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INTRODUCTION

"In the beginning was simplicity", wrote Richard Dawkins in *The Selfish Gene*. The implication of this starting point, though not necessarily believed to be true by Dawkins, seems to be that, ever since, things have become more and more complex. Indeed, when asked about the evolution of life on earth, many people would intuitively state that natural selection produces increasingly complex organisms, populations and ecosystems. When pressed, one will refer to the transition from unicellular to multicellular life; to the specialization and differentiation of cell types; or, more likely, to the evolution of nervous systems and brains, which are capable of gathering and processing information. Concerning the evolution of human societies, language and human cultural products like technology, most people assume the same trend towards growing complexity. The question why the rise of complexity is taken for granted by so many, is a tough one. One of the answers might be that it resonates strongly with the belief, deeply ingrained in western culture since the Renaissance, that the history of life, civilization and culture is somehow progressive. Progress and increasing complexity however, are different things. Depending on the criteria one is willing to use, progress might mean a reduction of complexity, and a rise of complexity can signify a decline of progress. To study the phenomenon of complexity in itself, one should separate it from other issues like progress, as was presumably already understood by Charles Darwin.

In a certain sense, it can be argued that complexity has been studied for over two thousand years. We live in a complex cosmos, a complex world, a complex society. Greek philosophers like Democritus, Plato and Aristotle tried to reduce the complexity by looking for building blocks, essential principles or universal causes. With the development of the experimental method in the seventeenth century, along with the use of mathematics, the understanding of complexity by studying it in its more simple components expanded enormously. In general, science still works in this very successful tradition. Among many other discoveries, the twentieth century owes relativity theory, quantum theory and molecular biology to it. Nevertheless, in the last three or two decades more and more people have argued that, despite all the impressive scientific achievements, something is lacking. Science has, the argument goes, discovered, explained and controlled many pieces of the puzzle, but has failed to put the pieces back together. Recent attempts to study the puzzle in itself crystallized into the realization of the main issue: complexity. Although many scientists, in many disciplines, were aware of the limits and difficulties of the reductionistic approach, it is only recently that science and philosophy started a serious investigation of these problems under the heading of complexity.

What is complexity anyway? The meaning of the concept seems to be a strange intermingle between accuracy and vagueness, like is the case with, for instance, 'time', 'life' and 'consciousness' (one is reminded of Louis Armstrong, who allegedly answered someone who wanted a definition of 'jazz': "Man, if you gotta ask you'll never know"). It has always been the good custom of science and philosophy to search for explanations about what may seem to be obvious, or, more precisely, to question the supposedly obvious. If anything, research has shown that complexity is far from obvious. Finding an answer to questions like: 'what is complexity'; 'how can we measure it'; 'is it true that the evolution of life shows a trend towards increasing complexity' and 'what does it mean when we say that something evolves from simple to complex' has proven to be, well, rather complex. During the two last decades, these and other questions have been studied within a framework that is now commonly called 'the science(s) of complexity'. Complexity is a property of certain systems, and the main quality of these systems is the ability to evolve and adapt to a changing environment. The basic units that compose the systems can be atoms, molecules, neurons, organisms, bits within a computer, people, species, and so on. The systems itself are, e.g., brains, organisms, cities, the internet, firms, ecosystems, immune systems or flocks of birds. The interactions of the individual units result in certain behaviour and properties of the systems, often called 'emergent', because they can only be described at higher levels than those of the basic units. Understanding the phenomenon of emergence has become one of the central issues in the study of complexity. John H. Holland's article in this issue clarifies the problems concerning emergence. Holland, one of the founding fathers of the sciences of complexity and the inventor of genetic algorithms, makes clear that the construction of computer-based models is essential to grasp emergence. He explains the role of models in science, while making comparisons with games and the rules that govern them. Emergent phenomena, according to Holland, are regular phenomena, which makes them in principle open to scientific understanding. Holland's approach, on the one hand, is situated in the reductionistic scientific tradition, but he accentuates, on the other hand, the importance of the *interactions* between the parts. This makes all the difference: interactions between building blocks lead to novelty on higher levels; which in itself creates novelty on more higher levels, and so on. Building blocks, or agents, organize themselves in a hierarchical manner. On each level behaviour emerges which is beyond the capacities of individual agents. Hence, according to Holland, "emergence is a matter of macro-laws, the obverse of reduction". In time, science should be able to discover some of the "laws of emergence".

Claus Emmeche discusses the various meanings and roles of the concept and study of complexity. He distinguishes between descriptive complexity; ontological complexity; the field of complex dynamic, or adaptive, systems; and the possible role the study of complexity has to offer in integrating several scientific disciplines and the concept of complexity as used in the social sciences. Subsequently, he draws attention to the metaphysical assumptions underpinning science in general and the sciences of complexity in particular, and puts the latter in a historical perspective. According to Emmeche, biology has studied complexity for centuries, culminating in the twentieth century in molecular biology and the theory of self-reproducing automata, two cornerstones of the contemporary study of complexity. Attempts to measure or quantify complexity, Emmeche explains, prove the peculiar difficulties surrounding the concept of complexity when not properly specified. He refines his analysis of the several descriptions and meanings of complexity, and, like John Holland, though in a more skeptical manner, points out the importance of computers, models and metaphors in the study of complexity.

As stated above, it is widely assumed that the evolution of any living language, like the evolution of life, goes from simple to complex. Claus Emmeche already pointed out the theoretical difficulties one encounters when trying to quantify complexity. Charles Blinderman exemplifies these problems by looking into the development of English. He notes the increase in vocabulary, but explains why this is no sign of increasing complexity. Nor can one consider the development of dialects to be a practicable standard to measure complexity. If one analyses grammar and syntax, there are even reasons to believe English evolved towards simplicity. In sum, one can argue there are no accurate criteria to quantify either the rise or decline in complexity of the English language.

A similar point is made by Daniel McShea, one of the few contemporary scientists who thoroughly investigate the empirical data we have on the problem of complexity in the history of life. Like Claus Emmeche, McShea lists several possible meanings of complexity, after which he suggests some feasible operational ways to measure a rise or decline in complexity, as understood in relation to the evolution of life. In investigating several studies, McShea takes the skeptical stance, i.e. he takes a neutral position with respect to the question whether or not a trend in complexity occurred; he accentuates the role of empirical data in the debates on complexity; he ignores the existing – theoretical – consensus on complexity and stresses the importance of studying organisms, structures, and so on, in an unbiased way. As a sceptic, McShea concentrates on the number of different types of parts or interactions a system has to measure complexity. His overview of relevant studies leads to the conclusion that, at this moment, we have to remain agnostic on the problem of possible trends towards complexity in the evolution of life.

If we think about contemporary high technology like computers, particle accelerators and satellites, and compare such artifacts with the first technological inventions of our prehistoric ancestors, it is easy to get the impression that the history of technology evolved from simple to complex. Subrata Dasgupta acknowledges the validity of this impression, but makes clear how intricate the scientific analysis of the relationship between technology and complexity is. He makes a clarifying distinction between systemic and epistemic complexity. The first form emphasizes the number and the interactions between the parts of a (technological) system; the latter concentrates on the richness of the knowledge that is embedded in (technological) artifacts. Dasgupta's thesis is that the epistemic component is the most important aspect of the evolution of complexity, related to the history of technology and the creation and invention of new technological artifacts. On the basis of examples borrowed from the history of architecture and computer technology, he discusses the possible connections between systemic and epistemic complexity. A relationship between systemic simplicity and epistemic complexity is also possible, as is illustrated in Dasgupta's treatment of the emergence and development of Stone Age technology. From the systemic point of view, one can argue that the history of technology does not decisively evolve from simple to complex, as is shown in the case of the 'reduced instruction set computer'. However, the same example makes clear that a reduction of systemic complexity brings with it a rise in epistemic complexity. Like other authors in this issue, Dasgupta remains skeptical on the question whether the complexity of systems in general and of technological artifacts in particular can be measured. Finally, he makes clear why, in his view, the sciences of complexity are not the appropriate disciplines for the investigation of epistemic complexity. This investigation demands a historical perspective, while the sciences of complexity are ahistorical, that is, they concentrate on systemic complexity. Dasgupta argues that, in order to understand the evolution of complexity in technology, we need the emergence of a *cognitive* history of technology.

Apart from the many insightful considerations the five articles in this issue bring forward, they also seem to make clear that the phenomenon of complexity, after years of study and although much progress has been made, remains in part an evasive subject. Complexity, whatever it is, is in us and out there, but it takes different shapes in different contexts, like organisms, species, physical objects, languages and artifacts. One of the main problems seems to be the lack of appropriate criteria and methods to define and quantify complexity. This does not mean that the very 'science of complexity' is a misnomer, but it does make clear that modern philosophy, defined as the study of problems for which science has not yet developed or discovered a consensual methodology, still has an important role to play in the clarification of the many fascinating problems concerning complexity. In time, this should lead to a deeper *scientific* understanding of the problems discussed in this issue.

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