the Laplacean argument as it has been framed in section 2 consists in denying the truth of entailment I_2 . This requires us to find some natural systems whose states are perfectly well-defined (so that S_o is true), and yet these states cannot be specified by a perfectly competent cognitive being (to the effect that S_e is false).

It has been shown that good candidates for such systems are quantum systems as considered in the light of a (ontologically) deterministic interpretation of quantum mechanics, on the model of Bohmian quantum mechanics (Albert (1992), Fine (1996))⁷. Indeed, while in such a framework L_e turns out to be true – for, given knowledge of the particles’ positions and wave functions at any given moment, one can thoroughly predict these at all future times, thanks to the predictive algorithm that is the conjunction of the Schrödinger equation and the guiding equation –, there is a consistent, available explanation, which can be formulated within the theory, of why a Laplacean demon should indeed lack the ability to precisely know the positions and wave functions of quantum particles at any given moment (see for instance Albert (1992), pp. 164-169). In a nutshell, such an explanation rests on the idea that non-disturbing measurements are precluded by the theory: being able to determine the position of quantum particles without changing their wave function would amount to a violation of the uncertainty relations.

Laplacean argument through the negation of I_2 – is even more acute when one supplements it with the claim that chaotic systems, like other physical systems, ultimately have a quantum-mechanical basis (Kellert (1993), p. 40, Schurz (1995), p. 138 or Bricmont (1995), p. 133). This second line of argument is addressed in the next section.

⁷I do not consider here the alternative, ontologically deterministic approach that is Everettian quantum mechanics, though I suspect that its stance towards the Laplacean picture is essentially the same as the Bohmian one. I also take “Bohmian mechanics” to refer to the ontologically deterministic interpretation of quantum mechanics that philosophers usually discuss, independently of the historical fact that, in the works of David Bohm himself, ontological determinism was not always embraced.

4. An original alternative: emergent evolutionism

In the previous section, I briefly mentioned how two specific scientific frameworks have recently provided us with the resources for objecting to the Laplacean argument, by rejecting either I_1 (in the case of chaos theory) or I_2 (in the case of Bohmian mechanics). In the present section, I turn to an original, older and often overlooked framework – emergent evolutionism – on the basis of which it can also be claimed that ontologically deterministic systems can be unpredictable in principle. I begin with an overview of the core tenets of the doctrine (section 4.1). On this basis, I explicate the way in which it objects to the Laplacean picture, namely by denying the truth of I_3 (section 4.2).

4.1. Central tenets of the doctrine

Historically, the doctrine of emergent evolutionism has been mainly championed in Great Britain by Lloyd Morgan (Morgan (1923)) and in the United States by Roy Wood Sellars (under the equivalent name of “evolutionary naturalism”; Sellars (1922)). In a nutshell, the core tenets of the view can be characterized through the following set of claims:

- Emergent evolutionism is a view about the natural world’s evolution broadly construed, *viz.* as the orderly advance, through time, of natural events.
- From the outset, emergent evolutionism is built in order to avoid the respective difficulties of two alternative, opposite views of evolution, namely gradualism and saltationism (Sartenaer (forthcominga)). Gradualism is the thesis – endorsed by Darwin himself and emphasized through his repetitive use of the maxim: “*Natura non facit saltum*” – according to which biological changes occur *continuously* by a *slow* accumulation of infinitesimal alterations on very large time scales. By contrast, saltationism is the view that biological change can occur as a result of saltations, or *sudden* and *discontinuous* alterations. As Huxley (Huxley (1893), p. 77) put it *contra* Darwin: “Nature does make jumps now and then”. From the point of view of emergent evolutionism, gradualism necessarily leads to an

unacceptable form of reductionism (due to the requirement of continuity, new entities are reducible to the substrate from which they have appeared, given some environmental conditions) and saltationism to an unacceptable form of dualism (due to the requirement of discontinuity, new entities are heterogeneous to the substrate from which they have appeared)⁸.

- Accordingly, emergent evolutionism can be seen as a middle course between gradualism and saltationism. By conciliating continuity and discontinuity in evolution, emergent evolutionism claims to be a monistic, yet antireductionistic view of evolution. As a result, even if all the natural entities that arise through time belong to one and the same tissue of events, some of these entities can be considered as “genuine evolutionary novelties” that cannot be reduced to the substrate from which they have appeared.
- Such a view is articulated around the notion of *emergence*, which captures an empirical relationship between a putative emergent E and its basis B , in such a way that (i) B univocally and completely determines E , and yet (ii) E is “genuinely novel” with regard to B . Emergent evolutionism is then the thesis according to which, during evolution, entities regularly emerge.
- The ambiguous expression of “genuine novelty” is unpacked by emergent evolutionists through the more precise notion of *in-principle unpredictability*. Accordingly, a given entity E is said to emerge on a basis B at a given time in evolution if (i) B univocally and completely determines E and yet (ii) the advent of E could not have been predicted from the most complete

⁸While it is clear that emergent evolutionists like Morgan and Sellars *did* consider Darwin’s gradualism and continuism as entailing reductionism – actually because they construed darwinian evolution as being also purely *quantitative*, so that the distinction between different orders of life was to be taken as a difference of degree and not of kind (Blitz (1992)) –, it is of course not entirely clear whether Darwin’s original theory has to be considered as intrinsically reductionistic.

knowledge of B , even by an absolutely competent cognitive being (*e.g.* a Laplacean demon).

- Why entities emerge through evolution can be understood on the basis of a continuous increase of their degree of “relatedness” (or “organization”)⁹. Each time some pre-existing materials aggregate in a certain way, a new mode of relatedness obtains that corresponds to an emergent. Such mode of relatedness did not exist, *even “implicitly” or “potentially”*, within these pre-existing materials.
- The advent of new modes of relatedness between pre-existing natural entities – *i.e.* the advent of emergents – is something to be noted as a *brute empirical fact* that admits no explanation whatsoever. It just has to be loyally accepted “in the frankly agnostic attitude proper to science” (Morgan (1923), p. 9). Put differently, the “emergence law” that connects an emergent E to its basis B is a *brute, ultimate, final, fundamental* or *sui generis* law, in the sense that it is non-deducible from other already existing laws (and, in particular, the laws that govern the behavior of B).
- The process of continuous aggregation of entities bringing about emergents is cumulative, so emergents can themselves aggregate to give rise to new emergents, *etc.* As a result, beside having a “forward” direction in time, evolution has an “upward” direction within what appears to be a layered natural hierarchy, in which natural entities are ordered from lower-level, less internally organized (and older) entities to higher-level, more complex

⁹It turns out that emergent evolutionists endorsed such a progressive construal of evolution (see for instance Alexander (1920)’s *nisus*, corresponding to an intrinsic evolutionary tendency driving things from lower levels of existence towards the ultimate quality, namely “deity”), but this is actually not a necessary tenet for the construal of emergence or novelty that matters here. Emergent evolutionists could perfectly have endorsed an emergentist view of evolution while considering – on Darwin’s model – that evolution doesn’t necessarily produce increasing complexity. I thank an anonymous reviewer of this journal for having drawn my attention on this.

(and more recent) entities.

A toy example can help to render more concrete this concise characterization of the core ideas of emergent evolutionism. Let us consider a chemist in her lab who somehow synthesizes a molecule XY on the basis of the pre-existing molecules X and Y . Let us also suppose that she knows everything there is to know about the chemistry of the individual molecules X and Y (and the chemistry of other compounds in which separately figure X and Y , like XW and YZ) as well as the environmental conditions in which the synthesis of X and Y into XY is performed. According to emergent evolutionism, the molecule XY corresponds to a new mode of relatedness of X and Y that is not “implicit” or “potential” in X and Y . Its advent then constitutes a brute empirical fact, to the extent that the very nature and behavior of XY cannot be explained from the most perfect foreknowledge of the chemistry of X and Y (and the chemistry of other compounds like XW and YZ). All the chemist can do is note the nature of XY and observe its behavior, in order to use her observations as a basis for a new (branch of) chemistry, namely the chemistry of XY . If we chose to tell this story by talking about laws, we could say that the laws of XY -chemistry are not deducible from the conjunction of the laws of X -chemistry and Y -chemistry (as well as the laws of XW -chemistry and YZ -chemistry), for the law connecting X and Y to XY – a compositional law called an “emergence law” – is brute, fundamental or *sui generis*, and therefore itself non-deducible from the laws of X -chemistry and Y -chemistry (as well as the laws of XW -chemistry and YZ -chemistry)¹⁰.

It then makes sense to claim that the molecule XY emerges from the molecules X and Y – or that there is emergent evolution from X and Y to their combination XY –, which is another way of expressing the following twofold idea: (i)

¹⁰This is actually the spirit of C.D. Broad’s construal of emergence (Broad (1925)), which would later become the direct target of the criticisms formulated by philosophers like Ernst Nagel, for whom metaphysically-flavored non-deducible emergence laws should be replaced by empirical bridge principles (see for instance Nagel (1961), chapter 11).

the nature and behavior of XY are univocally and completely determined by X and Y – in accordance with the corresponding emergence law –, and yet (ii) the chemist would not have been able to predict the nature and behavior of XY from her knowledge, no matter how perfect, of the chemistry of X and Y . Another, collateral idea implicit in this emergence ascription is that the molecule XY belongs somehow to a “higher level” of the world’s layered ontology, for it is a “whole” made of – and yet somehow “greater than” – its “parts” X and Y .

As this illustration makes clear, the doctrine of emergent evolution allows for the advent of “genuine novelties” through time, in spite of a thorough ontological determinism. As it has been claimed above, this is then a way of conciliating gradualism and saltationism: the evolution from X and Y to XY is not purely gradualist – insofar as something radically new appears in the synthesis process –, yet it is not purely saltationist – for the result of the process, XY , is compositionally determined, in accordance with the corresponding emergence law, by its conditions of advent, X and Y , so it is not broken off from them. Equivalently, emergent evolution is committed to ontological monism (X , Y and XY are made of one and the same “stuff”), yet it is antireductionistic (XY is irreducible to X and Y).

Before turning to the way in which emergent evolutionism deals with the Laplacean argument presented in section 2, some remarks are worth making. First, our toy illustration can easily be generalized to any field beside chemistry. The entities X , Y and XY can be replaced by whichever entities one likes (quarks, atoms, cells, organs, individuals, populations, galaxies, *etc.*), to the extent that emergence is a rather mundane and frequent relation – if it is not merely ubiquitous.

Second, it is important to stress the fact that the unpredictability involved in our toy example is to be taken in its *theoretical* sense, *i.e.* as the impossibility to specify in advance what the nature and behavior of XY will turn out to be on the *sole* basis of information that pertains to the chemistry of X and Y . In particular, what is assumed here is that the chemist does *not* have foreknowledge of the emergence law connecting X and Y to XY . Of course, should

she already know such a law – *e.g.* had she already noted and observed in the past (or heard about some other scientist having noted and observed in the past) the emergence of XY from X and Y –, she would indeed be in a position to foretell *inductively* the nature and behavior of XY, thanks to the ontological determinism underlying emergent evolution.

Finally, it is noteworthy that emergent evolutionism primarily construes emergence in an *ontological* sense, even if emergence has, secondarily, epistemic effects. It is indeed in virtue of the fact that emergents are brute empirical facts that emergence laws are non-deducible from basal laws, and hence that emergents are theoretically unpredictable before their advent¹¹.

4.2. Emergent evolutionism and the denial of I_3

Now that the doctrine of emergent evolutionism has been introduced, we can turn to the prime objective of showing how it objects to the Laplacean argument. To begin with, it should be clear through what has been said so far that emergent evolutionism actually *does* reject the Laplacean picture. As we have seen, emergent evolutionism universally endorses L_o and S_o : *all* natural systems – emergent and non-emergent – are considered as ontologically deterministic. In particular, the very nature and behavior of the newly synthesized molecule XY are indeed completely and univocally determined by the nature and behavior of the molecules X and Y – together with the corresponding emergence law – to the extent that each time a given compound is made of X and Y in the appropriate way, one can be sure that it will turn out to be XY (and behave like XY).

Yet, in spite of this, emergent evolutionism doesn’t endorse the claim that all deterministic systems (that is, in this case, all natural systems) should be

¹¹Accordingly, in the broad spectrum of the various possible forms of emergentism, emergent evolutionism is committed to what is sometimes called “ontological emergence” or “causal emergence” (Sartenaer (2013) or Sartenaer (forthcomingb)). Furthermore, one can also say that emergent evolutionism lies primarily within the “explanatory” – rather than the “prediction” – tradition of emergence, for emergence first entails non-deducibility, which then entails unpredictability (Sartenaer (2015)).

predictable in principle. In particular, emergent systems, on the model of the molecule XY, are unpredictable, even in the eyes of an absolutely competent scientist like a Laplacean demon. Such an unpredictability is, as we have seen, primarily theoretical. But it can actually turn out to be *also* inductive, in the special case where the system at stake undergoes its emergence for the first time in the history of the evolving universe, a case that Morgan refers to as “primary novelty” (in contrast with the subsequent emergences which are dubbed “secondary novelties”; see Morgan (1933)). In such a case – on which I will focus in what follows –, a Laplacean demon would indeed lack the evidence basis to inductively predict the nature and the behavior of the emergent.

Consequently, emergent evolutionism is committed to the existence of ontologically deterministic systems that are radically unpredictable. Before elucidating how emergent evolutionism actually manages to vindicate the consistence of $L_o \wedge S_o \wedge (\neg P)$ in the face of the Laplacean argument, it should first be noted that it does so *independently of* the truth or falsity of entailments I_1 and I_2 . Accordingly, emergent evolutionism is committed to the existence of ontologically deterministic, yet radically unpredictable systems for reasons that are, as it is expressed below, conceptually distinct from the ones invoked in section 3 in relation with chaos theory and Bohmian quantum mechanics. Put differently, all natural systems could behave “classically” – that is, not “chaotically” as well as not “quantumly” –, and emergent evolutionism would still conflict with the Laplacean picture¹². Emergent evolutionism completely tolerates – and even

¹²This conceptual independence between emergent evolutionism and the two frameworks that are chaos theory and Bohmian quantum mechanics is actually doubled by a contingent, historical independence. There is nothing in the doctrine put forward by Morgan or Sellars in the 1920s that even remotely appeals to something like algorithmic incompressibility or the unavailability of non-disturbing measurements. For that matter, algorithmic incompressibility has been put forward on the basis of the algorithmic complexity theory developed by Kolmogorov, Chaitin and Solomonoff in the 1960s, so more than 30 years after the fall of emergent evolutionism. So if emergent evolutionism endorsed a thesis like $\neg P$, it is obviously not through some computational criterion (Humphreys (2008), p. 434). Furthermore, and even without speaking about the Bohmian interpretation, the quantum revolution in the physical

more, actually endorsed – the idea that the whole universe at a given moment is perfectly transparent in the eyes of an absolutely competent cognitive being.

Now what emergent evolutionism *does* deny in order to refuse the Laplacean picture is thesis (I₃) $L_e \wedge S_e \rightarrow P$. So what *is* actually denied by emergent evolutionism is the idea that an absolutely competent cognitive being, for whom the world is perfectly transparent – to the effect that she is able to capture under a predictive algorithm all the laws that govern all natural (hence ontologically deterministic) systems at a given time (L_e) and know the precise state in which all these systems are at a given time (S_e) –, is nevertheless not able to predict (theoretically *or* inductively) the state in which systems that emerge for the first time will be at a later time ($\neg P$)¹³.

The emergentist way of vindicating such a claim – which is actually already encapsulated in what has been said so far about the doctrine – is ultimately grounded in the conjunction of two facts (see figure 1). First and by definition, there is always a temporal delay between the moment t_1 or t_2 when a Laplacean demon performs her prediction about a given system S , and the moment t_3 (such that $t_3 > t_1$ and $t_3 > t_2$) when this prediction about S matches reality (or not). Second, S can always undergo a primary emergence at a given moment t_e comprised between t_3 and t_1 and/or between t_3 and t_2 . And when this happens – for example between t_1 and t_3 –, the predictive algorithm of the demon having performed her prediction at t_1 becomes immediately obsolete for anticipating the states of S after t_e . The reason for this is that such an algorithm, which

sciences occurred after the advent of emergent evolutionism. It would even be part of the reason why the doctrine of emergent evolution collapsed at the turn of the 1930s (McLaughlin (1992)).

¹³At first glance, such a claim may seem highly counter-intuitive. However, it actually sticks to the letter of emergent evolutionism. As an illustration, see Broad's assertion (Broad (1925), p. 71): "If the emergent theory of chemical compounds be true, a mathematical archangel, gifted with the further power of perceiving the microscopic structure of atoms as easily as we can perceive hay-stacks, could no more predict the behaviour of silver or of chlorine or the properties of silver-chloride without having observed samples of those substances than we can at present".

contains all the laws $\{L_1^i\}_{i=1}^n$ that govern S at t_1 and into which the perfectly accurate specification S_1 of the state of S at t_1 has been plugged, cannot contain the emergence law L^{n+1} that will suddenly appear in the world at t_e , for this law simply did not exist – *even implicitly or potentially* – before t_e , and could not have been deduced from laws already in existence before t_e . Yet knowledge of L^{n+1} is required for predicting the states of S after t_e .

Of course, when no emergence happens between the moment t_2 when the demon performs her prediction and the moment t_3 when her prediction is supposed to come true, then the demon *could* inductively (though not theoretically) predict the future states of the system, for the predictive algorithm that she has at t_2 would contain all the relevant laws existing at t_2 , including L^{n+1} .

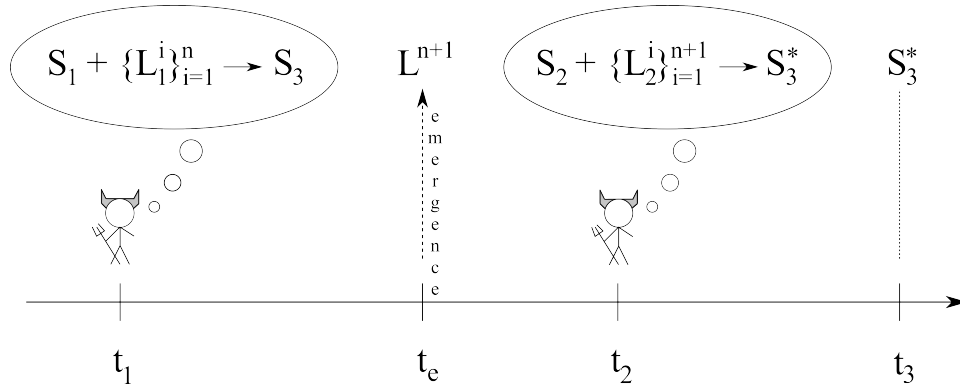


Figure 1: The way in which the advent of emergents can impact the predictive tasks of two Laplacean demons. Given a primary emergence occurring at t_e according to some brute law L^{n+1} , a demon could not predict (theoretically or inductively) at t_1 the right state S_3^* in which a system would be at t_3 . By contrast, and because the emergence law L^{n+1} is part of her predictive algorithm, the demon could predict (inductively though not theoretically) S_3^* at t_2 .

As a result, though L_o , S_o , L_e and S_e are taken to hold, emergent evolutionism denies the truth of P , where the predictability at stake can be construed theoretically and inductively. It follows that I_3 is false, and the Laplacean argument is successfully rejected.

Before closing this section, some remarks are in order. First, even though I insisted on the *temporal* facet of emergent evolution in the previous discussion, it should not be forgotten that a *hierarchical* order also underlies the whole picture. In the example depicted on figure 1, the system at t_2 and t_3 indeed belongs to a “higher level” of the world’s layered ontology than the system at t_1 , and the emergence law L^{n+1} governs the transition between these levels.

Second, emergent evolution is highly asymmetric (temporally and hierarchically), to the effect that, while prediction can be impossible in principle, *retro-diction* is always possible. The “retrodictive” algorithm that a demon would have at a time t would indeed always contain all the necessary laws to retrodict the state of the system at any previous time t' , even in the case where primary emergences have occurred between t' and t .

Finally, as we have seen, emergent laws are parts of a thoroughly determinate “natural plan”, whose content cannot be accessed in advance, or prior to its concretization in nature, by any cognitive being, even omniscient¹⁴. These laws are supposed to be brute and ultimate, to the effect that they cannot be explained. They simply have to be admitted with a so-called “natural piety” (Alexander (1920), p. 47). Such ideas are actually far from being metaphysically innocent. It is then no wonder that they have been the main focus of a great deal of early criticisms against emergentism (see for instance Russell et al. (1926), McDougall (1929), chapter 5, Montague (1929) or Ablowitz (1939)), and have contributed to the premature fall of this doctrine.

This being said, it is worth emphasizing the fact that emergent evolutionism has been recently revived in a far less controversial or heavily-loaded metaphysical way, especially by condensed matter physicists like the Nobel prize winners

¹⁴Of course, this suggests that there is paradoxically some limit to the possible omniscience of such beings. While they can know everything that exists at some moment in the natural world (including the states of all systems and all natural laws), they cannot know in advance the details of the plan of emergent evolution (which is supposed to be ultimately the manifestation of God’s inscrutable activity; see for instance Morgan (1923), p. 9).

P. W. Anderson or, in his wake, R. B. Laughlin. According to the latter (Laughlin (2005), 208-209), nature indeed generates “higher organizational laws” that “follow from collective behavior” and that “are not just a quaint side show but *everything* – the true source of physical law, including perhaps the most fundamental laws we know”. These laws “destroy predictive power”, insofar as they cannot be deduced from the underlying equations (see in particular Laughlin & Pines (2000), p. 30). The close connection of this set of ideas with the core tenets of emergent evolutionism that have been expressed in section 4.1 is even doubled by a common methodological prescription for science: science should not seek to capture the ultimate laws of a rock-bottom level of reality in order to construct a deductive path from it to higher-level laws; It should rather focus on experimentation and catalogue the different laws of emergence. Such a contrast can be illustrated with the help of figure 1. In the light of emergent evolutionism or its recent revival, scientists should stop working as the reductionistically inclined demon who tries at t_1 – without any chance of success – to predict the behavior that S will exhibit at t_3 . They should rather humbly content themselves with adopting the attitude of the emergence-friendly demon who waits until t_2 to make such a prediction (in an inductive sense), once she has been able to experimentally catalogue the relevant law of emergence L^{n+1} .

Of course the connection between the historical doctrine of emergent evolutionism and its recent revival in condensed matter physics should not be taken too far, as a more detailed analysis would certainly reveal some non-trivial divergences. Nonetheless, the connection is tight enough to be the ground of the claim that the coexistence of ontological determinism with in-principle unpredictability can still today be reasonably vindicated on the basis of a denial of (I_3), hence without the necessary recourse to some specific features of chaos theory or Bohmian quantum mechanics.

5. Conclusion

In this paper, I first framed an argument – referred to as the “Laplacean argument” – on the following model:

$$\begin{array}{ll}
 (P_1) & L_o \\
 (P_2) & S_o \\
 \hline
 (I_1) & L_o \rightarrow L_e \\
 (I_2) & S_o \rightarrow S_e \\
 (I_3) & L_e \wedge S_e \rightarrow P \\
 \hline
 (C) & P
 \end{array}$$

where L_o , S_o , L_e , S_e and P respectively denote the theses of *ontological determination*, *state determinateness*, *epistemic determination*, *state determinability* and *in-principle predictability*. This argument, which has been tacitly and massively endorsed from the advent of modern science onwards, captures the belief that ontological determinism ($L_o \wedge S_o$) entails epistemic determinism ($L_e \wedge S_e \wedge P$), and hence in-principle predictability (P). Put differently, given the fact that the states of a system are well-defined (S_o) and univocally determine the system’s other states (L_o), a perfectly competent cognitive being – *e.g.* a Laplacean demon – should be able to determine the state of the system at a given moment (S_e) and plug this specification into a predictive algorithm (L_e), to the effect that she should be in a position to predict any future state of the system (P). Framing the Laplacean argument in such a way has one non-negligible advantage: it allows us to identify three conceptually independent options for rejecting it, *viz.* denying either I_1 , I_2 or I_3 .

In section 3.1, I mentioned that chaos theory is an adequate framework to exemplify the first option – denying I_1 –, for the best algorithm one can come up with in chaotic situations is incompressible, and hence inadequate for the purpose of prediction. In section 3.2, I briefly expressed the reasons why Bohmian mechanics is suited for the job of rejecting I_2 . The principles of this

theory indeed prevent any cognitive being from simultaneously knowing the positions and wave functions of particles at any given moment, even given the assumption that these are perfectly determinate at any given moment. Both these approaches have received much attention over the last decades, to the extent that the divorce between (ontological) determinism and predictability is no more considered as heretical today.

Finally, in section 4, I exemplified the remaining approach – denying I_3 – in an older (though recently revived) framework that is often overlooked when it comes to the issue of determinism, namely the doctrine of emergent evolutionism as championed in the beginning of the 20th century by philosophers like Morgan or Sellars. On the basis of the metaphysical (though radically not innocent) claim that, during evolution, entities and laws emerge now and then as brute empirical and ultimate facts, such a view also succeeds in objecting to the Laplacean argument.

As a result, it should now be clear that a peaceful coexistence of ontological determinism with in-principle unpredictability doesn't necessarily require chaotic or quantum considerations (even if these can constitute sufficient conditions for such a coexistence). A “third way” is available, in the wake of a certain construal of emergence that has recently proved to be of a prime scientific interest.

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