EXPLAINING EMERGENCE: TOWARDS AN ONTOLOGY OF LEVELS

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SUMMARY. The vitalism/reductionism debate in the life sciences shows that the idea of emergence as something principally unexplainable will often be falsified by the development of science. Nevertheless, the concept of emergence keeps reappearing in various sciences, and cannot easily be dispensed with in an evolutionary world-view. We argue that what is needed is an ontological nonreductionist theory of levels of reality which includes a concept of emergence, and which can support an evolutionary account of the origin of levels. Classical explication of emergence as "the creation of new properties" is discussed critically, and specific distinctions between various kinds of emergence is introduced for the purpose of developing an ontology of levels, framed in a materialistic and evolutionary perspective. A concept of the relation between levels as being *inclusive* is suggested, permitting the "local" existence of different ontologies. We identify, as a working hypothesis, four primary levels and explicate their nonhomomorphic interlevel relations. Explainability of emergence in relation to determinism and predictability is considered. Recent research in self-organizing non-linear dynamical systems represents a revival of the scientific study of emergence, and we argue that these recent developments can be seen as a step toward a final "devitalisation" of emergence.

Key words: emergence, levels, explanation, determinism, ontology, reduction, materialism, vitalism.

INTRODUCTION

The subject of this paper is the concept of emergence – formulated as the idea that there are properties at a certain level of organization which cannot be predicted from the properties found at lower levels. The concept of emergence has an ambiguous status in contemporary science and philosophy of science. On the one hand, many scientists and philosophers regard emergence as having only a pseudo-scientific status. On the other hand, new developments in physics, biology, psychology, and crossdisciplinary fields such as cognitive science, artificial life, and the study of non-linear

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dynamical systems have focused strongly on the high level “collective behaviour” of complex systems which is often said to be truly emergent, and the term is increasingly used to characterize such systems. One reason for the widespread scepticism against the word is a historical load of confusion surrounding the metaphysical aspects of the concept, reflected in the fact that it has been used in a long series of different ways, apparently making it impossible to use it as a clearly defined term (cf. the historical review by Blitz, 1992; see also Beckermann *et al.*, 1992).

We want to argue that the concept of emergence conceptualizes certain key problems which is worth the effort to discuss. To this end, two approaches seem to be necessary. (1) It is necessary to take a viewpoint of the history of sciences to map the development of the concept and hence to understand its various uses. (2) It is necessary to explore these possible uses; the semantics of the various definitions must be examined to rule out interpretations of emergence which must be rejected to keep the concept in an actual scientific context. This combination of historical discussion, conceptual analysis and argumentation compatible with science is our explicit – and pluralistic – choice in this article. It not only synthesizes the three authors’ different backgrounds (philosophy, biology, linguistics, literary criticism, psychology), it also proves to be a fruitful way of dealing with a concept of this kind. It would not be enough to present the reader for a proposal for a clear cut “solution” to a problem which to a very high extent is mingled up with the interpretation of the structure of basic concepts as well as with the very structure of science in our culture. Instead, we find that it is historically and structurally essential to reveal the implications of the concept to reach some provisional solutions.

The main lines of argument in the paper is the following. In section 1, we claim that the historical discussion of the vitalism/reductionism debate in the life sciences clearly indicates that a philosophical concept of emergence as something exceptional and in principle unexplainable by science always runs the risk of being overridden by history in the development of science. Nevertheless, specialization of science in numerous subfields has given rise to metaphysical or ontological reflections on levels of reality, as seen in the classical “system builders” of the 19th century. We argue that any non-reductionist theory of levels must imply some version of the concept of emergence as a necessary component in the evolutionary accounts of the origin of levels. So one can hardly escape from reflecting upon the philosophical implications of a concept of this kind. In section 2, we therefore discuss the classical explication of emergene as “the creation of new properties”. We show that even though every term in this definition raises specific philosophical problems, these can to some extent be overcome.

We introduce some necessary distinctions for the purpose of developing a general ontology of levels. Most importantly, we suggest a refined concept of the relation between levels as being inclusive, permitting “local” existence of different ontologies. In section 3, we consider the tension between a description of properties of natural systems according to the classical ideals of science and the idea of emergence as something unexpected, new and undetermined. As emergence describes the passage between levels, the problem of explainability of emergence must be considered separately for cases in which a complete deterministic theory of a lower level exists and respectively does not exist. We argue that even if determinism prevails, this does not entail predictability. If emergence deals with the passage between “levels of organization”, one has to explicate this intuitive notion; so in section 4, we propose an ontological theory of levels, framed within a materialistic and evolutionary perspective. Important forerunners are discussed, and we outline an idea of primary levels, which (in this local, “earthly” ontology) is exemplified by four levels (the physical, biological, psychical, and sociological), whose respective interlevel relations are not all formally homomorphic. Finally, we argue that recent research in self-organizing nonlinear dynamical systems represents a revival of the study of emergence, that can be seen as attempts at a final “devitalisation” of emergent phenomena.

1. Vitalism and reductionism

The concept of emergence was, according to C. Lloyd Morgan (1923), coined by G. H. Lewes in his *Problems of Life and Mind* in 1875. Morgan specifies that similar concepts are to be found in the theories of J. S. Mill and the psychologist W. Wundt. All these authors are in agreement regarding the definition: emergence is the denomination of something new which could not be predicted from the elements constituting the preceding condition. In accordance with this, the authors differentiate between “resultants” and “emergents” – that is, between properties which can be predicted and properties which cannot be predicted. It is noteworthy that these definitions of emergence are close to modern definitions and discussions. Take for instance the holistic argument: “the product is not a mere sum of the separate elements”, the well-known examples of chemical combinations of two substances each possessing a number of specific and known properties, creating a new substance with a property nobody could predict – and so on. It could seem like the discussion of emergence has not developed one single step further in the last 100–150 years. But can this be true? Before we try to answer that question and substantiate our denial, we have to analyze the historical and scientific conditions under which the concept of emergence was coined.

It is no pure accident that the concept was in frequent use at the beginning of the 20th century. In most of the more recent discussions of the concept of emergence, it is opposed to those of reductionism, determinism and/or mechanistic materialism. But before the concept of emergence was coined, reductionism and mechanism were most often discussed in connection with another concept. This discussion partner was vitalism. One of the most farreaching scientific debates in the 19th century was the one between vitalism and reductionism/mechanistic materialism. The last influential vitalist was Hans Driesch (1867–1941) whose scientific culmination took place from 1900–1915, and even if there still may be philosophers and a few scientists calling themselves vitalists, it is really very few, and in our day coloured with provocation.

Historically conceived, when vitalism was discarded as an unusable concept, a new concept was coined, preserving some of the vitalistic viewpoints; this concept is emergence. Are the various theories of emergence thus mere vitalisms in disguise, or is the connection only superfical, coincidental, and without any value?

As far as we can see, there is a hidden and mostly unnoticed historical value in this “coincidence”: *the concept of emergence is exactly that reasonable aspect of vitalism which is worth to maintain*. The classical vitalist doctrines from 18th century insist upon the idea that all life phenomena are animated by immaterial life spirits. These life spirits determine the various life phenomena, but are in themselves unexplainable and undescribable from a physical point of view. In opposition to this, the reductionist position (in 18th century) insists upon a large part if not all of the life phenomena being reducible to physics and chemistry. Apart from a few radicals, the reductionists do not claim the higher psychological functions to be reducible to physics and chemistry. And this is the primary difference between the two versions of the debate, “vitalism versus mechanical materialism” in the 18th and the 19th century, respectively. As a consequence of the scientific development in especially cytology, neuroanatomy, and neurophysiology, it became very difficult to maintain the classical positions. You cannot continue to claim that the speed of the nervous impulse is astronomical and that it never will be measured by human beings (Johannes Müller in 1830s) when an experiment was made in which its value was measured as 30 m/s (by Hermann von Helmholtz in 1844).

The 18th century “classical” position may be resumed in the following way:

VITALISM	REDUCTIONISM
– GOD is behind everything	– GOD is behind everything
– Soul = life spirits = immaterial	– Immaterial soul is different from life spirits. Life spirits are material
– Every mental and living phenomenon is a direct manifestation of the soul. Soul/life spirits cannot be scientifically described – they are self-explainable	– A very large part of the existing phenomena can be described by the concept of material life spirits
– Life is teleologically formed and conducted	– A large part of life is casually determined and is describable in accordance with physics and chemistry

The discussion between vitalism and reductionism is one of the best examples of a debate which was continuously influenced by scientific discoveries. The difference between vitalism and reductionism was continuously transformed. After a number of scientific discoveries in the beginning of the 19th century – to name just a few: du Bois Reymond's proof that the nervous impulse was electrical, Schwann's and Schleiden's proof that every biological creature was composed of cells, Bell's and Magendie's proof that the old philosophical distinction between sensation and motor reaction was correlated to sensory and motor nervous tissue, Helmholtz's measuring of the nervous impulse, the first thermodynamic law relating every possible type of energy to any other – the vitalists did not give up, but they gradually limited their viewpoints to a narrower field. Now the vitalists insisted that only the higher psychological functions were irreducible, but admitted that a large range of biological phenomena could be described scientifically. They still claimed a crucial difference between organic and inorganic matter, but life spirits were no longer the ultimate cause to each single biological phenomena or entity, they were restricted to determine the evolutionary direction. The life spirits became teleological and conducting entities. Reductionism now claimed, on the other hand, that every phenomenon in the whole world, including the highest psychological ones, was reducible to physics and chemistry.

VITALISM	REDUCTIONISM
– GOD has minor significance	– No GOD
– Immaterial soul is different from the material life spirits, which are identical with nervous energy	– No soul
– Certain phenomena, such as higher psychological functions cannot be reduced to physics and chemistry	– Every phenomenon can be reduced to physical-chemical laws, including the higher psychological phenomena
– Differences between inorganic and organic matter	– In principle no difference between organic and inorganic matter
– Teleological conduct	– Causal determinism

If we compare the two summaries the development in points of view is evident. Vitalism has gradually taken over some crucial viewpoints which were earlier held by reductionists. In the 19th century, some outstanding scientists tried to synthesize the two approaches (such as Claude Bernard and du Bois Reymond), but the line of development is clear enough for our arguments.

If we try to relate these differences between vitalism and reductionism to the concept of emergence, the concept is obviously primarily vitalistic – but it also transforms vitalism, or at least restricts it in a very important aspect.

Emergence is first of all defined as “the creation of new properties”. To quote Lloyd Morgan:

> Under what I call emergent evolution stress is laid on this incoming of the new. Salient examples are afforded in the advent of life, in the advent of mind, and in the advent of reflective thought. But in the physical world emergence is no less exemplified in the advent of each new kind of atom, and of each new kind of molecule. It is beyond the wit of man to number the instances of emergence. But if nothing new emerges – if there be only regrouping of pre-existing events and nothing more – then there is no emergent evolution. (Lloyd Morgan, 1923, pp. 1–2).

It is worth to notice in this quotation that it is *not* only in psychology or biology, but also in physics and inorganic chemistry that emergence resides. This is a very important difference between the vitalists and the emergentists: the vitalist’s creative forces were relevant only in organic substances, not in inorganic matter. *Emergence hence is creation of new properties regardless of the substance involved.*

There is one central problem which Morgan does not specify in his definition of emergence – the question of levels. The question of levels is always more or less implicity discussed, and its explicit discussion is one of the modern aspects of the concept. But levels were also discussed in the 19th century, especially in relation to evolution.

The vitalistic ideas are generally discussed as if they only applied to the biological theory of evolution. However, in the 19th century the theory of evolution was a much larger field than it became after neo-Darwinism – as is evident in the general historicism of the epoch covering most scientific work except for physics and chemistry. The evolution of the human psyche, the evolution of culture and society became integrated parts of large, synthetic theories of evolution. And as the theories of the so-called *system builders* showed, evolution could denote creation of anything – from the simplest atom to the most developed societies.

The thought of the system builders is another historical fact which is not very often related to the development of vitalism and theories of emergence. But these system builders' discussions are very important, and they are one of the main reasons that the concept of emergence was "devitalized", that is, deprived of an immaterial causal agent. Among the main system builders in the 19th century were Auguste Comte (1798–1857), Herbert Spencer (1820–1903), Friedrich Engels (1820–1895), Ernst Häckel (1834–1919), and Charles S. Peirce (1839–1914). The name "system builders"[1] refers to the fact that they all created theories which analyze the relation between a scientific description of the total world and the different scientific disciplines – two systems were related, the system of sciences and the system of the objects of the different sciences (in total = the world). None of them claimed that all other sciences in the last resort could be reduced to physics, or that the world could be described exclusively by physics.

It is not our aim here to discuss the differences between the system builders' theories, but let us as an example look at Friedrich Engels and his so-called dialectical materialism. According to Engels, it is not possible to reduce complex objects of one level to less complex objects on a lower level. Each level contains materialistic entities, but of different sorts, and being created at different times during an evolutionary process beginning from the physical entities. What controls this evolutionary process is not a vitalist immaterial principle, but the famous dialectical laws. The only teleological principle in these dialectical laws is the idea that evolution as such is not able to regress – you cannot "develop backwards", – but only forward, that is, the union of complex entities will always synthesize into more complex units. At a certain point in the evolutionary process, the dialectical development will cause quantitative elements to synthesize into qualitatively different elements.

If this was the case there would be no problem in the concept of emergence. But the dialectical laws have not showed themselves useful in science, or they merely denote the problems, they do not solve them. The dialectical laws are nevertheless *an example* of an attempt at what we would like to call "the devitalisation" of emergence. In Engels' theory the evolutionary and teleological vitalistic principle is reduced to a set of laws which in themselves do not contain any qualitative empirical statement. The concept emergence merely denotes the creation of new entities (properties) which cannot be derived from the preceding conditions. And this is precisely the great potentiality of the concept.

We also want to draw another conclusion from the system builders. Every time you have a theory differentiating between levels which cannot be reduced to each other (to the lowest or to the highest), you *must* operate with a concept or idea structurally parallel to emergence. Emergence is among other things the concept which relate levels to each other – or to be more precise, the concept which denotes the very passage between them. It does not in itself solve anything, but it poses the problem in a general way, making it visible at the border of every specialized branch of science.

2. Creation of new properties

In Lloyd Morgan's definition of emergence as "creation of new properties" there are three key words: "properties", "new" and "creation". By a more detailed discussion of these key concepts, it is possible to grasp the primary topics in the concept of emergence.

(a) Properties

The properties mentioned in the definition are very different phenomena. They can, in fact, range from the property of being a unique, individual object which has never existed before to properties characterizing a whole class of beings coextensive with the one of the classical sciences, for instance all phenomena treated by biology. The problem which can be stated as a question is: how particular resp. general must the phenomenon of creation of new properties be in order to be describable as emergent?

The most general answer would be: every new property whenever it is created and every time it is created is emergent. If ontologically interpreted then, emergence will characterize the one and only "creative force" in the whole universe, and if epistemologically interpreted, it will be a name designating a large scope of various and perhaps very different types of processes. In any case, this is the broadest definition at all. This is obviously *not* what most scholars intend by using the word emergence. They tend to think of more *general* properties emerging, so as to distinguish a whole new *kind* of beings (like chemical objects emerging out of physical, biological out of chemical, psychological out of biological etc.).

Very few scholars insist on this first and broadest interpretation of emergence, but the fact that the word can be stretched this far, is significant: it shows that it is not beforehand determined *how general* the property being emergent is to be conceived (and correspondingly how large the set of individuals possessing the property has to be); it reveals an internal problem in the use of the word regarding the generality of the emerging objects. A second, and more commonly used definition, tells us that emergence is at stake at the borders between the large sciences: where the explanatory power of one science must give in, another must take over at the level of the hitherto unexplainable – emergent – property. But it is not possible to restrict emergence to these borders. As already Morgan realized, the science usually considered more basic than all others – physics – in itself contains numerous cases of emergence. The whole field of macrophysics – the description of properties in objects larger than molecules – is ripe with properties which cannot be explained solely at the molecular level. To name a few: crystal growth and morphology, phase transitions, the surface texture of a substance, aerodynamics and especially fluid dynamics. Mario Bunge is one of the best known representatives of this viewpoint and it is important to keep in mind that physics is *not* (yet?) in all respects a full-fledged deterministic science as it is often spontaneously supposed in various juxtapositions of higher level sciences and parts of physics.

From the point of view that emergence defines a few large scientific classes, a tendency follows to draw a parallel between subdisciplines within sciences and *sublevels*. Physics is in this opinion a primary level which consists of a large number of secondary levels, or sublevels, each described in the various physical subdisciplines. Biological entities constitute a primary level which consists of a large ladder of sublevels described in the biological disciplines treating genes, cells, organisms, populations, and ecosystems etc. It seems intuitively correct to talk about, for instance, biology as one coherent field, while at the other hand this field seems to be internally subdivided into a lot of levels also defined by emergence. Genetics does not explain cytology, cytology does not explain morphogenesis, morphogenesis does not explain physiology, physiology not ethology, ethology not ecology etc. – to take a synchronic version of the problem or, if you prefer diachronics, macroevolution and speciation is not explained by population genetics.

In general the concept of properties is thus used in three different ways – to designate *primary levels*, *sublevels* and aspects of *single entities*. In accordance with this, emergence is used as the description of the creation of primary levels, creation of sublevels, and creation of single entities. If emergence in these three different cases were to be considered the same, then it would be difficult to see how one could possibly defend the distinction between them. If there is not any principal difference between the "jump" (as the popular notion of emergence is often named), whether ontological or just epistemological, from organic chemistry to biology (often recognized as giving rise to a level) and the "jump" between microphysics and macrophysics, then the distinction between primary levels and sublevels must be discarded – and it is very possible that this might be the consequence. If there is a difference, then the concept of emergence must be divided into several subtypes according to whether the emergent property give rise to a level or a sublevel. (Philosophically, the problem resides in a spontaneous Aristotelianism: it is more or less explicitly assumed that emergence gives rise to not only new properties, but a new natural kind, defined by the new set of properties. But how many new properties does it take to constitute a new natural kind?).

One possible solution to this problem – numerous different cases of emergence vs. two basic forms, primary and secondary emergence – would be the idea of a continuous scale of "smaller" and "larger" cases of emergence. The drawback in the idea of "primary" emergence is that it is by no means evident that the emergent process itself contains information about how "big" the resultant class of new objects is going to be. If one, for instance, takes for granted that the emergence allowing biology to come into being is a case of "primary emergence" it is, nevertheless, not possible to forecast the range of biology from the first primitive DNA or cell synthesis. It is possible to imagine a scenario in which very primitive forms of DNA based life were created in the "primordial soup" just to perish immediately afterwards. In this case, would biology constitute a "primary level"? The "primacy" of this emergence is only known retroactively from our knowledge of far more complicated biological entities presupposing other emergent processes (for instance endosymbiosis leading to the fullfledged eukaryotic cell or the cooperation between billions of cells to form multicellular organisms). Nevertheless, we will continue talking about "primary" and "secondary" emergences merely as epistemological concepts, and as pragmatical denominations of cases of emergence with a larger or smaller amount of consequences.

(b) Creation.

The second key concept in the definition of emergence as "creation of new properties" is "creation". Also this concept implies different possible ways of viewing emergence. If we restrict creation to its possible scientific meaning – and not its religious – there will always exist some conditions for the creation of a new property. The question is: will these conditions exist autonomously, so to speak side by side with the created properties, or does the act of creation in the same moment create conditions and product. The first interpretation, of course, favors a historical explanation of emergence, while the second favours a structural explanation. This may sound as two sides of the same coin, but each of the two viewpoints gives rise to different conception of emergence.

If we apply the historical version of creation to *levels* we find ourselves saying things like: the organic level emerges out of the inorganic level. This is not totally untrue, but it requires a more precise statement. One should avoid a parallelistic interpretation saying that one level is created out of another, and that it exists in parallel to the first level, as two separate levels without any further interaction. To exaggerate a little: if the *parallel* existence was true, as a human being you would not be one but several different entities on several different levels. Your physical body, your biological body and your psyche etc. – and it would seem rather miraculous that it always happened to be focused at the same point in space. As far as this goes we have to conclude that one level cannot be created as such in one emergent process. And when the level is constituted it does not exist in parallel. Levels are *inclusive* in that respect, i.e. the psychological level is built upon the biological and the physical, the biological upon the physical. Phenomena on one level cannot be reduced to the lower level, but on the other hand they can never change the laws of the lower level. Biological phenomena cannot change physical laws, – but neither can physical laws as we known them fully explain biological phenomena. The fact that levels are inclusive mean that a lower is a necessary condition for the higher level, and that the higher level supervenes upon the lower (see Figure 1).

Nevertheless, what is indicated by this notion of *supervenience* must be made more precise. Very often the idea of a temporal succession in the creation of new levels is spontaneously interpreted so as to imply a causal process. This idea leads to a metaphysical mistake which is evident when one considers objects in which several levels coexist at the same time: the idea that the lower levels *cause* the higher levels to exist. Of course this is true in a common-sense use of the word “cause” but not in the standard scientific way of using it: if the higher level consists of units of the lower level, then they exist simultaneously. There is no temporal, causal process going on “creating” the higher level out of the lower one, and no reductionist saying so has ever been able to show a cause running from the lower towards the higher level. What the reductionist means to say by stating that the lower level causes the higher one is (a) that the lower is ontologically primary, and (b1) that the higher can be totally identified with the lower level (eliminativism), or, alternatively, (b2) that the higher level *supervenes* upon the lower one in the sense that once the lower level properties are fixed, so are the higher level ones (so one cannot have two systems with an exact micro-level identity in all respects which differs in macro-level properties).

But this indicates that the relation of supervenience is not a case of efficient causation. The type of cause making the higher level exist is a special arrangement of the units of the lower type and thus the lower level could be said, Aristotelianly speaking, to be the *material* cause of the higher one. The mistake sketched here is of course a part of a classic mistake: to interpret the concept of cause as possessing the anatomy of a distinct cause opposing a distinct effect. The scientific use of the words forbid this, because there is no natural distinction between cause and effect. The two are parts of one and the same process, and the scientific idea of cause is rather to be interpreted as the regularity of this process. Again Aristotelianly speaking, this regularity should rather be interpreted as the "formal cause" of the process. What we use to call "efficient cause", close to the common sense of the word, is only the subjective focusing on one element in the causal process, an element being made solely responsible for the process. But all relevant parameters in the regularity of a process of cause are equally determinant for its outcome – and the upper level is in this respect as much part of the regularity as is the lower one.

But what remains, then, of the idea of levels? One special argument against the idea of emergence giving rise to a hierarchy of levels merits to be mentioned because it throws an illuminating light back onto the very status of the word level. In a very clear form, the argument is found in the Danish philosopher Hans Fink, who makes his point to ensure a certain kind of philosophical monism. According to Fink, a long series of principal philosophical notions share a common and very peculiar structure: taken in their most principal sense, they include their opposition. Thus, reality has in this sense no real (*sic*) opposition, because every candidate (fiction, simulation, ideas or whatever), in some respect must possess real existence and hence be a special part of reality. The same goes for the concept of nature, involving as parts notions commonly opposed to nature: in this respect, culture is but a very complicated and specialised subspecies of nature.[2] Consequently, this analysis entails that there be no sharp dualist border between two autonomous areas – and this further implies the advantage that the eternal question of determining the possible interaction between the two (archetype: the famous Cartesian pineal gland) becomes obsolete. As is evident, the argument can be repeated so as to cover cases with more distinctions than one dual division. Thus – so goes the argument – if physics really is, as the Greek root of the word seems to ensure, the science of *physis*, of nature, then it must somehow comprehend any other possible science (at least any science with an empirical object, perhaps leaving out mathematics and philosophy?). Every possible object is a natural object, hence any possible science concerning a natural object is a natural science, thus being a part of physics. Now, it is important to emphasize, this Finkian metaphysics is by no means a version of physical reductionism. What is at issue here is not a claim that any science be physical in the sense that it can or at some later time may be reduced to physics as we know it – it is a claim that (for instance) biology as we know it is *already* a part of physics, it is just a part that cannot be studied with any other means than the means used studying it. The consequence then is that *there are no levels inherent in nature*. The further consequence for physics is that it ceases to be identified with the science bearing this name to-day: the so-called "physical" description of a particle is not exhaustive, because a really exhaustive description would contain a description of the possible combinations of the particle with other particles to larger entities, for instance biological, psychological, social ones. As Fink states: "A certain knowledge can be the condition for another knowledge, but it is not because the first knowledge concerns a deeper, and the second a more superficial level in nature" (Fink 1990, p. 37). Whilst this point of view entails the seemingly reductionist consequence that biology is part of physics, it consequentially also must make room for the opposite idea: what we used to call physics is *already* biology, even if it is biology in a rather restricted sense. The evident practical consequence of these ideas is that the borders between sciences must never be maintained rigoristically: we can never know if a given border can or cannot be transgressed by some empirical or theoretical result. Differences may be objective - it is no subjectivist or purely epistemological point of view - but they are always relative to other relations of similarities between the objects compared.

As is evident this stance is sceptical towards any idea of emergence (openly stated in a note p. 37), but the question is whether the difference between the two is as principal as it may sound. Take the evergreen example of the relation between physics and biology. The emergentist would state that biology is a science involving physical entities which in certain contexts and processes pop up with properties which were not evident from a physical point of view – therefore, a new science christened biology must be ready to take care of the study of these properties. The Finkian monist would state that in certain parts of physics, properties pop up which were not evident from a point of view studying only some simpler elements of the process, that is, some simpler part of physics – therefore, a new branch of physics named biology must be ready to study these properties. It is as if any well-known science could be rebaptized with "physics" as its family name, with biophysics, chemophysics, psychophysics, sociophysics, semiophysics and so on as the results. But if so, the quarrel between the emergentist and the Finkian would be only a matter of words, of arguing whether physics should be the basic level in relation to a series of levels, or whether physics should be a common denominator for any other scientific activity – the difference between the two seeming rather small. This becomes especially clear if one bears in mind that the Finkian point-of-view is by no means purely epistemological. As a matter of fact, this might reintroduce levels into the monist point of view through an unexpected back door: if everything is nature, so the very process of doing science is nature as well, and then the characterization of the various branches of monistic physics expressed in terms of what the scientist can or cannot do (biology is the part of physics which can be studied so-and-so and which presupposes this-and-that more primitive knowledge which it cannot be reduced to) – then this characterization is objective in itself, because the scientist's knowledge is in itself a natural relation between him and his object.

What remains for the emergentist to apprehend from the Fink criticism is that levels are not metaphysically distinct in a sense so that for instance physics is more metaphysically prominent than the sciences presupposing it. Physics as we know it is only basic in so far that it is presupposed by others, it is not basic in any first-philosophy use of the word – in that respect, sociology or semiotics are as "basic" as physics, because they are all parts of one and the same universe.

Now, to return to our discussion of the relations between the "creation" of new levels and the relations between them, this implies that a rational idea of levels must entail that the more basic levels are basic in the sense of the word that they are presupposed by the higher levels – but the word "basic" does not entail any ontological priority. The higher levels are as ontologically pre-eminent as the lower ones, even if being presupposed by them, that is, they are defined by properties by special cases of the lower levels. In this respect, levels are ontologically parallel, but non-parallel in so far as they coexist.

The most non-parallel view of levels imaginable is what we will call *the Gestalt view*. The higher level manifests itself as a pattern or as special arrangement of entities of the lower. If you imagine yourself existing on the lower level you would hence not be able to realize or grasp the pattern which is only possible to conceive of at a higher level. Many – if not all – emergent phenomena shares this gestalt property of being a pattern in time and space of elements of the lower level. Very often, this idea of emergence is dismissed as being a subjectivist stance: the higher level requires a perceiving subject being able to perceive – or construct – the patterns involved. It is important here to underline that the gestalt view need not by any means entail subjectivism and all its scepticist consequences. As some of the early Gestalt Theorists (Ehrenfels, but also parts of the Berlin school, for instance Köhler) realized, the notion of Gestalt need not demand a constituting subject, at least not an empirical subject. Still, on the other hand, pattern-making itself seems not to be enough to fulfil the requirements of emergence (many patterns, even if objectively existing and discernible by for instance neural networks – for instance ornaments – can be constructed which are not evident examples of emergence); emergence seems to require patterns whose stability and reproducability over time is assured by self-organization.

This discussion must be separated from the discussion of *the first emergence* of a level/sublevel/property. As we will show, there is a fundamental difference between the first emergence and the later ones connected with the first one. If we stick to the example inorganic-organic matter, this can be viewed in the two ways mentioned. As a structural relationship, all of the time being present inside every living creature, and as a question of natural history, evolution leading from the former to the latter. The relation between evolution and emergence can be separated in two questions – first, the question of *the first time ever* the specific emergent process occurred (such as: when did life originate for the first time in the course of the universe?) and second, the question of *later repetitions* of this primary process (such as: the creation of life later in the history of the universe on other planets, or the *de novo* creation of life in the laboratory).

In our opinion is it essential to separate the two. To substantiate this claim, we have to make a distinction between *global* and *local* processes. It is necessary and evident that evolution of life for the first time and the repetitious evolutions in every single case should be held apart in a global context, that is, unless they are causally connected. It does not seem likely that the first-time creation of life, maybe in a faraway corner of the universe, in any way can influence upon later creations on earth, in laboratories or elsewhere. To maintain such a global view, it would require a sort of global construction matching the herostratic "morphogenetic fields" of Sheldrake and the quantum non-locality. But, on the other hand, it is necessary to differentiate at a local scale, regarding creation of life on Earth and its reproduction. When the entities have constituted the biological level on

Earth, it has at the same time selected the specific "Earth-life", and no other forms of life are possible (in a specific period). We will elaborate the argument later.

In physics, the distinction between global and local does not have the same meaning as in biology, because the global scale is one of the fundamental subject matters of physics. If we move far enough back in the history of the universe to a time shortly after Big Bang, the universe was so small that signals with causal powers could travel all the way across it within a relatively short time, which invites the treating of all of cosmos as one, local system. For instance the symmetry break causing primitive energy to differentiate into energy and mass (an archetypical example of a first-time emergence) seems to determine the present state of the whole universe, hence the very existence of mass, hence the possibility of forming mass out of energy and vice versa. But in this case, every place in the universe is by its history causally connected with this early phase while the creation of life on earth is (probably) not causally connected with creation of life anywhere else in cosmos.

The following figure shows the meaning of the distinction between global and local, and the meaning of inclusive levels:

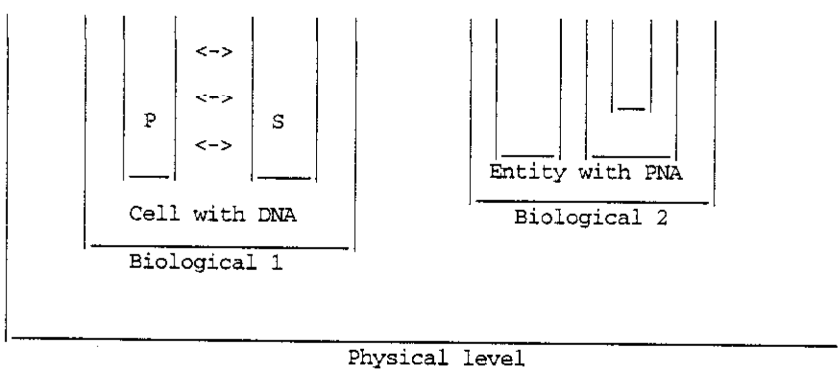

Fig. 1. Schematic representation of a theory of levels that recognizes the possibility of emergence of specific higher levels which may have different inter-level relations to each other. The horizontal lines roughly indicate 'space'; vertical lines indicate time. Different biological levels (whose respective constituent entities or 'organisms' have some general properties in common, e.g. the capacity for selfreproduction) emerge at separate places and times within the global physical level. "Biological 1" represents a biological level including two higher levels (P, a psychological level, and S, a sociological level) that emerges at the same time; arrows indicate their interwovenness (see section 4 in text), "Biological 2" represents a hypothetical other local ontology in which an even higher level has emerged, and where the inter-level relations do not need to be the same as in the 'earthly' case.

Inside the global physical level – cosmos – there can in principle locally emerge essential different biological life forms. At the locality Earth, there emerged a life form with the cell and its DNA as the primary entity. At another locality in cosmos, there may have emerged a life form with an entity containing the hypothetical PNA. As we will discuss later inside the biological level, again at the locality Earth, two other primary levels have emerged – the psychological and the sociological. They are created in interaction and parallel with each other, and do not therefore evolve in a serial manner, as the biological in relation to the physical. At another locality, with PNA-life, essentially different levels could evolve, which we cannot have the faintest idea about. And at our locality, maybe hitherto unknown levels will evolve at some later time. The specified levels are inclusive in the sense that a level which has evolved at the basis of another is not able to change the laws of the lower level. The specific emergent evolution of a level *at a specific locality* in the universe does only happen once. The entities, which the level contains, are repetitiously created, and it is by this repetition, that the level is maintained.

(c) New

The third key concept in the definition of emergence as "creation of new properties" is "new". Even worse terminological and philosophical questions than the numerous ones already mentioned are contained in the sparse adjective "new". What does it imply that a property be "new"?

A property is new in relation to what is old, that is, what is already known. We can of course immediately exclude the subjectivist interpretation of this. It is irrelevant and absurd to call the murder of John F. Kennedy an event emerging today just because I have not heard it before. When new is related to the already known, there is in "already known" implicit reference to the scientific community, administrating what is generally known by human culture. But this, as is evident in a Kuhnian age, does not exclude subjectivism from returning at a larger scale. To emerge as a new property in relation to what is already known might be due to the fact that what we already know might be very poor. It is easy to see if one looks back in the history of sciences: the fact that no tolerable theory of electricity was known before Maxwell does not imply that electricity before Maxwell was to be considered an emergent property. To generalize: what is at any time in the history of science supposed to be emergence may at a later stage be fully reduced to phenomena at a lower level, so that it is not in any principal way "new" in relation to anything anymore.

The idea of emergence may refer to two kinds of processes: first, processes that we cannot explain at present, but which are not in principle unexplainable, and second, processes that in some use of the word are in principle unexplainable. Nevertheless, the idea of the word emergence refers mostly to the latter, and *the emergence paradox* can be said to cover the fact that we can never known if the processes that we refer to as emergent actually suit this definition. Tomorrow a smart scientist might come up with a genuine physical causal explanation of the creation of life – this is not likely, but it is not totally impossible.

This implies that it becomes in principle impossible to draw a distinction between a purely epistemological use of emergence (processes which involves properties we cannot yet explain from a lower level) and the harder, ontological use (processes which involves properties that can never be explained from a lower level because they are ontological irreducible and *sui generis*). Of course, the very reason why the word has emerged is that scientists are spontaneous realist: when the total scientific effort of millennia still ceases to let a unified science arise, then is interpreted as a sign that it never will and henceforth at least some of the various levels involved in present-day science do possess more than a temporary status.

Emergent phenomena are unpredictable and unexplainable, it seems. They are unpredictable until the moment when they are described. Then they are in a certain sense not unpredictable anymore. After the relations between the preceding conditions and the phenomena produced are described for the first time, one can claim that the event hereafter can be predicted and therefore is causally described. However, before it is possible to define emergence in relation to causality, you have to differentiate between description and explanation. To describe an event is not an explanation. In continuation of this, we can distinguish between a descriptive causality and an explainable causality.[3]

The problem can be stated as follows: if it is the fact that emergence only denotes cases of descriptive causality, and only after the event is recorded, and if this descriptive causality can never be transformed to an explainable causality, is the conclusion then that emergence is unexplainable? The problem of “novelty” is thus connected with determinism.

3. Emergence and determinism

One of the classical positions in theory of science is that scientific theories are able to define deterministic relations between the elements under investigation. The main characteristics of this kind of determinism is prediction. When you are able to predict the development of a system from some predefined condition, then you have established a deterministic relation between the elements which constitute the system. From this classical perspective, thorough explanation of a system demands the capacity of predicting its development, and this seems to preclude the appearance of new (emergent) properties.

One of the most interesting results of recent developments in physics and in theory of science is the remodelling of the relation between determinism and predicition. Today it is evident that a lot of systems exist which on the one hand are described adequately as being strictly deterministic but on the other hand remain unpredictable. As a consequence of modern chaos theory some historical facts have been found showing that this in fact is a rather old insight. The impossibility of predicting the properties arising within many systems considered totally deterministic is the consequence of the well-known Poincaré treatment of three-body problem and the French mathematician Hadamard's investigation of the "sensibility of the initial state" – insights from the latter half of the 19th century which have in recent years been elaborated under the headline of chaos theory. A lot of processes in physics – and hence also in the many levels and sublevels above physics – are in this way unpredictable even if they still are deterministic (they are computably irreducible – cf. below). Thus, one of the very important theoretical consequences of chaos theory is the divorce of the old couple determinism and predictability. In systems considered perfectly deterministic, for instance those described by Newtonian mechanics or the theories of relativity, an unpredictability is at issue which is not tied to the observing subject's lack of power to obtain information about the single elements of the system. No matter how much information obtained, the behaviour of the system will still be unpredictable after a certain lapse of time – the uncertainty of the information about the system will grow exponentially in relation to the uncertainty on the initial conditions – which defines the so-called "sensibility on the initial conditions" in these systems.

One of the main characteristics of emergence was the formation of new properties, that is, properties which could not be predicted. As far as we can see, it is no longer a problem to defend the statement that systems with emergent processes can be deterministic. If this is the case, there need not be any principal opposition between emergence and determinism: a system may be fully deterministic and yet show emergent phenomena – or, to put it another and perhaps more compelling way: the concept of emergence does not necessarily entail the presence of indetermination, or of any kind of "invention" of the process. As we stated above, emergent phenomena behave the same way if repeated, even if not explainable.

The relation between determinism and emergence can be elucidated by a recent debate in French science and philosophy involving amongst others René Thom and Ilya Prigogine. The background is a provocative article named “Halte au hasard – silence au bruit” (“Stop the chance, shut up with the noise”; this article as well as the various replies in the discussion around it is collected in Pomian, ed., 1990). In this article Thom argues against the Prigogine idea of “order out of chaos”. This idea argues that in the absence of a deterministic description of certain processes (in the Prigoginian case, the well-known “dissipative structures” of non-equilibrium thermodynamics), one may discard the deterministic description as a whole and see the evolution in the system in question as the effect of a micro-level fluctuation which might as well have sent the system off in another direction. Thus concepts like “fluctuation”, “turbulence”, “chance”, “noise” and “disorder” are conceived as *ontologically* existing phenomena and deterministic description is but an unprecise mapping. Against this, Thom answers that all these concepts are relative to a given *epistemological* description, and it makes no sense to talk of for instance fluctuation except in relation to a description from which it deviates. Thus Thom imagines the phase space mapping of the process, yielding a bouquet of different roads to follow – then the fluctuation will be the small “push” determining which of these ways is chosen through phase space. In this respect, the fluctuation is determining the developmental outcome – but only measured against an already structured phase space. Against this, Prigogine argues that when no detailed description of the phase space exists, then one must discard the phase space mapping altogether as irrelevant and instead insist that the sequence of fluctuations is somehow “creating” the trajecory through phase space. This solution of course makes the world inherently “creative” and ripe with emergence: in this case, emergence should be at stake every time no deterministic explanation is possible, that is, in any system equipped with fluctuations big enough to trigger the choice of alternative routes along the bifurcating landscape of possible trajectories of the processes.

The debate thus uncovers some principally very interesting differences: Thom maintains his ontological view of science by expelling the various ideas of indeterminacy as being a real fact – what leads Thom to posit his idea of science as the embedding of a realized process in the space of virtual processes. On the other hand, Prigogine dislikes the idea of potentiality (the various trajectories of phase space of course being potential) inherent in Thom’s idea of science and invokes instead the unpredictable event as his deepest level of explanation. This makes evident that a point of view like Prigogine’s, completely deprived of potentiality, – contrary to its own intention – ends up as scepticism: we can never know anything but what is actually realized, that is, the other possibilities for a given process to go do not in any sense exist beforehand and the outcome is “created” by the fluctuating event. If one wants to avoid this consequence, one has to accept the idea of potentiality – but in a restricted sense. Potentiality as the possibility of saying: if this process is repeated with this and that parameter changed, then the development will change in such-and-such a way. In this point of view, emergence is not an omnipresent creative force, but simply the fact that some of these virtual processes possess new properties.

In the problem of determinism and prediction the crucial relation is between the deterministic description of a system at one level, and the emerging new properties, possibly at a higher level. There are at least two versions of this:

(a) *There exists a full-fledged deterministic theory of the domain, and yet it ceases to yield an explanation of certain properties.* This seems to be case for instance in thermodynamics. In principle, given certain boundary conditions, the behaviour and macrophysical properties (such as heat, pressure, volume and temperature) of a gas is only determined by the place and momentum (and form) of every single molecule within it – parameters which we could in principle know – and is thus governed by mechanical laws which are at our disposal. Nevertheless, this knowledge is for practical reasons impossible to obtain, and one has to resort to consider the *statistical* behaviour of the constituent particles in order to derive the equations of state (of these properties) of the gas, i.e., the phenomena at the macro level. However, not all macroproperties can be derived, and truly emergent phenomena like phase transitions, still unexplained at micro level, can take place. It is not explained, for instance, at the micro level, that the four phases solid, liquid, gazeous and plasma are the general options possible – and not two, five, or seven phases. This is of course not to say that the micro level cannot tell us a lot about how the phases are constituted at the higher level, but still these seems to be only necessary and not sufficient conditions for the phases to occur.

The crucial point in this example is that it is not even possible to *identify* the macrophysical phenomena at the microphysical level. If you only existed at the microphysical level, you would never be able to identify the macrophysical phenomena. And this is one of the large facts in favour of emergence in contrast to the hard reductionists and eliminativists: *the fact that it is impossible in these cases to interpret a lower level explanation without using some higher level concepts to identify what is going on*. René Thom (and many others) have pointed out a similar problem in genetics where biologists pretend to be chemical reductionists making DNA the ultimate cause of the organism – but all the time doing this by using higher level concepts like “information”, “code”, not to talk about “messenger-RNA“.

In this respect Kincaid argues (Kincaid, 1988), that not every lower-level theory needs to commit to such sins. It is perfectly possible to imagine a genetics deprived of any expressions foreign to chemistry, but any explanation of a recognized higher-level phenomenon must start with the higher-level phenomena in order to identify what to investigate, thereby using some identification of the process or object. A purely chemical genetics would be a branch of chemistry and would hardly be recognizable as genetics. This very identification can never be totally discarded in a lower-level explanation, because in the ultimate through-and-through lower-level explanation one might never know which higher-level phenomenon it was an explanation of. The reductionist idea to create a sort of dictionary, in which every higher-level phenomenon can be translated to its micro-level constituents in itself proves that a conception of the higher level as merely reducible, subjective epiphenomena is never possible: one always has to use a description of the higher level to identify what is going on.[4]

To conclude on case (a): even when a system is described 100% deterministically it does not follow that it is possible to predict the behavior of the system or to reduce its behavior to a more elementary level. Chaos theory and related subjects have shown that even inside physics it is only a very small amount of systems, in which it is possible to define each step in the deterministic processes. Emergence in cross-disciplinary cases (for instance, the relation physics-biology) involves more complicated issues of physics which are not yet deterministically described.

(b) *No fully fledged deterministic theory of the lower level exists, but the lower level phenomenon partakes in a domain which is generally considered deterministically explainable and predictable.* This is most often the case in the relation between physics and the various higher-level sciences. The conceptual background in which the emerging (i.e., not yet deterministically explained) phenomenon is conceived is physics' own ideal as a science which will soon be able to explain "everything" completely deterministically. This is taken as a background on which the emerging – that is, not yet deterministically explained – phenomenon is conceived. At the moment we are not able to explain a great amount of phenomena, but it is only seen as a question of time. This point of view, which could be coined "potential determinism" has not the slightest bearing in reality. As is evident, this practice can in most cases be characterized as an ideology exactly because even physics in itself does not posses this complete determinism (thoroughly argued in Penrose, 1989) or predictability, against which every emergent phenomenon should be measured.

The problem primarily arises when you define determinism as closely related to prediction. The idea that science only can cope with deterministic processes goes back to at least Thomas Hobbes, but can also be found in a more critical version in Immanuel Kant, who held determinism to be a necessity, i.e. a condition of the possibility of natural science. Indeed, the idea contains a rational core. If a phenomenon behaves completely indeterministic, it would be impossible to reach a scientific description of the process. Even physics must admit that classical determinism remains an ideal – and it is in this way every phenomenon, also emergent phenomena, must be characterized as deterministic.

4. EMERGENCE AND LEVELS

(a) Some ontological specifications

In the preceding discussion, we have been taking the notion of *levels* for granted. The concept of levels is for instance implied in the preceding distinction between global and local processes. When we say that physical processes are global and biological processes are local, the implication is that physical laws are identical all over the universe – the physical level is the most basic level, from which all other levels arise. The biological level is local because it seems evident that essentially different sorts of life could emerge in local corners of the universe (this does not preclude that universally valid principles of biological organization might exist). Life as such, independent of its specific nature, will always be related to the physical level by a relation we term “inclusive”.

That levels are *inclusive* means that a higher level does not violate lower level laws, that the higher level is materially related to the lower one, and that this does not imply that the organizing principle of the higher level can be deduced from lower level laws. The organizing principles are, as the entities belonging to various levels, ontologically existing. It is not just epistemologically a level theory (saying that ontologically all entities belong to the lower level), but also ontological.

At this place it is necessary to explicate our ontological theory. It must satisfy the following conditions:

(1) Dualism, the belief in the existence of some immaterial substance, is not useful in a scientific context. In this respect we prefer some version of the monistic position.

(2) Eliminativism, physicalism or reductionistic materialism are not useful in a scientific context either. If the elementary particles and the fundamental forces of physics were the only phenomena existing, you have to be

reductionist also in your scientific theories – we should all study physics in this restrained, non-Finkian use of the word.
(3) These two viewpoints can be combined in the following statement: ontologically, there exist other entities than elementary particles. These entities are no less material or materialistically existing than elementary particles. By *materialistic* we only mean that these entities exist independently of a human subject, that is without any subject having thought of, measured or otherwise related itself to the entity. They exist not only epistemologically but also ontologically – understood as independent, objective, and materialistic existence – one might as well say realistic – without reducibility to elementary particles. It is important to note that this concept of matter or of objectivity – as existing independent of the observer – encompasses both sides of the traditional form/matter distinction of the Aristotelian tradition, so that the structural relations of an entity are considered material. It permits us to make the old idea of the whole as more than sum of the parts more precise. What is "more" about the whole is a specific series of spatial and morphological relationships between the parts. This implies that this conception of matter could as well in a figure-ground reversal be interpreted as a conception of form: any whole is a form composed of material elements, but each of these material elements considered in turn can only be described by looking at a lower level of form arrangements of smaller elements in space ... Thus matter and form are in this view opposing but not contradictory points of view of the same reality: seen "from above" a given phenomenon is form which is secondarily composed of material elements; seen "from below" a given phenomenon is matter which is secondarily moulded into some form. A common materialist mistake now amounts to see the first of these views as superficial or subjectivist, making questions of form impossible to grasp for science. But if form, structure, relation, Gestalt etc. are no longer considered as subjectivist features, but rather as objectively existing then form and matter may unite as equally objective.

(b) Primary levels and sublevels

We further have to elaborate upon the idea of a pragmatical distinction between *primary levels* and constitution of *sublevels*. To exemplify, it is reasonable to suggest that the primary levels include the physical, the biological, the psychological, and the sociological level; as possible sublevels within the primary biological one we many mention the cell level, the organism, the population, the species and the community levels. One of the key concepts to this distinction is the preceding notion of the *first time emergence of a primary level* and the *repetitions of the creation of entities* at the primary levels, which eventually constitute sublevels. No doubt, it is in relation to the emergent constitution of the primary levels that the concept of emergence might seem to have some theological connotations. If you think of the constitution of a primary level like something popping up or out of the blue – this would be identical with revitalizing the concept of emergence. We think it is possible to give a solution to this problem that is describing the constitution of levels without theological connotation by the concepts of initiating and constraining conditions.

(c) Boundary, initiating and constraining conditions

It was Polanyi who introduced the notion of boundary conditions as useful for describing conditions which constrain the behaviour of an entity at some level within a hierarchical system. The concept of boundary conditions is a mathematical one, often used more or less informally on physics too, but Polanyi used the term in a more general way in his paper “Life’s irreducible structure” (1968). Its mathematical meaning is that if the solution to a differential equation contains *r* arbitrary constants, these may be eliminated to give one unique solution to a problem if there are *r* given conditions that the solution must satisfy; some of these may be boundary or initial conditions. Boundary conditions (which may be for the function and/or its derivatives at certain boundary points) may be used to obtain a solution which is valid over the region specified by the conditions. One could say that the general idea is that of restricting the space of possibilities by choosing or specifying conditions to get an actual solution to a problem.

Polanyi observes that machines are peculiar things which, even though they work by applying mechanical power according to the laws of physics, possess a structure shaped by man in order to harness these laws to serve man’s purpose. Accordingly, the machine as a whole works under the control of two distinct principles: “The higher one is the principle of the machine’s design, and this harnesses the lower one, which consists in the physical-chemical processes on which the machine relies”; the higher one is considered as “the imposing of boundary conditions on the laws of physics and chemistry” (1968, p. 1308). Polanyi distinguishes between very simple types of boundaries (e.g., a test-tube bounds a chemical reaction, but we cannot gain knowledge of the reaction by just studying the test-tube) and more complex ones (e.g., the strategy of a chess-player imposing boundaries on several moves), the latter are also exemplified by the machine. A living organism is submitted to boundary conditions of the machine type, and is thus working according to two distinct principles: Its structure serves as a boundary condition harnessing the physical-chemical processes by which its organs performs its functions. Systems under such ‘dual control’ as machines and organisms are thus governed in part by irreducible higher principles which are “additional to the laws of physics and chemistry” (p. 1310, ibid.). (This does not imply, of course, subscription to the Cartesian idea of animals being machines, rather to an idea of machines as being constructed by animals). Thus, Polanyi’s theory of boundary conditions lends itself to a general theory of levels and their relations. Each level relies for its operations on all levels below it. The level reduces according to Polanyi the scope of the one immediately below it by imposing on it boundary conditions that harnesses it to the service of the next-higher level, and so on. The operations of a higher level cannot be accounted for by the laws governing the entities at the lower level.

Polanyi identifies the information content in the DNA with a set of boundary conditions, because during ontogenesis, the genetic information regulates the growth and morphogenesis of the developing organism. (He even speculates about further controlling principles such as morphogenetic fields or Waddingtonian epigenetic landscapes). Even though DNA is a macromolecule, its role as carrier of information is not entailed merely by its chemical constitution. It follows that life is irreducible to chemistry. For example, if you list all known chemical regularities and laws, it would be impossible for you, on the basis of this list and without any knowledge of the biological cell, to select those entities, regularities and types of behaviour which are specific for the biological cell. It would be not only impossible in relation to your actual knowledge, but in principle impossible (regardless of your knowledge) for computational reasons: to determine which possible chemical combinations possess life-like properties, you have to “run” all possible proto-cells and their development, a task which is apt to be computably irreducible. We cannot say much more than that the constitution and reproduction of life uses a microscopic part of the possible combinations of basic elements (by Salthe called initiating conditions, cf. below).

(d) The emergence of a primary level

In general, we can claim that a level is constituted by the interplay between a set of elementary entities and processes acting on a level below (the initiating conditions), constrained by specific boundary conditions (that may have an environmental origin relative to the emerging entities) that determines the “shape” or “form” of the entities at the emerging level.

If we combine Polanyi’s view of constraining conditions with the distinction between global and local processes, we can *define* the constitution of *primary levels as the emergent process which selects the constraining conditions*. And further: this level constitution does not happen in “a moment” – it may take millions of years, but when it has happened, it seems to be exclusive and will probably never be redone at that specific locality. When in fact (as concluded in the preceding) it is not possible to constitute a level in one emergent process, we also have to distinguish between the entities and the level.

Let us take an example. The life-constituting process in the “primordial soup” can be seen as a very time consuming process. There exists competing theories about the specific phases and details in this process, but our purpose here is not to commit ourselves to any of these, but to draw attention to general aspects of the process which is interesting from an ontological point of view. A possible scenario is that the primordial soup has produced very different primitive life forms, each with their set of boundary conditions, during thousands of years – and that vitually all of them became extinct. The life form which we identify as basic to life on Earth, the cell including DNA, was just one sort of proto-life. When it became the dominant part, and later the only one, it is probable due to a combination of “directive” (natural selection of “fit” structures relative to the environment) and “contingent” (mutation, environmental changes) factors.

There are two noticeable points in this. First, the *entity* constituting this process did not happen in a moment. It was a very long process. Second, what defines *the primary emergence of life* has to be split up in (a) an *entity* constituting emergence, and (b) a *level* constituting emergence. The first one is (in a material and temporal sense) the primary one, but both are necessary to constitute a level. The first processes within the system will constitute a basic (primary) entity, and subsequently the level-constituting relations between entities will appear. Thus, the primary emergence of a level of living systems on earth consists of (a) the emergence of an entity, a living cell with DNA, where the genetic information in the DNA constitutes the constraining conditions for life on Earth (the “boundary conditions” of Polanyi 1968), and (b) the subsequent constitution of the (ecological, physiological, genetical, etc.) relations between various versions of the primary entity. This latter process of a level constituting emergence is in general the process unfolding when the potentialities in the entity develop in relation to other entities.

When the biological is constituted, the further development inside the biological level may lead to the constitution of a lot of biological sublevels which do not, however, remove or transcend the cell with DNA as the primary entity. But on the other hand, you cannot derive all biological sublevels from the DNA-equipped cell.

We have thus specified four conditions which characterize the emergence of a primary level (at least in the biological case):

(1) The constitution of a primary entity presupposes a time consuming "Darwinian trial-and-error" period, where different sorts of potentially primary entities are created and die out.
(2) One forms wins the battle[5], and after that, in principle there only exists one (or very few) specific local form (DNA is hereafter constraining condition for life). Starting with a very poor ontology, it later gains in complexity.
(3) When the primary constituents exist exclusively, there is locally no repeted emergence of the primary entity. When the DNA and the cell is established as the primary entity, it will not be created again.
(4) The primary *level* is constituted by a number of subsequent emergent processes characterized by – in case of biology – intercellularity (see R. Chandebois, 1983) and the ecological relations between individuals of various species generated by the process of evolution. Following this, a level can be defined by its entities and the relations between entities.

Likewise we have specified three conditions which characterize the subsequent processes of level constitution:

(1) Level constitutions organize primary entities into a new structure of relations.
(2) Entities which by the subsequent level constituting processes are developed out of the primary entity cannot transcend the primary entity. It is not possible to develop biological entities which can dispense with cells with DNA. If this happened it could only be understood as the constitution of a new primary level entity.
(3) Entities at sublevels will always be reproduced. That is, later repetitions of entity emergence is specific for sublevels.

Now primary levels will be the levels whose entities are central to a large population of higher levels. Thus physics, biology, psychology and sociology seem to be the most important primary levels. There may be other primary levels, for instance chemistry, multicellular biology, animal psychology (entities with consiousness but not selfconsciousness) etc.

This level-model can be characterized further by discussing it in relation to some key concepts in different level theories. One of those is *potentiality*. Certain writers have stated that the development of a level always exists implicit, that is, as a potentiality. Now, the plausibility of this idea depends highly upon the use of the word "potentiality", so let us analyze it in detail. In S. N. Salthe's *Evolving Hierarchical Systems* (1985), the author introduces potentiality in relation to his so-called *Basic Triadic System*. According to Salthe, it is only relevant to describe an entity at a given (focal) level in relation to the level beneath and the level above. In the dynamics of the basic triadic system, both upper and lower levels produce effects which according to Salthe constrain the dynamics of the focal level. Salthe's argument for the Basic Triadic System is epistemological, and is, in short, that in the scientific operation of choosing an object, or selecting the scientific object, the scientist automatically chooses a point of view, a level of description, which restrict the possible description to the levels beneath and above. Further, in relation to Polanyi (and Pattee) Salthe stresses the importance of higher-level constraints, called boundary conditions, which harness or regulate the dynamics of the focal level. The lower-level constraints are called initiating conditions, which is the set of possibilities which the boundary conditions select from or constrain. According to Salthe, the initiating conditions give rise "autonomously" (ibid, p. 69) to focal level dynamics. In relation to the biological level, the initiating conditions are all those possible combinations of organic substances which in the primordial soup could be basic for the primary emergence constituting the primary entity.

Salthe's theory[6] accentuates a paradox in level theories which is very common. If one defines levels as boundary conditions working on initiating conditions it is a problem where to locate these conditions. Salthe's answer is that initiating conditions are manifested at the lower level and the boundary conditions at the level above. Probably this is a workable hypothesis from an epistemological point of view, but it is clearly ontologically unreasonable or rather only consistent with a certain interpretation of potentiality. If the constraining conditions are to be placed at the level above, the only solution is that all levels and entities exist potentially from the beginning – and what is more, exerting their potentiality as some kind of "cause" before being realised themselves, in short you have a constitution of levels presupposing that the next level already exists. In a materialistic or realistic context this is of course an argument of an uncanny Münchhausenian flavour. It is of course not possible (materialistically or realistically) to presuppose the biological organism as a biological sublevel constraining the constitution of the primary cell level. As far as we can see, there is only one possibility if constitution of a level presupposes higher levels with boundary conditions – and that is an idealistic ontology where every level and every entity are potentially existing and exerting attracting influences downward in the level system (the organism as attractor for the cell). We think this idealistic concept of potentiality can be refused on ontological grounds; we do not hereby want to refuse every sort of potentiality, but only in this holistic level-constituting sense.

In a previous paragraph we saw the impossibility of getting totally rid of potentiality. Any theory claiming only the actual to exist will end up in some kind of scepticism (does the particle exist when not being observed etc.). In one sense potentiality is evidently relevant. If it was possible to draw the whole phase space of the universe, the formation of for instance biology would occupy some regions of this space, that is, the possibility of biology is determined by physics, and given some specific changes the universe might have developed in a direction with no realized (but still potential) biology. As can be seen, any evolutionary theory presupposes this kind of potentiality (as in the Darwinian case: the host of species extinct or unrealized at various steps of development (from zygote to ecological niche) which we can never know as actual but must be posited as a potential to explain the selection of the known species.

(e) The kinds of primary levels

To generalize our discussion of levels, we find it a realistic and stimulating working hypothesis to concentrate on four primary levels – the *physical*, the *biological*, the *psychological* and the *sociological*. As sociobiology has shown, there are a lot of group structures in the animal kingdom. We see the primary entity defining the sociological level as the *institution* (and the associated concept of institutionally defined social role), and, in accordance with this, we do not see status hierarchies and pecking order as sufficient for institutions. Institutions are changeable by the members of the society and presuppose symbolic systems (language). The psychological level is defined by the *self-consciousness* (the primary entity at the psychological level), and not some lower cognitive activity, such as sensation and perception or plain consciousness which may define animal psychology. Sensation exists in principle when biological evolution has developed receptors, and perception does only require sensation and some primitive form of memory to select between incoming sensations. Consciousness as such – as representational mapping of the local surroundings – is presumably a function in most higher animals, while man's specific defining feature seems to be self-consciousness, intimately related to language acquisition, to the possibility to transcend the local situation both spatially and temporally, and again to intersubjectivity. It remains to be analyzed further what the defining entity of the psychological level is. If an entity, like most emergent entities, is to be composed of an arrangement of entities from the lower level, some specific electrophysiological patterns in the brain would be the most vital parts of the arrangement, having self-consiousness as a property. Others will argue that self-consciousness might itself be this entity; we shall not go further into this discussion here.

It is very interesting that even if we shall become able to point out the defining entities for the psychological and the sociological levels, some primary characteristics are the same for both of them. Intersubjectivity and language are necessary for both self-consciousness and institutions. We thus have to see the development of the psychological level and the sociological level as interconnecting. It seems we have two levels interwoven in such a manner that they are each part of what constitutes the other. If this is the case, we might have *another kind of level constituting process*, different from the one constituting the biological level. Still, another possible direction of research is that the two levels form different descriptions of properties in one and the same psycho-social level to be defined.

Thus it may not be possible to sketch a general theory of interlevel relations in the emergence of primary levels, because the genesis of four primary levels are asymmetric or nonhomomorphic.

We cannot say with certainty which primary ontological levels exist and whether the most important ones are actually the four mentioned. Furthermore, our idea of the inclusiveness of levels discussed above implied that other "local ontologies" of other higher levels may exist within the global, physical primary level (see Figure 1), and we cannot tell beforehand which other initiating conditions for mentality or sociality other "local biologies" may constitute. We think that the philosophical connections between epistemology and ontology are so interwoven that the specification of levels is very difficult to prove, and that the specification in the last resort stands on epistemological grounds. But – and this is the important thing – there is a very big difference between saying that levels are only epistemological forms, and saying that levels have a materialistic existence.[7] One of the main differences is the concept of evolution or development. The distinction between global and local, and the notion of ever developing levels (including the physical) are in essence ontological statements. In accordance with this, the levels exist ontologically (and materialistically/realistically), but we might never be able to say where exactly the borders are.

5. Concluding remarks: emergence explained

New developments in science have constantly challenged the philosophical approach to emergent phenomena. The recent approaches to emergence and their implications for the ontology and epistemology of the concept of emergence will be considered in detail in a separate paper, but the general implications for explaining emergent phenomena seem to be clear and shall be considered briefly.

(a) Recent approaches: complex systems

In a popular book dealing with the philosophical implications of non-equilibrium thermodynamics, the physicist Paul Davies (1987) claims that "as more and more attention is devoted to the study of self-organization and complexity in nature so it is becoming clear that there must be new general principles – organizing principles over and above the known laws of physics – which have yet to be discovered" (Davies, 1987, p. 142; see also Needham, 1941; Schrödinger, 1944). It is important that Davies emphasizes that such organizing principles do not mean that we have to conceive of them as "deploying mysterious new forces specifically for the purpose", which would be tantamount to vitalism. Though it cannot be exluded *a priori* that physicists may discover new forces, the collective behaviour of particles may take place entirely through the operation of known interparticle forces. So the organizing principles "could be said to harness the existing interparticle forces", they "need therefore in no way contradict the underlying laws of physics as they apply to the constituent components of the complex system" (ibid p. 143). Today a whole branch of research – not only within physics but also across its borders to biology, computer science – deals with complex dynamical systems and can be seen as an attempt to find such organizing principles; and related efforts have been made, often in vain, to define the notions of complexity and organization quantitatively (cf. Aschby, 1962; Baas, 1994; Bennett, 1988; Cariani, 1992; Chaitin, 1992; Jantsch, 1980; Kauffman, 1993; Landauer, 1988; Langton, 1989; Pagels, 1988; Wicken, 1987; Wolfram, 1984; Yates, 1989). Though it is not possible to extract a single general theory of emergence from these approaches with rather different points of departure, this whole area of research reveals an important take home lesson about emergent structures, namely that they are in many respects indeed accessible for formal and scientific treatment, e.g. by the computational methods of dynamical systems theory, automata theory and in simulations within such fields as artificial life and cognitive science. In a broader historical view it is a fact, that the concept of emergence does have a central position inside these new domains. Even if it is only a part of the total set of emergent processes which they can handle, it is a very promising step in relation to a fully developed theory of emergence.

(b) Origin of life: emergence explained

The title of a previous version of this paper was the rather pessimistic "In search of the unexplainable", alluding to the implicit contradiction in the concept of emergence, that everyone uses it as a notion of processes which they cannot explain. However, we want to stress that emergence is not necessarily unexplainable. In the discussions of this paper we have argued that it is possible to reach an understanding of emergent phenomena which does not exclude them from a reliable scientific context, and that the very idea of emergence should be viewed as one of the most central ideas in modern science. Especially in relation to the epistemological and ontological consequences of non-reductionist theories of hierarchical organisation and level theories.

We are going to conclude this paper by an example: how it is possible to view the creation of life from the angle of emergence.

As the neo-Darwinian geneticist Theodosius Dobzhansky once noted, nothing in biology makes sense except in the light of evolution. Hence, the question of the origin of the cell as a fundamental entity of the biological phenomenology or level is a crucial case of the nature of emergent entities. In a sense, the emergence of cells constituted the emergence of life (we can, at least preliminarily, define life to be a cell-based phenomenon) and the creation of one of the "primary" levels of a hypothetical irreducible materialistic ontology, the biological level of organization. If we accept that in principle this case can be convincingly accounted for by natural science, be it contemporary or future (and in fact, "protobiology", or inquiry into the conditions for the evolution of life from a prebiotic "soup" of macromolecules is today a legitimate area of research), then we have a strong case that the emergence of new levels in evolution can be scientifically explained, even if we still consider life as irreducible to the laws of physics or chemistry because it manifest very specific properties. Thus "emergence" is a genuine phenomenon, but we can conceive of an explanation in the form of a scenario or a sequence of plausible events, each contributing to increase the complexity of the constituent sub-system (macromolecules and their chemical reactions) and ending up with full-fledged cells. We do not claim here that such a scenario already has been constructed in any satisfying way (e.g., in a way that would allow a test under laboratory conditions in the form of a formidable sequence of controlled experiments to generate biological cells, not "constructed by design", but generated merely by application of self-organizing principles). We only claim that this would constitute a case for the explainability of emergent phenomena.

These lines of thoughts contribute to dissolve the apparent paradox, involved in attempts to "explain" the emergence of new irreducible levels of reality, by loosening the requirements for explanation. Something which is unpredictable does not have to be unexplainable. The phenomenon of deterministic chaos in complex dynamical systems has shown how futile it is to demand that the competence of prediction in physics should be complete, when the development of systems in phase space may be extremely sensitive on the initial conditions. This is no obstacle to make as good as possible descriptions of the system in terms of their basic mechanisms of movement, or in terms of their qualitative behaviour to catch these mechanisms in a proper model. A comprehensive model of the emergence of life must account for many separate steps and should thus decompose into separate submodels of various kinds (chemical, biophysical, genetical) which might be linked up with an overall historical account. Thus, we argue for a multiplicity of explanatory models, linked by a general historical or, if you wish, evolutionary model – similar to the cosmology-crafting of physics. As is the case in any historical explanation, we can never know for certain the actual sequence of events in complete detail, but we can invent hypothetical, virtual or artificial universes in which we can re-run the conditions that make the new phenomena appear and compare them to different developments caused by various parameter changes. The theories of proto-cells, the computer simulations of "emergent" autocatalytic reaction networks of molecules, or artificial cells in the form of proteinoid micro-spheres in the test tube, all points to the possibility of establishing a scenario for the origin of autonomous self-reproducing entities.

One might criticize the idea that such an explanation is within reach, because it could be based on a too simplified view of the simplest forms of life, which are indeed eminently complex. It is not enough to know the structure and functions of the molecules of a prokaryote cell, or how for instance some conceived component molecules of the first cell membranes got together and formed closed compartments. Contemporary cells have all a coded "message" contained in their DNA which code for the primary sequence of aminoacids in each protein building block. How this genetic code, and the whole machinery for its translation in the cell originated is still a huge mystery. Even if we today know the mechanisms of DNA-replication, repair, and protein synthesis fairly well, many details still elude us, and what is more crucial in this context, it is extremely difficult to establish some mechanisms in which much simpler kinds of metabolic systems could evolve and transform into the elaborate structures that constitute contemporary cells. This kind of complexity is a nice example that indicates the rise of new principles of organization in evolution, here, the emergence of a "genetic language" and of "measurement processes" in the form of entities capable to respond selectively to inputs from their surroundings (the semantic and measurement emergence of Pattee, 1989). These properties transcend the mere self-organization of physical systems far from thermodynamic equilibrium, which does not rely on coding ("semantic closure") or measurement.

To summarise our conclusions regarding emergence, we have argued that:

- Emergence exists as a key phenomenon, and it should be taken seriously in science.
- Emergence does not exclude explanation, in some cases not even a deterministic one, and emergence is not an indeterministic process.
- Emergence in relation to levels can only be analyzed within the distinction between gobal/local perspective.
- Emergence as a single process does not constitute levels but only entities; the emergence of primary levels are a combination of entity constitution and subsequent level constitution, by generation of relations between the entities.
- Though it may not be possible to reach a final conclusion regarding the existence of objective ontological levels and their specification, we adopt as a useful "working hypothesis" an ontology of four primary levels: the physical-chemical, the biological, the psychological and the sociological.
- Some emergent phenomena may be described within a formal framework and computationally modelled. To which extent this will adequately explain emergent processes in a material world cannot yet be decided. However, it is the hope that aspects of emergence can be accounted for by exact, mathematical approaches.

NOTES

[1] Discussed by Sven-Eric Liedmann, 1977.

[2] These concepts seem to be linguistically analysable by means of f.i. Roman Jakobson's marked/unmarked distinction (hence nature is unmarked, culture is marked).

[3] As far as we can see, it is not decisive which of three primary types of physical causality we are talking about: the classical causality in mechanical physics, the statistical causality in statistical mechanics or the probability-causality in quantum mechanics. Each of the three types can be used as descriptive causality and explainable causality, respectively.

[4] This argument is similar to Pattee's idea (Pattee, 1977) – inspired by Bohr's principle of complementarity – that it is never explainable in micro terms what a measurement actually is: this requires the passage to a macro level. In micro terms, a measurement is but a process as any other process.

[5] One should note, that we do not imply that there is selection for a "globally fittest" form of life – Darwinian selection does not mean creation of the perfect. The process is probably characterized by what Gould (1989) terms contingency: if one could "replay the tape of history", it would yield an entirely different outcome.

[6] We are aware of Salthe's subsequent elaboration of his ideas of hierarchy, emergence and complexity (as presented in Salthe, 1993), which are, however, too difficult to be dealt with here. We hope to contribute to a deeper discussion of Salthe's work in a subsequent paper.

We would like to thank Stanley Salthe for his kind help and comments to an earlier version of this paper.

[7] We find that this stance is supported by various recent developments in theories dealing with complex phenomena – chaos theory, theories of self-organizing phenomena, complexity and algorithmic information theory. We analyse this in a another article.

[8] This is in fact the same principle as used for constructing data compression algorithms used in electronic communication and data processing. Some picture compression algorithms are based on fractals, an instance of iterated function systems. Think of the fact that the highly complex Mandelbrot set (or other popular and spectacular fractals) are defined by a very short formula describing an iterative process.

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