

Emergence: Contemporary Readings in Philosophy and Science

edited by Mark A. Bedau and Paul Humphreys

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Introduction

Emergence relates to phenomena that arise from and depend on some more basic phenomena yet are simultaneously autonomous from that base. The topic of emergence is fascinating and controversial in part because emergence seems to be widespread and yet the very idea of emergence seems opaque, and perhaps even incoherent. The topic has special urgency today because of the burgeoning attention to emergence in contemporary philosophy and science.

This book examines how emergence is treated in contemporary philosophy and science, and one of our goals is to facilitate informed discussions between these communities. Less insular discussions should clarify what the main categories of emergence are thought to be today, and how well they apply to the paradigm cases considered in contemporary philosophy and science. We hope that the eventual outcome will be an understanding of emergence that is both philosophically rigorous and useful in empirical science.

This general introduction to the book gives some examples of apparent emergent phenomena, calls attention to a few methodological subtleties, and then highlights some central open questions about emergence that the chapters in this book collectively address. The first section covers contemporary philosophical perspectives on emergence. Part II covers today's scientific perspectives on emergence. The last group of chapters collects contextual and background material from both philosophy and science. Each section's introductory essay discusses the chapters' unifying themes and issues.

One of the best ways to get a feel for emergence is to consider widely cited core examples of apparent emergent phenomena. The examples involve a surprising variety of cases. One group concerns certain properties of physical systems. For example, the liquidity and transparency of water sometimes are said to emerge from the properties of oxygen and hydrogen in structured collections of water molecules. As another example, if a magnet (specifically a ferromagnet) is heated gradually, it abruptly loses its magnetism at a specific temperature—the Curie point. This is an example of physical phase transitions, which often are viewed as key examples of emergence. A third

example involves the shape of a sand pile. As grains of sand are added successively to the top of the pile, the pile forms a conical shape with a characteristic slope, and successive small and large avalanches of sand play an important role in preserving that shape. The characteristic sand pile slope is said to emerge from the interactions among the grains of sand and gravity.

Life itself is one of the most common sources of examples of apparent emergence. One simple case is the relationship between a living organism and the molecules that constitute it at a given moment. In some sense the organism is just those molecules, but those same molecules would not constitute an organism if they were rearranged in any of a wide variety of ways, so the living organism seems to emerge from the molecules. Furthermore, developmental processes of individual organisms are said to involve the emergence of more mature morphology. A multicellular frog embryo emerges from a single-celled zygote, a tadpole emerges from this embryo, and eventually a frog emerges from the tadpole. In addition, evolutionary processes shaping biological lineages also are said to involve emergence. A complex, highly differentiated biosphere has emerged over billions of years from what was originally a vastly simpler and much more uniform array of early life forms. The mind is a rich source of potential examples of emergence. Our mental lives consist of an autonomous, coherent flow of mental states (beliefs, desires, memories, fears, hopes, etc.). These, we presume, somehow emerge out of the swarm of biochemical and electrical activity involving our neurons and central nervous system.

A final group of examples concerns the collective behavior of human agents. The origin and spread of a teenage fad, such as the sudden popularity of a particular hairstyle, can be represented formally in ways similar to a physical phase transition, and so seem to involve emergence. Such phenomena often informally are said to exhibit “tipping points.” Another kind of case is demonstrated in a massive traffic jam spontaneously emerging from the motions of individual cars controlled by individual human agents as the density of cars on the highway passes a critical threshold. It is interesting to speculate about whether the mechanisms behind such phenomena are essentially the same as those behind certain purely physical phenomena, such as the jamming of granular media in constricted channels.

The chapters in this book are full of many other examples of apparent emergent phenomena. These examples can serve as useful guides against which to test an account of emergence. However, testing accounts with these examples is not always simple. Everything else being equal, it would count in favor of a theory of emergence if it could explain how all these examples do involve emergence. But there is no guarantee that the best theory will classify all these examples as genuine cases of emergence. When we finally understand what emergence truly is, we might see that many of the examples are only apparent cases of emergence. Indeed, one of the hotly contested issues is whether there are *any* genuine examples of emergence.

Identifying the genuine examples of emergence is possible only given an appropriate definition of emergence, but as the chapters in this book amply illustrate, the proper characterization of emergence still is contested. Finding appropriate definitions or theories of emergence with indisputable instances has obvious consequences for the scientific legitimacy of emergence. One of the most important differences between contemporary accounts of emergence and their precedents is that the earlier accounts quickly became metascientific because the examples used to illustrate emergence tended to be phenomena such as life that at the time were well beyond the realm of serious scientific understanding. Nowadays, we know much more about complex phenomena like life, so many of the plausible candidates for emergence now are well understood by science. Any adequate definition of emergence would take these into account in the sense that at least some of these examples should be included under the definition in a clear naturalistic fashion. Fashioning such a definition, however, involves an inescapable back-and-forth process, hinted at above. Definitions and theories may be sharpened to account for more examples, but also candidate examples may be abandoned because they fail to fit an otherwise convincing theory. In a similar way, we must be prepared to abandon some of our preconceptions and background beliefs about emergence if a persuasive and detailed theory of emergence calls them into question.

One small caveat is needed here. Hunting for emergence is an exciting sport, but the claim that something is emergent should be made with care and supported with persuasive evidence. Indeed, some of the articles reprinted in this collection ultimately are quite skeptical about emergence and argue that emergent phenomena, if they exist at all, are likely to be uncommon. One should not lightly abandon nonemergent, reductionist approaches that have been successful in many areas of science and philosophy. At the same time, one also should note that many of the conceptions of emergence developed and defended in this book are consistent with many common forms of reductionism.

The study of emergence is still in its infancy and currently is in a state of considerable flux, so a large number of important questions still lack clear answers. Surveying those questions is one of the best ways to comprehend the nature and scope of the contemporary philosophical and scientific debate about emergence. Grouped together here are some of the interconnected questions about emergence that are particularly pressing, with no pretense that the list is complete.

1. How should emergence be defined? A number of leading ideas appear in different definitions of emergence, including irreducibility, unpredictability, conceptual novelty, ontological novelty, and supervenience. Some definitions combine a number of these ideas. We should not presume that only one type of emergence exists and needs definition. Instead, different kinds of emergence may exist, so different that they fall under no unified account. Emergent phenomena might well come in fundamentally

different types that should be distinguished along various dimensions. A further issue is whether emergence should be defined only relative to a theory, or a level of analysis, or a system decomposition. The controversy about how to define emergence is exacerbated by the casual way that terms such as “emergence” and “emergent” often are used. At least two separate issues are important here: controversies about the proper definition of emergence, and controversies about the proper way to test and evaluate definitions of emergence. Perhaps the proper definition of emergence can be attained only in the context of a comprehensive theory of emergence, resulting in a definition that is implicit rather than explicit. Another possibility is that the concept of emergence is best characterized by a cluster of features such as novelty, holism, irreducibility, and so on, but that the features drawn from the cluster differ from case to case, and that what counts as novel, for example, differs with different subject matters. Given the high level of uncertainty about how to properly characterize what emergence is, it should be no surprise that many other fundamental questions remain unanswered.

2. What ontological categories of entities can be emergent: properties, substances, processes, phenomena, patterns, laws, or something else? Within the literature on emergence, different authors say that different categories of entities are emergent. There should be no presumption that these different categories are mutually exclusive; it could be that emergence applies to many or even all of them. But it is important to be clear about which of these candidates is under discussion in any given context. Emergence in one of these categories sometimes entails emergence in another, but that is not always the case. For example, it seems clear that emergent laws can link nonemergent properties, whereas a genuinely new emergent property would seem to require new, and probably emergent, laws.

3. What is the scope of actual emergent phenomena? This question partly concerns which aspects of the world can be characterized as emergent. The examples of apparent emergence above show the prevalence of the claim that emergence captures something distinctive about consciousness and about other aspects of the mind. Another common idea is that emergence is one of the hallmarks of life. But examples of apparent emergent phenomena also include the behavior of human social organizations and of nonhuman social organizations. In addition, certain kinds of physical aggregations are commonly cited as examples of emergent phenomena. The question of the scope of emergence also concerns the question of how widespread emergence is. For example, many contemporary philosophers think that emergence is a rare and special quality found only in extremely distinctive settings, such as human consciousness. Others think that emergence is quite common and ordinary, applying to a myriad of complex systems found in nature. For those who think that nothing is truly emergent, the question still arises whether this state of affairs is simply an accident or whether the very idea of emergence is incoherent.

4. Is emergence an objective feature of the world, or is it merely in the eye of the beholder? Does emergence characterize only models or descriptions or theories of nature, or does it apply also to nature itself? Is emergence only a function of how something is described or viewed or explained? Question 4 is connected to the issue of whether emergence is defined only relative to a theory or model or representation. Some maintain that emergent phenomena are real features of the world, while others maintain that emergence is merely a result of our imposing certain kinds of representation on the world, or a result of our limited abilities to comprehend correctly what the world is like. Candidates for emergent phenomena in the real world include the physical process called *spontaneous symmetry breaking*. A simple case of this can occur when a uniform body of liquid has a flat surface. If the bottom of the liquid is heated uniformly and sufficiently, the fluid breaks up into a field of different convection cells in which the liquid continually cycles between the bottom and top of the fluid. An example of emergence that might reflect merely our limited ability to understand the world is the stable patterns that emerge in John Conway's Game of Life. If the Game of Life is initialized with the now-famous R-pentomino pattern of 5 active cells, it takes 1103 iterations of the rules to arrive at a final stable pattern. The discovery of this final pattern occurred only after the game was implemented on a computer; exploring the rules of the game "by hand" was insufficient.

5. Should emergence be viewed as static and synchronic, or as dynamic and diachronic, or are both possible? This is a major division between accounts of emergence. In synchronic emergence, the emergent feature is simultaneously present with the basal features from which it emerges. By contrast, in diachronic emergence, the base precedes the emergent phenomenon which develops over time from them. If mental phenomena emerge from neural phenomena, this is generally thought to be synchronic, there being no time gap between a recollection of one's fifteenth birthday and the brain state that gives rise to the memory. The development of the traffic jam over time is a good candidate for a diachronically emergent pattern. Discussions in the philosophical literature usually focus on synchronic emergence, while those in the scientific literature often concern diachronic emergence. A further question about diachronic emergence is whether and how it applies to both discrete and continuous systems.

6. Does emergence imply or require the existence of new levels of phenomena? A great many discussions of emergence use the terminology *levels*, with the levels having three characteristic features. First, the hierarchy of levels has no precisely defined order, but instead is determined implicitly by the organizational complexity of objects. These levels tend to coincide with the domains of individual sciences. Second, each level is assumed to contain at least one kind of object and one kind of property that is not found below that level. Third, at each level kinds exist that have novel causal powers that emerge from the organizational structure of material components. Pressing

questions thus include whether this framework of levels corresponds to an objective hierarchy in the world, whether appeal to these levels is useful or misleading, and whether there are clear criteria to identify the levels.

7. In what ways are emergent phenomena autonomous from their emergent bases? Emergent phenomena are Janus faced; they depend on more basic phenomena and yet are autonomous from that base. Therefore, if emergence is to be coherent, it must involve different senses of dependence and independence. A number of different kinds of autonomy have been discussed in the literature, including the ideas that emergent phenomena are irreducible to their bases, inexplicable from them, unpredictable from them, supervenient on them, and multiply realizable in them. In addition, emergent phenomena sometimes are thought to involve the introduction of novel concepts or properties, and functionally characterized properties sometimes are thought to be especially associated with emergent phenomena. Another important question about the autonomy of emergent phenomena is whether that autonomy is merely epistemological or whether it has ontological consequences. An extreme version of the merely epistemological interpretation of emergence holds that emergence is simply a sign of our ignorance. One final issue about the autonomy of emergent phenomena concerns whether emergence necessarily involves novel causal powers, especially powers that produce “downward causation,” in which emergent phenomena have novel effects on their own emergence base. One of the questions in this context is what kind of downward causation is involved, for the coherence of downward causation is debatable.

The chapters in this book provide a variety of perspectives on possible ways to construct answers to these questions. Many of the questions are discussed at greater length in the introductions to the book’s three sections, where the central themes treated in the individual chapters are highlighted.

Emergence seems to arise in many of the most interesting complexities in the world we inhabit, but it is simultaneously palpable and confusing, as the questions above reflect. New advances in contemporary philosophy and science, many of which this book collects, now are converging to enable new progress on these questions, so emergence is a topic ripe for new clarifications, unifications, and other creative conclusions. This book’s chapters illuminate these questions from many perspectives to help readers with framing their own answers.