literature. The relative importance of natural selection and internal constraints has always been contended by biologists: molecular and developmental biologists tend to focus on internal mechanisms; ecologists and evolutionary biologists prefer to address external ones. But even Darwin accepted the importance of both: in *Origin*, his 'laws of variation' acknowledge that variation is constrained, and his 'correlation of growth' implies that organismal traits are interdependent.

Fodor and Piattelli-Palmarini misappropriate the famous critique of adaptationism (the idea that natural selection is sufficient to explain every complex biological trait) that Stephen Jay Gould and Richard Lewontin presented in their 'spandrels' paper of 1979. Gould and Lewontin warned about the dangers of invoking natural selection without considering alternatives. But Fodor and Piattelli-Palmarini grossly overstate that case, concluding that natural selection has little or no role in the generation of biological complexity, contrary to much evidence.

In their second line of attack, Fodor and Piattelli-Palmarini maintain that biological phenomena are a matter of historical contingency. They argue that generalizations are impossible because of the interplay of too many local conditions, such as ecology, genetics and chance. In their narrow view of what counts as science, only law-like processes allow for the testability of scientific hypotheses. Thus, they claim, an explanation of adaptations that is based on natural selection is defensible in only two cases — if there is intelligent design, or if there are laws of biology analogous to those of physics, both of which they reject. Here the authors ignore the entire field of evolutionary ecology, countless examples of convergent evolution of similar structures in different lineages that show the historical predictability of evolutionary processes, and the literature on experimental evolution, in which similar conditions consistently yield similar outcomes. There is clearly a logic to evolution.

Evolutionary biology is a mix of chance and necessity, as French biologist Jacques Monod famously put it, in which endogenous and exogenous factors are in constant interplay. It is a fertile area for rigorous philosophical analysis. Fodor and Piattelli-Palmarini offer only sterile and wrongheaded criticism. Fortunately, other philosophers of science and theoretical biologists are coming together to clarify and build on the conceptual foundations of science and explore issues of its practice; this is a better way to bridge the two cultures. ■

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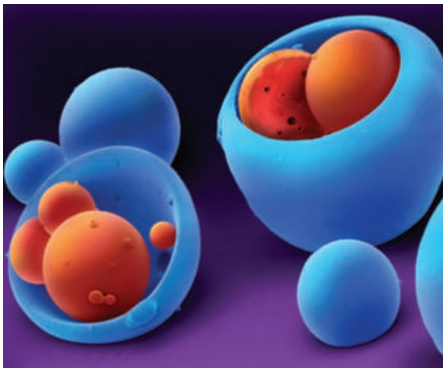
A macromolecular history

Giant Molecules: From Nylon to Nanotubes
by Walter Gratzer
Oxford University Press: 2009. 144 pp. $24.95, £11.99

The study of large molecules follows two strands that have alternately diverged and intertwined over the subject's history. The first strand explores the natural macromolecules of biology, including proteins, polysaccharides and nucleic acids. The second is concerned with synthetic macromolecules, the invention of which in the early twentieth century launched industries based on plastics such as nylon, polyethylene and Perspex. In *Giant Molecules*, biophysicist Walter Gratzer weaves together both stories.

Initially the two strands developed together, sharing experimental methods and theoretical approaches. The simpler chemistry of the synthetic materials offered tractable analogues of the natural systems. Then, as the inherent complexity of biological molecules became central to their understanding, the fields split. The flowering of structural biology in the late 1950s and 1960s was driven by the technique of X-ray diffraction and owed little to polymer science.



Tiny capsules made of synthetic polymers can be used to deliver drugs for slow release in the body.

A. CAVANAGH/WELLCOME IMAGES

Gratzer describes the history engagingly, and includes many anecdotes. He explains how German chemist Hermann Staudinger's concept of polymers as giant molecules became accepted amid controversy, rancour and the ugly academic politics of German universities in the period up to the Second World War. Not all of the anecdotes he chooses are reliable: he includes, for example, the widely held but incorrect notion that the windows in medieval cathedrals are thicker at their base because the glass has flowed. This lapse is symptomatic of a general weakness in the book when it comes to the physical science of macromolecules.

Recent developments in the physics and chemistry of macromolecules get short shrift. The book's discussion of ways of measuring the size of polymer molecules, for example, is many years out of date, and the influential work of those such as Nobel laureate Pierre-Gilles de Gennes, who brought theoretical physics concepts to molecular science, is not mentioned. New methods of polymer chemistry, such as living polymerization, ring-opening metathesis and solid-phase peptide synthesis, all of which allow unparalleled control of the size and architecture of synthetic macromolecules, are not mentioned, despite yielding Nobel prizes.

In recent years, the two strands of macromolecular science have converged again. Techniques such as laser tweezers and single-molecule force spectroscopy have allowed us to study the behaviour of biological macromolecules as individual physical objects. Aspects of protein behaviour, such as their mechanical unfolding and the structures they form when they misfold, re-emphasize the analogies between biological and synthetic macromolecules. The increasing ability of chemists to control the architecture of synthetic polymers has made new applications possible, especially in nanotechnology. The new forms of carbon — fullerenes, nanotubes and graphene — earn their place in the book.

Gratzer covers the promise of polymer nanotechnology in brief. Some applications — such as glues inspired by shellfish; drug-delivery devices based on self-assembled polymer vesicles; and scaffolds for tissue engineering — are directly inspired by biology. Others, such as the plastic electronics made possible by semi-conducting polymers, use properties of macromolecules that have not been exploited by nature.

Arguably, DNA is the most important macromolecule, and I share the author's particular fascination with its potential uses, for example as the basis of synthetic molecular motors, for information processing and to make intricate self-assembled nano-objects. Only time will tell whether such beautiful laboratory demonstrations will yield practical technologies that have the impact in the twenty-first century that plastics had in the twentieth. ■

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