OLM 1.1. Deductive and inductive approaches in ecology

The introductory chapter of this book (TBE for short) has shown that the conceptual background of Darwin's encyclopaedic work is an explicit and logically coherent theory (Figure 1.1). This section is a brief exposition of our approach to the discipline of ecology from a theory of science aspect. TBE provides a theory-based, deductive approach attempting to integrate the results of model-based, inductive research. In this sense we follow the Darwinian tradition on modern methodological grounds.

Ernst Haeckel, who has given the name „ecology" to the discipline occupied by understanding the "economy of nature", defined it as the "scientific study of the struggle for existence" (Cooper 2003, p. 4). Likewise, Gause considered the struggle for existence as competition among individuals of the same and of different species, thereby laying down the foundations of population ecology (Gause 1934). This Darwinian idea is obviously and naturally present in the work of Lotka, Volterra and Kostizin, the heroes of the golden age of European theoretical ecology (Scudo and Ziegler 1978) as well. The North American school of population biology – whose landmark names are Evelyn Hutchinson, Robert MacArthur and Richard Levins (Cody and Diamond 1975, Vincent and Brown 2005) – and the Danish pair of authors Christiansen & Fenchel (1977) attempted unifying evolutionary genetics and ecology – which had long been spited by then – on the same Darwinian grounds. TBE is a follow-through of this thread of thought.

In spite of its potentially solid conceptual foundations provided by Darwinian theory, ecology is still in a challenging state as a scientific discipline. Two different epistemological views on the possible scientific aims and roles of theoretical work in ecology prevail: one may be called the *model-centred view*, while the other is the *theory-centred view* (del Rio 2008). According to the *model-centred* stance we may not expect universal rules to apply without exceptions to the immensely complex natural systems being studied by ecologists. Consequently, any understanding of patterns and processes in ecology is necessarily particular; each model we build can cover a specific situation or, at best, a very limited range of empirical observations. That is, lacking a universal ecological theory has been considered – either explicitly or implicitly – a necessity originating from the very nature of ecological phenomena (e.g. Peters 1991, Aarssen 1997, Weber 1999, Cooper 2003, Hansson 2003).

In contrast to the model-centered view, the *theory-centered view* of ecological research adopts the fundamental conviction on which science is based: the material world obeys a few universal rules, and these rules can be assembled into universal theories (Feynman and Leighton 1963, 1. lecture). Scientific theories are built on the simplest possible principles and considerations, from which they deduce simple, comprehensible statements that need to be

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tested against empirical facts and serve as the basis for obtaining new knowledge. Scientific rules are logically tied to each other. The structure thus constructed maintains the coherence of theoretical and empirical research. It is in this sense that the core of a scientific theory is metaphorically comparable to the function of the armature of a statue: without the armature consisting of principles and their logical ties the components of a theory could never be organized into a consistent and empirically testable system of knowledge (Figure 1.1.1). Scientific theories are judged against their potential to explain and predict empirical phenomena and to solve new problems that arise within the discipline. The more universal, the simpler and the more consistent a theory proves to be in these respects, the higher its scientific value (Thagard 1993).

Figure 1.1.1: The armature metaphor.

The logical structure of the Darwinian principles plays the same role in ecology that the armature plays in holding the statuette firm. The principles also connect the conceptual structure of ecology to the outer framework of science. This sculpture by Degas (*Arabesque over the Right Leg, Left Arm in Front*, c. 1882/1895, National Gallery of Art, Washington) can be regarded as a metaphoric representation for the notion of a constitutive theory within the framework of a general theory (Scheiner and Willig 2011).

Instead of going into detailed arguments for and against the model- and the theory-centered views, our book reflects our integrative intention: its structure and full content are based on a few rules, which constitute a logically consistent armature for ecology. Besides its deductive coherence, theory based ecology also need to be efficient in terms of explanatory breadth and simplicity. Accordingly, the statements mathematically deduced from the ecological principles must apply to, or predict, a wide range of real-world ecological phenomena; the theory provides explanatory coherence in relation to empirical facts, besides being as simple as possible (Thagard 1993, p. 62-82).

Darwin's rules of natural selection, just like Newton's laws of motion, are dynamical rules. While the Newtonian laws of mechanics describe the states of movement for solid objects, Darwin's principles apply to the population sizes of different varieties of biological entities. The population dynamical approach to ecology is basically *mechanistic*: it explains the dynamics of populations and their communities from life history events of individuals: births, deaths and migration. These events of individual life are in turn determined by the environment dependent physiology of the individuals. Consequently, the regulated dynamics of populations directly follow from regulated molecular processes, even if the connections are cryptic and remain unrevealed in most cases. The consequent fact that the dynamics of each specific population will be unique does not make the rules of dynamics inapplicable. Physics and biology are similar in this respect as well: general rules apply to any specific phenomenon, but studying their specific aspects requires specific approaches (Colyvan and Ginzburg 2003).

Newton's efficient and general differential equation formulation of the principles (rules) of mechanics was one of the most important innovative steps ever taken towards modern science. The mathematical arsenal of science, the toolkit of describing and handling the rules of change, has immensely enriched and expanded since Newton. Likewise, the formalized outer layer covering the innermost core – the verbal armature constituted by the principles – of ecological theory is a coherent dynamic theory, which can be developed further in many different ways and directions, for example to include stochasticity and various types of interactions. Each specific ecological case obviously requires its own specific experimental and modeling approach, but each application must remain consistent with the principles just as, for example, any research in physics (or in any other branch of science, for that matter) must be consistent with the three main laws of thermodynamics, even if the connection is not necessarily obvious for the first sight. The specific models of specific cases may help us understand, predict or change the specific features of the system at hand, but they must also obey the general principles in the meantime.

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