Summary

This monograph focuses critically on the foremost recent discussions on emergence, its tradition, and its various conceptual landscapes. The book supports the belief that classical reductionism has its limits and that the strong reductionist programme is flawed. Reductionism can be methodologically successful only as a top-down, explanatory strategy, a reductionism "in principle", whereas the bottom-up, predictive, constructionist approach is more problematic and cannot arrive at the observed variability of the world's complexities. This book illustrates the principle of emergence and its universal role across many different areas of complexity, pointing to its naturalism, which allows for scientific and philosophical investigation.

The main aim is to recognize emergence as a universal principle, in the same sense as the principle of evolution is universal, setting out its ontological criteria and their role in the proposed hierarchical emergent ontology (HEO). The work focuses mainly on the discussion of ontological emergence, while in accordance with the mainstream view, the epistemological and conceptual forms of emergence are considered secondary. The fulfilment of this task presupposes a detailed analysis of the main ontological concepts of emergence, especially with regard to specific examples within the natural sciences. Thus, working conclusions are not primarily measured with respect to "high-level" questions of the relationship between mind and brain, but on the contrary, with respect to the universality of the principle of emergence in "low-level" examples from physics, chemistry, cellular automata, etc.

The universal principle of emergence (UPE) is partly built upon new analyses and partly upon a synthesis of traditional viable aspects of emergence within one universal structure. Traditional discussions of emergence have tended to be corralled by the distinction between strong and weak emergence, generally accepting the commitment to supervenience as a synchronic relationship between basal entities and emergent whole. Recent discussion veers away from supervenient emergence and presents diachronic emergence as the only solution

to traditional causality problems. These recent approaches emphasize only the diachronic aspect and maintain that there is no way of creating an acceptable framework which unifies synchronicity and diachronicity. This monograph does not share these tendencies, and in its formulation of UPE, it benefits from the following four crucial distinctions: 1) a distinction between weak and strong emergence; 2) a distinction between emergence and supervenience; 3) a distinction between synchronicity and diachronicity; 4) a distinction between dependence and autonomy.

The detailed work and analyses of many emergentists and their critics have enabled the formulation of alternative syntheses for each distinction. In brief, this means: 1) the distinction between weak and strong emergence is only apparent; they are instead two instantiations of the one UPE; 2) supervenience is not an exclusively reductive relationship but is, in fact, predominantly non-reductive and as such demonstrates the meaning of "the whole is more than the sum of its parts"; 3) there is an ontological necessity for the unification of the synchronic and diachronic aspects of emergence so that emergence can be understood as a natural process of organization and complexity in many natural phenomena; 4) UPE has to conceptually explain the general form of interconnections between the base and the emergent considering the standard commitments of the emergentist view of the world. On the one hand, emergentists must accept the determination of an emergent by its base and, on the other hand, they want to prove the causal autonomy of the emergent. Regarding this, UPE strengthens the unity of the emergent entity, which is maintained in the dynamic persistence of its autonomy.

Likewise, this book does not share in the tendency to reject hierarchical ontology in solving the traditional problems of top-down causality, overdetermination, etc., instead showing in what a true hierarchy is based without reviving the naive and oft-criticized hierarchy of levels of the special sciences. Upon these foundations are built the new concepts of UPE and HEO. Both are not only developed tightly-bound to particular cases from the special sciences and their critical discussions but also the utility and practical applicability of the proposed HEO and UPE are analysed and tested in three

different fields of science: cellular automata; quantum Hall effects; and the neural network of the mind. It is demonstrated that in these three different fields of phenomena—the algorithmic of automata, quantum physical phenomena, and biological neural networks—the operation of the principle of emergence can be identified. The tests applied herein prove that similar criteria for emergence, evaluated in three different domains and different processes, can be unified by the establishment of one universal principle. The hierarchical nature of these phenomena is also proven and tested via their number of degrees of freedom, which serves as an objective criterion of hierarchy. In this way, the resulting metaphysics of HEO plays a fundamental role in unifying science, a result which is impossible via classical reductionism.

Chapter 1: Reductionism and holism

I discuss the reductionism/holism dilemma as a metaphysical view of the world which impacts the different approaches to the explanation of complex and structured entities. Haunting such discussions is the notion that the problem with reductionism lies in its pretension to provide complete explanations from nothing but the fundamental elements of the world. Reductionism presupposes that a successful top-down explanation means that the reverse path has to be similarly fruitful. Although I do not deny that reductionism as a metaphysical concept and scientific methodology is a successful approach, employed in many scientific explanations and predictions, I unequivocally incline to the view that there are boundaries that cannot be crossed. I disagree that the "Battle of the Ages" between reductionism and emergentism only begins or is ongoing (Laughlin 2005, Gillett 2016). It seems to me that this battle was won long ago. Reductionism does a lot when it knows where to proceed, yet is confused over when to advance without additional information on how things really are in nature. Thus, the recipe for deriving the universe from first principles always needs more information than those first principles provide. In this sense, reductionism can always fight under the victorious banner of holism.

I prefer to prove this background presupposition on some suitable examples from the natural sciences, where reductionism and emergentism can compete. One of these examples is the prevailing belief that chemistry can be reduced to physics via quantum mechanics. Recently many competent authors have shown chemistry not to be fully reducible to physics and that the prevailing belief in its reducibility arose from the overly optimistic approach of some physicists and philosophers towards the early results of quantum theory. Consequently, it is argued, if chemistry and other higher special sciences are irreducible and deal with emergent entities, then there is a question regarding the autonomy and top-down causality of such entities.

To express the range of possible strategies both pro and con top-down causality, I present Kim's standard arguments from analytical metaphysics against the possibility of emergent causal powers, i.e., the principle of downward causation and the exclusion of causality. In favour of top-down causation, we consider the famous rolling wheel argument (Sperry and Searle) and then discuss these arguments' possible results in the broader context of mental causation in the philosophy of mind (Davidson, Crane). The ongoing dispute between reductionists and emergentists I want to present and test in suitable natural science examples. There are excellent opportunities to test the consequences of the reductionist and holistic conceptions on the QMC and PDFs models of the atomic nucleus and theoretical–experimental pentaquark research. Ultimately, the limits of classical reductionism and the holistic approach's legitimacy are laid out in a general conclusion about the possibility of the derivation of our universe's current form from the few initial principles. This then leaves open a route to UPE.

Chapter 2: Towards a universal principle of emergence (UPE)

My route to UPE has to start with the discussion of basic concepts and commitments. Because I take emergence as a primarily ontological concept, the other possibilities are of secondary relevance. Many authors want to reflect upon all kinds of emergence at once, and they discover that emergence is so multifarious it is impossible to create

a single universal frame for them all. They usually end up with pessimistic conclusions about the philosophical aims of such a task. My conviction is different. It is not philosophically acceptable "not to see the wood for the trees" but it is, indeed, philosophically obligatory to open up a new, unifying perspective to shine a bright light on hitherto tangled skeins. To this end, I answer some key questions. Can a unified conception of emergence be achieved? What is the difference between a universal principle of evolution and the principle of emergence? What is ontological and epistemological emergence? Is it reasonable to divide emergence into several types, such as inferential, conceptual, etc., and which methodological conclusions follow?

Clarifying these issues, I seek to remove possible misunderstandings via further steps in shaping the concept of UPE. The journey towards UPE begins with the detailed analysis of different conceptions of ontological emergence, covering Searle's emergence1 and emergence2; different supervenient approaches to emergence (Kim, Van Cleve, O'Connor, McLaughlin, Crane); non-supervenient approaches (Humphreys); and the influential conceptions of "weak" and "strong" emergence (Bedau, Chalmers, Gillett). Searle and McLaughlin, similar to Bedau, fear emergent properties which are fully autonomous irreducible causal powers: they assume that a disruption of causal fundamentalism, or causal transitivity, is unacceptable. Ontological emergence in the "strong" sense, i.e., as the existence of irreducible ontological entities or properties (Van Cleve, O'Connor), is sometimes compared to mythical vital properties (e.g. Cunningham) and considered a scientifically unacceptable form of emergence (Bedau, Kim).

Thus it is questionable why we have a convincing belief in a "downward" determination from wholes to their parts which evidently contradicts the logical principles attributed to connections between causes and consequences. Similarly, we feel the autonomy of the whole yet cannot reject the work done by components for the existence of the whole. How can we escape this standard emergentist puzzle of opposing commitments? Usually, the best approach is to adjust or abandon some traditional presuppositions. The results which flow from such branching possibilities form the subject matter of my ensuing analysis.

Chapter 3: Emergence in physical systems

Here I analyse ontological emergence as it branches out into the various possibilities provided by the adjustment of the substance-accidence model of an entity and its properties and the rejection of the causal character of determination of and by basal entities and wholes. Both such new approaches and their combination provide fruitful possibilities for the conceptualization of emergent relations.

I begin with paradigmatic examples from condensed matter physics and phase transitions because these physical processes are often analysed from the emergentist point of view. Phenomena such as quasiparticles and other quantum effects have inspired some conceptions of emergence. Initially, the importance of such phenomena was recognized by condensed matter physicists (Anderson, Laughlin, Pines) and later reflected by philosophers (Humphreys, Morrison, Falkenburg, Lederer, Guay and Sartenaer, Ellis, etc.). They provide strong motivation for "fusion emergence" (Humphreys), "dynamical emergence" (e.g., Kronz and Tiehen) and "transformational emergence" (Humphreys, Guay and Sartenaer). Such dynamical conceptions are characterised by strengthening a diachronic aspect of emergence at the expense of its synchronic (supervenient) relations. Even if the detailed elaborations of fusion and transformation emergence seem to be tightly connected with quantum examples I am not convinced that their interpretation is consistent with quantum effects. I show that there are quantum counterexamples in which we need the existence of parts to continue during the existence of the whole.

For this reason, I support critical concerns about the basal loss features of structural properties (Wong). Furthermore, many macro-phenomena are not dependent on the kinds of their constituents because emergent phenomena are independent of any specific configuration of their microphysical base. Thus fusion emergentism would have to presuppose that the fusion of different collectives of particles leads to the same macro-phenomena. If parts do not exist in the whole, then fusion emergence needs some unique mechanism to restore the original particles. Even though it is reasonable to investigate approaches to emergence solely on the basis of the emergence of

properties and the part/whole relation, my conclusion is that radical fusion emergence has unacceptable consequences.

More likely to further my end is the evidence of strong emergence examples in simple physical systems, which prove that weak emergence is insufficient in such cases and that the state of the system is determined not only by their parts but via links to their environment and to globally restrictive constraints (Bar-Yam). It is surprising that this understandable aspect is generally underestimated in many emergence concepts and that all attention is focused on the internal ties between base and emergent. I consider global constraints to be one of the essential ingredients of the proposed emergent ontology.

The other branch of possibilities lies in how basal entities determine their wholes (or vice versa) because these are vertical synchronic relations and it is questionable how they can be causal when causality as a relation between cause and consequence has extension in time and is paradigmatically diachronic. Recently, one possibility has been offered in "mutualism" (Gillett), which takes the synchronic relationship as "non-productive mutual determination" and "non-productive mutual interdependence" between the whole and its components. Mutualism is generally a sound way forward but is excessively impacted by a fear of the whole's autonomy and admits productive (horizontal) powers only to its components. Thus I am not entirely convinced that one can prove emergentism without causal autonomy and the causal powers of emergent entities.

Similarly, the computational and combinatorial approaches to emergence (e.g. Hunemann) reject approaches oriented solely towards properties resulting from emergence. These tendencies also support new ideas about the dynamical character of emergence and its processuality yet in addition jab a finger at the one key question: how strong is strong emergence and how weak is weak emergence? I show that the distinction between weak and strong emergence is only apparent, they being, in reality, only two instantiations of the one UPE.

Finally, I am obliged to save scientific emergence from a strong attack by agent-based modelling proponents (e.g. Epstein). Generativists are convinced that when modelling complex phenomena based on actors, systemic properties only depend upon the full specifica-

tion of actors or entities participating in their formation. They generally remain strongly opposed to emergence as something unscientific and try to prove that agent-based modelling and classical emergentism are incompatible. I am required to show that this attack is unfounded and fails in its central presupposition, i.e., that the whole can be generated from a correct description of the agents involved. My conclusion is that even the best description of an actor or entity can never provide the result of the whole, whilst a good-enough description of the whole must contain that which determines the actor or entity. I conclude that the existence of a universal emergent principle has not been disproven and remains as a mechanism through which new entities, qualities and relations are formed on manifold and relatively independent contextual levels of a hierarchized reality.

Chapter 4: Hierarchical emergent ontology (HEO)

I begin with two short analyses, the non-reductivist concept of supervenience and the synthesis of the synchronic and diachronic aspects of emergence, this being an extended version of my article (Havlík 2020). Both are essential prerequisites to the formulation of UPE.

The concept of supervenience as an exclusively reductive relation is rejected, with proof provided that supervenience is predominantly a non-reductive relationship. This is essential because non-reductive supervenience in its original Moore and Hare flavour can show how "the whole is more than the sum of its parts". Supervenience is a merely functional relation, not an alternative to emergence, but when I reject fusion emergentism and accept a commitment that "parts exist inside the whole" then there is still a legitimate question about the whole's supervenience on its parts. If supervenience is a reductive relation, as Kim tried to prove, then it is impossible to show that the whole can be more than the sum of its parts. However, I show that the original nonreductive sense of supervenience is similar to cases in complex systems where parts in complex correlated interactions produce emergents described by non-reductive supervenience.

The second prerequisite is the solution of the synchronic/dia-

chronic dilemma. I reject those unilateral solutions which favour only synchronic or diachronic concepts because they are inconsistent with emergent natural processes. I suggest the necessity of unifying synchronic and diachronic concepts of emergence because these unified features are recognizable in many natural phenomena and organizational processes. I analyse pattern emergence in cellular automata as a suitable example for detailed analysis of the synchronic and diachronic approaches. I accept the standard commitments of type and token emergence and specify what is emergent from the computational point of view. I demonstrate that the developmental history of a pattern alone is insufficient as a decisive criterion for emergence and that we need more criteria for evaluating a pattern as an emergent entity. Many approaches concentrate on a pattern's appearance as an essential aspect of its emergent nature but I seek to prove that their persistence is equally crucial. The "appearance" and "persistence" of patterns are both integral to an understanding of their autonomy and identity. These mutually conditioned aspects allow me to show how the whole's autonomy persists in time under its parts' persisting contribution. I prove that this process is a unification of synchronic slices in diachronic extension. It is only a cellular automaton model of emergent autonomy but its general features are similar to those of natural emergent processes.

These two essential prerequisites need be fulfilled before the formulation of UPE. Having done so, I discuss the roles and taxonomies of the available criteria for emergence. My criteria cannot be entirely new but I can distinguish them from others by showing why I reject some standard options and prefer others. What renders my system of criteria unique is that every criterion is offered in juxtaposition to its antithesis and tightly bound to the ensuing metaphysical concept of HEO.

Crucial to my concept is the hierarchy of ontological levels. The hierarchical view of nature has recently come under heavy criticism with alternatives having been provided, such as domains or scales. I do not deny that the naive and oft-criticized hierarchy of levels connected with the special sciences' complexity is too simplified and cannot appropriately express genuine natural hierarchies. However,

this is no reason to reject such a crucial ontological concept, all the less so if this is motivated by a vision of solving the traditional problems of causality (top-down causality, over-determination, etc.). I seek to show that reality is a multi-level ontology, and that the levels exist not in an absolute sense, such as layers resting on top of one another, but that they can sprout from every fertile spot and boundlessly increase with the growth in degrees of freedom at every level. These multi-hierarchical complexities I call the "multi-level inverse pyramidal structure".

Consequently, the presuppositions to UPE are embedded in this HEO. It may seem strange not to formally define such a universal principle. However, I believe it is sufficiently conceptually described by the presuppositions, a formal shape not being something which would add any new information. However, I do not assume that the metaphysical concept might seriously be accepted without thoroughly testing its ability to do explanatory or predictive work in science and this is the task of the rest of the book, engaging in a detailed discussion of different areas of the multi-hierarchical level of complex entities.

The utility and practicality of the proposed HEO and UPE, in both explanation and prediction, are assessed and tested in three different fields: cellular automata, quantum Hall effects, and the neural network of the mind. These three areas are often employed to provide examples of emergence but my interest is more profound than simply illustrating suitable exemplars, instead going into details hitherto unanalysed and connecting the metaphysical concept with recent research on cellular automata, composite fermion theory, and the neurological analysis of the mind. These are not only examples but territories where UPE can be developed further.

These analyses demonstrate firstly that there is a recognizable effect of the principle of emergence even in such disparate phenomena as the algorithmics of automata, physical phenomena, and biological neural networks; and secondly, that similar emergence criteria are evaluated across the three different domains, with different processes being unified by the realization of one universal principle. Furthermore, the multi-hierarchical nature of such phenomena is proven,

having been tested via the number of degrees of freedom, which serves as an objective criterion for the existence of hierarchy.

I believe that such a metaphysical concept of UPE in the multilevel HEO will have an explanatory and predictive impact upon science and scientific metaphysics.