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Emergence

Intermediate article

Achim Stephan, University of Osnabrück, Osnabrück, Germany

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In ordinary language, to 'emerge' means to 'appear' or 'come into view'; but the technical use of the term is associated with features such as novelty, irreducibility, and unpredictability. The basic idea of emergence is that as systems become increasingly complex during evolution, some of them may exhibit novel properties that are neither predictable nor explainable on the basis of the laws governing the behavior of the systems' parts. Thus, complex wholes can come to have properties that are not reducible to the properties and relations of their constituents.

INTRODUCTION

During the 1990s, the term 'emergence' became widely used in such different fields as the philosophy of mind, self-organization, creativity, artificial life, dynamical systems, and connectionism. The term, however, is not used in a uniform way. It can imply novelty, unpredictability, irreducibility, and the unintended arising of systemic properties,

particularly in artificial systems. Thus, it is rather controversial what the criteria are by which 'genuine' emergent phenomena should be distinguished from non-emergent phenomena. Some of the suggested criteria are very demanding, so that few, if any, properties would count as emergent. Others are inflationary, in that they count many, if not all, system properties as emergent. First of all, therefore, one should be clear about the various types of emergence. (See **Philosophy of Mind; Self-organizing Systems; Creativity; Artificial Life; Dynamical Systems, Philosophical Issues about; Connectionism**)

VARIETIES OF EMERGENTISM

Three theories among the different varieties of emergentism deserve particular interest: synchronic emergentism, diachronic emergentism, and a form of weak emergentism. In synchronic emergentism, the relationship between a system's

properties and its microstructure (i.e. the arrangement and properties of the system's parts) is at the center of interest. A property of a system is taken to be emergent if it is irreducible, i.e. if it is not reducible to the arrangement and properties of the system's parts. In contrast, diachronic emergentism is mainly interested in predictability of novel properties. Those properties are taken to be emergent that could not have been predicted, in principle, before their first instantiation. Both of these stronger versions of emergentism are based on a common weak theory from which they can be developed by adding further theses.

Weak Emergentism

Physical monism

The first thesis of current theories of emergence – the thesis of physical monism – concerns the nature of systems that have emergent properties or structures. It says that the bearers of emergent features consist of physical entities only. Thus, all substance-dualistic positions are rejected; for they base properties such as being alive or having cognitive states on supernatural bearers, such as an entelechy or a *res cogitans* respectively. (See **Dualism; Descartes, René**)

Physical monism is the thesis that entities existing or coming into being in the universe consist solely of physical components. Likewise, properties, dispositions, behaviors, or structures classified as emergent are instantiated by systems consisting exclusively of physical entities.

Systemic properties

While the first thesis places emergent properties and structures within the framework of a physicalistic naturalism, the second thesis – the thesis of systemic properties – delimits the types of properties that are possible candidates for emergents. It is based on the idea that the general properties of a complex system fall into two classes: those that some of the system's parts also have, and those that none of the system's parts has. These latter properties are called systemic or collective properties.

The second thesis is that emergent properties are systemic properties. A property of a system is systemic if and only if the system possesses it but no proper part of the system possesses it.

Both artificial and natural systems with systemic properties exist. Those who would deny their existence would have to claim that all of a system's properties are instantiated already by some of the system's parts. Countless examples refute such a

claim, e.g. it is among the properties of a leopard to run, but no part of it (head, heart, nor any cell assembly) can run; and it is among the properties of a connectionist network to recognize patterns, but no single part of it (unit, etc.) has this property.

Synchronic determination

The third thesis specifies the type of relationship that holds between a system's microstructure and its emergent properties. Namely, a system's properties and dispositions to behave depend nomologically on its microstructure, that is to say, on the properties and arrangement of its parts. There can be no difference in a system's systemic properties without some difference in the properties or arrangement of its parts.

Anyone who denies the thesis of synchronic determination has either to admit properties of a system that are not bound to the properties and arrangement of its parts, or to suppose that some other factors, in this case non-natural factors, are responsible for the different dispositions of systems that are identical in their microstructure. One may have to admit, for example, that there may exist objects that have the same parts in the same arrangement as diamonds, but that lack the diamond's hardness. This seems implausible. Equally implausible is the idea that there may exist two physically identical organisms, one viable and the other not. In the case of mental phenomena, opinions may be more divided; but one thing seems to be clear: anyone who believes, for example, that two physically identical creatures could be such that one is colorblind while the other is not, is not a physicalist.

Weak emergentism as sketched so far specifies the minimal criteria for emergent properties. It is the common base for all stronger theories of emergence. Moreover – and this is a reason for distinguishing it as a theory in its own right – it is held not only by some philosophers (e.g. Bunge, 1977), but also by some cognitive scientists (e.g. Varela *et al.*, 1991; Rumelhart and McClelland, 1986) in exactly its weak form. Weak emergentism is compatible with current reductionist approaches; and some champions of weak emergentism cite this compatibility as one of its merits compared with stronger versions of emergentism.

Synchronic Emergentism

The essential theses of the two more ambitious theories of emergence are the theses of irreducibility (synchronic emergentism) and of unpredictability (diachronic emergentism). These are closely

connected: irreducible systemic properties are *eo ipso* unpredictable before their first appearance. Hence, synchronically emergent properties are also diachronically emergent, but not conversely.

A systemic property is irreducible if it cannot be explained reductively. For a reductive explanation to be successful several conditions must be met: the property to be reduced must be functionally construable or reconstruable; it must be shown that the specified functional role is filled by the system's parts and their mutual interactions; and the behavior of the system's parts must follow from the behavior they show in isolation or in simpler systems than the system in question. (It is an open question whether or not properties exist that demand a construction or reconstruction other than being functional.) If all these conditions are met, the behavior of the system's parts in other contexts reveals what systemic properties the actual system has. (*See Reduction; Functionalism*)

Since these three conditions are independent of each other, there are three different ways in which systemic properties may be irreducible. Namely, a systemic property is irreducible if: it is not functionally construable (or reconstruable); if it cannot be shown that the interactions between the system's parts fill the systemic property's specified functional role; or if the specific behavior of the system's components, over which the systemic property supervenes, does not follow from the component's behavior in isolation or in simpler configurations. (*See Supervenience*)

Thus, we have to distinguish three different types of irreducibility of systemic properties. Their consequences are also different. If a property is irreducible due to the irreducibility of its bearer's parts' behavior we seem to have an instance of 'downward causation'. For, if the parts' behavior is not reducible to their arrangement and the behavior they show in simpler systems, then there seems to exist some 'downward' causal influence, from the system itself or from its structure, on the behavior of the system's parts.

Such 'downward causation' would not violate the principle of the causal closure of the physical domain. We would just have to accept additional types of causal influences within the physical domain besides the known types of mutual interactions.

Likewise, if it cannot be shown that the interactions between the system's parts fill the specified functional role, it seems that the systemic property has causal powers that the microstructure does not have; hence in this case too there would be some downward causal influence.

In contrast, the occurrence of properties that are not functionally construable does not imply any kind of downward causation. Systems with properties that admit of no functional analysis need not be constituted in such a way that their components' behavior is irreducible. Nor is it implied that the system's structure has a downward causal influence on the system's parts. Thus there is no reason to assume that properties that cannot be analyzed themselves exert a causal influence on the system's parts. Rather, the question is how properties that cannot be functionally analyzed might have any causal role to play at all. And if one cannot see how they might play a causal role, then, it seems, such properties must be epiphenomena. (*See Epiphenomenalism; Mental Causation*)

Diachronic Emergentism

All diachronic theories of emergence are based on a thesis about the occurrence of genuine novelties in evolution. This thesis excludes all preformationist positions. According to this thesis, in the course of evolution exemplifications of genuine novelties occur again and again. Existing building blocks develop new configurations; new structures are formed that constitute new entities with new properties and behaviors.

However, the thesis of novelty does not by itself turn a weak theory of emergence into a strong one, since reductive physicalism remains compatible with such a variant of emergentism. Only the addition of the thesis of unpredictability, in principle, will lead to stronger forms of diachronic emergentism.

The first occurrence of a systemic property can be unpredictable for at least two different reasons. Firstly, it is unpredictable, in principle, if it is irreducible. This does not mean, however, that further occurrences of the property might not be predicted adequately. Secondly, it can be unpredictable because the microstructure of the system that exemplifies the property for the first time in evolution is unpredictable. Since in the first case the criteria for being unpredictable are identical with those for being irreducible, this notion of unpredictability will offer no theoretical gains beyond those afforded by the notion of irreducibility. Let us focus, therefore, on the second case: unpredictability of structure.

The structure of a newly formed system can itself be unpredictable for two reasons. If the universe is indeterministic, then its novel structures will be unpredictable. However, from an emergentist perspective, it is of no interest if a new structure's

appearance is unpredictable only as a result of its indeterminacy – most emergentists claim that the development of new structures is governed by deterministic laws.

Nevertheless, deterministic formings of new structures can be unpredictable in principle if they are governed by laws of deterministic chaos. Against that claim one might argue that a Laplacean calculator could predict even chaotic processes correctly. Whether or not this ‘actually’ could be the case is not yet settled. It depends mainly on the question of what kind of information we allow such a creature to have. At least we can be sure that creatures of our mental capacities do not have these forecasting abilities, and thus, we can legitimately suppose that where chaos exists, structures exist that are unpredictable in principle.

The thesis of structure unpredictability is that the rise of a novel structure is unpredictable in principle if its formation is governed by laws of deterministic chaos. Likewise, any property that is instantiated by the novel structure is unpredictable in principle.

Although diachronic emergentism with the thesis of structure unpredictability implies the unpredictability of all properties instantiated by systems that emerge from chaotic processes, it does not thereby imply their irreducibility. The unpredictability, in principle, of systemic properties is entirely compatible with their being reducible to the microstructure of the system that instantiates them.

Synopsis

Figure 1 shows the logical relationships that hold between the different versions of emergentism.

Weak diachronic emergentism results from weak emergentism by adding a temporal dimension in the form of the thesis of novelty. Both versions are

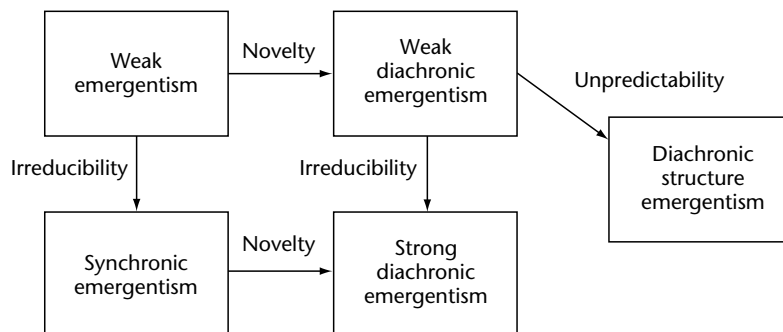


Figure 1. The logical relationships between the varieties of emergentism. Each arrow represents the addition of a thesis to a weaker theory.

compatible with reductive physicalism. Weak theories of emergence are used today mainly in cognitive science, particularly for characterization of systemic properties of connectionist networks, and in theories of self-organization. Synchronic emergentism results from weak emergentism by adding the thesis of irreducibility. This version of emergentism is important for the philosophy of mind, particularly for debating nonreductive physicalism and qualia. It is not compatible with reductive physicalism. Strong diachronic emergentism differs from synchronic emergentism because of the temporal dimension in the thesis of novelty. Structure emergentism is entirely independent of synchronic emergentism. It results from weak diachronic emergentism by adding the thesis of structure unpredictability. Although structure emergentism emphasizes the boundaries of prediction within physicalistic approaches, it is compatible with reductive physicalism, and so it is weaker than synchronic emergentism. Theories of deterministic chaos can be considered as a type of structure emergentism. This perspective is important for evolutionary research. (See **Qualia**)

HISTORY

Although some hints of emergentist thinking can be found in the works of Empedocles, Epicurus, and Galen, the proper development of emergentism began in the mid nineteenth century in Britain. George Henry Lewes (1875) introduced the term ‘emergent’ into philosophy, to distinguish ‘emergent’ from ‘resultant’ effects. Here Lewes picked up on John Stuart Mill’s distinction between ‘homogeneous’ and ‘heterogeneous’ effects: joint effects of causes are called heterogeneous (or emergent) if they are not the ‘sum’ of their separate effects; otherwise they are called homogeneous (Mill, 1974). Mill’s distinction between ‘ultimate’ and

'derivative' laws was also of great importance for the development of emergentist ideas. Some decades later, C. D. Broad oriented himself by Mill's distinctions and his subsequent considerations about the limits to explanation of psychophysical laws.

In the 1920s, theories of emergence began to attract greater philosophical and scientific interest. In rapid sequence the major works of British and American emergentism appeared: in 1920 Samuel Alexander's *Space, Time, and Deity*, in 1922 Roy Wood Sellars's *Evolutionary Naturalism*, in 1923 Conwy Lloyd Morgan's *Emergent Evolution*, and in 1925 Charles Dunbar Broad's *The Mind and its Place in Nature*.

Most of these philosophers' theories of emergence are reactions to the debate on the nature of life. While vitalists like Hans Driesch and Henri Bergson claimed, for the explanation of vital processes, the existence of supernatural entities such as an 'entelechy' or an *élan vital*, biological mechanists were trying to reduce all phenomena of life to physical and chemical processes without residue. Both positions seem to have implausible consequences: substance-dualistic approaches violate the principle of the causal closure of the physical domain, and it is hard to square them with evolutionary cosmologies; while mechanism does not seem to capture genuine organic and mental processes adequately. The emergentists steered a middle course. They denied both substance-dualistic and reductionist theories: they were non-reductive naturalists.

In the following decades, theories of emergence were much discussed. However, the criticism by Hempel, Oppenheim, and Nagel seemed to put an early end to emergentism, for their analysis led to an uninteresting concept of emergence as meaning nothing but: 'considering all theories we know of, we cannot explain why system *S* has property *P*' (Hempel and Oppenheim, 1948; Nagel, 1961).

With the decline of positivism, interest in metaphysical questions returned. It is the unsettled question about the nature of mental states that has helped emergentism to return to the philosophy of mind. The concept of emergence has also gained ground in such fields as self-organization, artificial life, the philosophy of science, and cognitive science.

EMERGENCE IN THE PHILOSOPHY OF MIND AND COGNITIVE SCIENCE

In different fields of philosophy and cognitive science the idea of 'emergence' has different roles.

Thus, within the philosophy of mind, and particularly within the debate about qualia, there is a need for a strong notion of emergence; while within the fields of connectionism and artificial life, weaker notions of emergence suffice.

Emergentism as Nonreductive Physicalism

Within the philosophy of mind, emergentism is the most recent form of what has been called 'nonreductive physicalism' since the 1970s: a doctrine that in one way or other has tried to establish a compromise between physicalist reductionism and various sorts of dualism. First, physicalistic functionalism was seen as a species of nonreductivism because of its violation of biconditional bridge laws of the Nagelian type by its acceptance of multiply realizable mental properties. Subsequently, psychophysical supervenience was thought to be a theory of mind that is essentially both physicalistic and nonreductive. (See **Materialism; Dualism; Functionalism; Reduction; Supervenience; Multiple Realizability**)

Careful analyses, however, particularly by Jaegwon Kim (1993, 1998), revealed that both positions fall short of being what they are supposed to be. Physicalistic functionalism turned out to be reductionistic (it guarantees reductive explanations); and psychophysical supervenience, even in its strong form, turned out to be too weak to establish any specific theory of mind at all. Since even such diverse positions on the mind-body problem as reductive type physicalism and epiphenomenalism entail psychophysical supervenience, theories of supervenience fail to guarantee nonreductivism. In fact, it is synchronic emergentism that comprises the tenets originally associated with supervenience: property covariation and the dependence of supervenient properties on their subvenient bases are captured by the third thesis (synchronic determination) of weak emergentism; irreducibility, of course, is captured by the fourth tenet which is specific to synchronic emergentism. (See **Mind-Body Problem; Epiphenomenalism**)

Since weak emergentism (like mind-body supervenience) is compatible with both reductionism and nonreductionism, strong emergentism seems to be the only adequate representative of nonreductivism in recent philosophy of mind. An interesting question, however, is whether or not synchronic emergentism really is physicalism. Some philosophers maintain that such a position should be characterized as a kind of dualism, namely property dualism. However, insofar as psychophysical

supervenience is regarded as defining minimal physicalism (Kim, 1998), synchronic emergentism can be seen as physicalism, too, and thus be treated as a genuine instance of nonreductive physicalism.

Qualia Emergentism

A case in point for the idea that nonreductive physicalism might be an adequate answer is the problem of phenomenal consciousness. Chalmers, Jackson, and Levine, among others, have argued in various ways that qualitative mental phenomena are not reducible to physical or functional states. If their arguments are sound, they imply strong emergentist positions. Most interesting and powerful seem to be Chalmers's argument for the 'hard problem' of consciousness and Levine's 'explanatory gap' argument. (See **Consciousness, Philosophical Issues about; Knowledge Argument, The; Explanatory Gap**)

According to Levine (1993) and Chalmers (1996), reductive explanations require two stages. The first stage involves the *a priori* process of working the concept of the property to be reduced 'into shape' for reduction by identifying the causal or functional role for which we are seeking the underlying mechanisms. The second stage involves the empirical work of discovering just what those underlying mechanisms are.

Since our concepts of phenomenal qualities do not seem to represent – at least in terms of their psychological contents – causal roles, a failure, in principle, of the first task seems to be unavoidable. Thus, to the extent that there is an element in our concept of qualitative character that is not captured by features of its causal role, qualia are irreducible emergent properties.

Emergence in Connectionism

Connectionism gives rise to emergentist considerations in several ways: trained networks show cognitive features such as 'rule following', 'schema formation', or 'pattern recognition', that their parts do not have. Thus, the systemic properties that a network acquires are weakly emergent. However, they are not irreducible: they are fully deducible from the network's structure, the properties of its units (their activation formulae), and the properties of their links (the distribution of weights, and the formulae for changing the weights). Thus, systemic properties of connectionist networks are not synchronically emergent.

Connectionists often make use of the word 'emergent' in its ordinary sense, sometimes

intermingled with a more technical usage. For example, Rumelhart and McClelland (1986) say that a network's high-level properties 'emerge' from low-level interactions: rules and schemata come into being by themselves without being explicitly fed into the system. However, Rumelhart and McClelland do not thereby subscribe to emergentism. They mainly try to differentiate their position from traditional representationalism, accordingly to which all rules and schemata have to be fed in explicitly. (See **Representation, Philosophical Issues about; Implicit and Explicit Representation**)

Connectionist networks develop their specific distribution of link weights (their soft structures) in a somewhat evolution-like process. Again, this is not a case of genuine emergence. Since the changes of weights are calculable exactly if we know the initial magnitudes, we should not speak of structure emergence in connectionism. On the other hand, regarding their soft structures, networks show great plasticity, compared with other objects. Chemical compounds, for example, have no freedom to change their internal structure: the diamond's property of being hard is always manifest; it does not emerge.

Emergence of Creativity

The notion of emergence is also of interest in the field of creative cognition. There we seem to face a paradox: how is it ever possible to form a truly creative idea? If we could predict it, it would be determined and not creative. If we could not in principle anticipate it, how could we produce such an idea at all? Some psychologists assume that the cognitive structures involved in creative thinking have emergent properties that could be discovered when those structures are explored, at least some of which could not have been anticipated in advance. This seems like a postulation of unpredictable cognitive features as a result of structure emergence. (See **Creativity**)

Emergentism and Artificial Life

Within the field of artificial life, the notion of emergence is central. It refers to adaptive features of artificial systems that result both from 'clever' interactions of many simple components and from couplings between agents and their environments (including other agents). However, the term 'emergence' is not used in its strong sense here, since all phenomena studied in artificial life are reductively explainable, at least in principle. Rather, emergence is associated with behavior that is not centrally

controlled and that cannot be reduced to the behavior of single components within hierarchical systems, but is seen as the result of the interactions of multiple simple components or as the outcome of the overall dynamics of the agent and its environment. Thus, the notion of emergence used in artificial life is close to that used in connectionism. (See **Artificial Life**)

ARGUMENTS FOR AND AGAINST EMERGENCE

Clearly weak emergent properties exist: indeed, one might ask why such properties should be called 'emergent' at all, and not just 'systemic'. Furthermore, since there are chaotic processes of structure formation, structure emergence exists too. Thus, what is really in question is synchronic emergence. What we need is an argument for the existence of properties that are not and will not be reductively explainable. Many natural scientists deny the existence of such properties, since they do not know of any properties that could not be reductively explained, at least in principle. Without exception, all systemic properties studied in the natural sciences are functionally construable, their functional roles are always filled by the interactions of their systems' parts, and the behavior of the parts of any system always seems to follow from their behavior in simpler systems. Therefore, some critics question whether it is useful to develop the notion of synchronic emergence at all. But, even if it should turn out that all systemic properties studied in the natural sciences are reductively explainable, it is useful to have the strong notion of synchronic emergence. More than any other notion, it can be used to clearly formulate nonreductive positions concerning the mind-body problem.

Whether or not synchronically emergent properties actually exist does not seem to depend on empirical, but rather on conceptual grounds. Among others, Broad, Levine, and Chalmers have argued forcefully that properties such as qualia are not functionally analyzable. If they are right, then phenomenal qualities may be emergent properties in the strong sense.

If mental properties such as qualia are emergent in the strong sense, then new problems arise. Some philosophers have claimed that irreducible properties necessarily exert downward causation. In the case of mental phenomena, however, this would conflict with the principle of the causal closure of the physical domain.

However, as we have seen above, properties that are irreducible for conceptual reasons do not imply

downward causation. Rather, they give rise to another objection: how can properties that escape reconstruction via their causal role play any causal role at all? The reply to this objection mainly depends on our concept of causation. If we think that supervenient causation suffices for causation, then irreducible emergent properties can be causally efficacious. If we think that supervenient causation does not suffice, then irreducible emergent properties do not seem able to play any causal role. But these are still open questions (Kim, 1998; Stephan, 1997). (See **Mental Causation**)

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Emotion

Introductory article

Paula M Niedenthal, National Centre for Scientific Research, Blaise Pascal University, Clermont-Ferrand, France

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Emotions are sets of processes involved in an organism's response to significant, goal-relevant life events. Such processes include expressive behavior, cognitive appraisals, physiological arousal, action tendencies and subjective feelings.

attention, perception, categorization, memory and judgment.

INTRODUCTION

It is difficult to imagine life without emotions. We would feel no joy at successfully accomplishing a task, no sadness at failing an examination, no anger when we witnessed displays of prejudice and discrimination. We would not feel ashamed upon insulting another individual in social interaction. Nevertheless, emotion as a field of study remained firmly ensconced in the realms of philosophy and literature for many centuries. Now of central interest to psychology, the cognitive sciences and the neurosciences, emotion is finally also a topic of empirical investigation. Neuropsychological and psychological investigation shows that it is indeed hard to imagine life without emotions, because emotions are essential for human functioning. Social interaction, decision-making and judgment would be very poor without the capacity to experience emotion. Normal and pathological emotion states are determined and controlled by almost all of the systems of the human body, and emotional states in turn influence the cognitive functions of

EMOTIONS AS MULTICOMPONENT PROCESSES

A precise definition of emotion eludes scientists. This is because no single event or process constitutes an emotion. Emotions are sets of processes that involve different components including subjective feelings, but also expressive motor action, cognitive appraisals, physiological arousal, and tendencies to take particular actions. If you see a bear in the forest, a favorite example of the nineteenth-century psychologist William James, you might experience strong physiological arousal, have an urge to run, open your eyes and mouth wide, and feel something that you label as fear. In this example the components are quite coherent and conform to a common emotional experience. However, the different components of emotion can be decoupled. In different situations and across different cultures, social norms influence the expression and experience of emotion. For example, an adult in an industrialized Western country might feel like laughing at a funeral if a funny joke about a priest or a rabbi suddenly comes to mind; however, the person would probably suppress any laughter, avoid smiling, and display some