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efficient killers. Such is the case of a family of nematodes that infects insects. When the nematodes penetrate an insect, they release compounds to deplete the immune response of the insect, in the process releasing some specific bacteria they have transported with them. The bacteria proliferate once the innate immune response of the insect is knocked down, and the nematode and bacteria reproduce to huge numbers at the insect’s expense. When the resources are exhausted, the remaining nematodes feed on some of the bacteria, then millions leave the corpse to look for new potential hosts. This association of nematode and bacteria has been exploited and used in biological control programs to reduce agricultural damage caused by lepidopteran and coleopteran pests to acceptable levels. The biotechnology industry is exploiting the compounds produced by nematodes and bacteria to develop new drugs, all of them possible because of a very successful symbiotic association between two lowly organisms.

Some of the chapters describe the use of bacterial pathogens to reduce pest insect populations that cause losses in human agriculture. It should be noted, however, that beneficial insects such as honeybees have bacterial and viral diseases of their own, which may result in hive death and reductions in agricultural production. Despite hives’ innate immune defenses, the loss of colonies or apiaries to bacteria, viruses, or mites is often severe. We still have not found measures to protect hives from these pathogens, and we cannot expect insects we consider beneficial to be exempt from having them.

Fungal diseases of invertebrates also abound, some of which have been developed and exploited to control pests such as the gypsy moth or locusts. Scientists’ keen observations of sick insects led to the discovery of these compounds, which are now sprayed from airplanes to control outbreaks of these pest insects. The associations described above are symbiotic, and we have exploited these close linkages to achieve biological control of a problem species. Often, though, humans created the problem in the first place through extensive monocultures or by moving organisms to regions where natural controls are in short supply.

Davidson has done a good job of describing the historical context in which these pathogens have been developed as controls. She also portrays the individuals from a range of countries who have worked together in their own symbiotic relationships to solve the problems. It should be noted that many activities of scientists, such as sending live biological material from laboratory to laboratory and continent to continent, are not as simple today as they may have been only a few decades ago.
In chapter 3, on modeling evolutionary phenomena in adaptive landscapes, McGhee reproduces a fascinating illustration from Signs of Life: How Complexity Permeates Biology (Solé and Goodwin 2000) that shows how an adaptive landscape might look for extinct trilobites from the Palaeozoic era. Every peak in the landscape corresponds to some beautiful trilobite morphology. Unfortunately, the landscape is not based on measurements—it is entirely conceptual. Although it is not entirely straightforward to visualize the fitness landscape for extinct trilobites, it would have been instructive for McGhee to show not only conceptual models but also a mathematical model of an adaptive landscape, as Kauffman did in The Origins of Order.

Yet when trying to explore the adaptive landscapes of such a mathematical model, many questions need to be answered. Two key ones are, How can the fitness of an individual be determined? and How can the multiparameter spaces of an adaptive landscape be visualized? Exploring these questions is a worthy research endeavor in itself.

In chapter 4, McGhee introduces the concept of theoretical morphospaces, which he defines as n-dimensional geometric hyperspaces produced by systematically varying the parameter values of a geometric model of form. The most famous theoretical morphospace is the one constructed for mollusk shells by Raup (1966). In Raup’s paper, a range of hypothetical mollusk shell morphologies was visualized as a function of the number of parameters controlling the morphology of the shell. A pioneering publication in many ways, this paper was the first to introduce the concept of morphospaces. In this early application of scientific visualization, the results of a mathematical model were visualized on a computer screen even before the field of computer graphics existed!

A general problem with morphospaces is that the underlying mathematical model is based largely on just a description of the organism’s form. In the mollusk morphospace, the morphology of the shell is controlled by parameters such as the whorl expansion rate and the translation rate of the shell. The advantage of such a description is that the shell’s morphology can easily be captured by a small piece of computer code; the disadvantage is that these parameters do not necessarily have a connection with the developmental process. McGhee’s book would have been more interesting with examples of a connection being made between the underlying developmental gene regulatory networks and the form of an organism. There exist among the echinoderms some beautiful examples of how models of growth and form.

McGhee has made a courageous attempt to develop a mathematical theory connecting models of morphogenesis and evolution, and his book offers an opportunity to learn about the enormous diversity of palaeontological examples of evolution. He has done a very good job in bringing all this material together in one book, and I would recommend The Geometry of Evolution to anyone interested in morphogenesis and evolution. Mathematicians and computer scientists in particular will find that the book poses many interesting questions.

The book intrigues, enticing readers to ask new research questions: Can we develop mathematical models of growth and form that are useful for investigating the role of natural selection in evolution? What do these adaptive landscapes look like? Do many possible solutions exist in evolution, or does the evolutionary process converge on a few choice answers?

Visualizing n-dimensional parameter spaces and adaptive landscapes is highly relevant to optimization problems and a good example of the challenge of information visualization. Finally, the book intrigues, enticing readers to ask new research questions: Can we develop mathematical models of growth and form that are useful for investigating the role of natural selection in evolution? What do these adaptive landscapes look like? Do many possible solutions exist in evolution, or does the evolutionary process converge on a few choice answers? The reader who is open to such questions will find much here to stimulate reflection and experimentation.

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