A whole chapter ("The gene as information") is devoted to reassessing historically significant information metaphors: the gene as information, as genetic "code," as genetic "program," as genetic "code," as well as the relevance of the mathematical theory of communication and semantic and teleosemantic theories to genetic transmission.

The behavioral gene covers gene concepts that function in behavioral genetics practices. Building on work by Tabery and Griffiths, the authors argue that the traditional debate over nature versus nurture, spawned by behavior genetics’ apportionment of relative causal or statistical contributions to trait heritability, is now dissipating. Molecular tools are increasingly deployed in behavioral genetics (e.g., in genome-wide association studies, to search for the genetic bases of phenotypic variation and behavior traits increasingly considered in biomedical applications of the molecular biosciences).

In "The evolving genome," the authors canvass implications of the genomic revolution for evolutionary biology in ideas of extended synthesis, evo-devo (evolutionary developmental biology), and the constructive roles of developmental constraints.

One of the more useful features of this book is a cross-cutting thematic summary chapter, "Four conclusions." The first conclusion is that the gene carries several "identities," which accumulated over the twentieth century, as genetic practices diversified: an instrumental Mendelian unit of genetic analysis; a nominal structural unit used to annotate genomes and stand as a unit of Crick information; a "postgenomic" gene that recognizes that units of Crick information do not correspond exclusively to structural units of DNA, given exogenetic inputs from non-DNA sources in the production of RNA and protein sequences; and an abstract "developmental gene" as a hypothesized anchor (whether Mendelian, nominal, or postgenomic) for a parameter in a developmental model.

The second conclusion is that there is more to heredity than the inheritance of nuclear DNA. The regulatory apparatus specifying DNA involves a wide developmental niche involving inherited legacies of distributed specificities rather than concentrated exclusively in DNA.

The third conclusion is that reductionism cannot be understood solely as a matter of taking systems apart and explaining system behavior in terms of the independent operation of parts. Neomechanist accounts add an integrative phase to explanation in which the interaction and organization of parts produces emergent, functional system behavior incorporating top-down as well as bottom-up effects. The integrative addition is supported by the rise of systems biology.

The fourth conclusion is that the demise of the nature–nurture dichotomy is not so much the result of one stance vanquishing the other—either a triumphant reductionist molecular biology explaining nurture in terms of micronature or a sophisticated nurture theory subsuming nature. Rather, the interdependence of organism and environment, together with the expanding utility and power of molecular tools, is leading to new appreciation on both sides of the context sensitivity of biological mechanisms of molecular epigenesis and the value of reductionist research strategies in a new science of nurture. Heredity, in brief, is a mechanism for both fixity and plasticity of behavior.

Genetics and Philosophy is written in clear, readable prose that I have field tested on undergraduate philosophy and biology majors. A few small errors mar this otherwise well-researched book. For instance, on page 42, the authors report that up to three triplets of nucleotides code for one and the same amino acid, but because six codons code for leucine, the number should be six.

The book brings debates about reduction, mechanism, explanation, theories, and gene concepts up to date and casts a fresh perspective over the history of the field. The authors thoughtfully engage recent studies in several areas of philosophical and molecular genetics research. They chose not to address the relationship between the molecular biosciences and historical, evolutionary, and population biosciences, so in that sense, the book is not a comprehensive philosophy of the gene. Genetics and Philosophy’s best contributions are its rich taxonomy of gene concepts, the concept of Crick information, the developmental niche concept articulated with arguments about molecular epigenesis and distributed specificity, and the updated critique of informational concepts in genetics and genomics.

JAMES GRIESEMER
James Griesemer (jrgriesemer@ucdavis.edu) is a professor of philosophy in the Department of Philosophy at the University of California, Davis.
According to Godfrey-Smith, philosophers of biology pursue two projects. The first is the “philosophy of nature”—that is, philosophical reflection on the implications and significance of the findings of biology. Researchers working in this tradition draw on the best current science to help us understand the universe and our place in it. Under this general heading, Godfrey-Smith asks the following questions: Can we make sense of teleological language within a purely physicalist understanding of the world? Are biological species “real” (mind-independent) entities? If so, are they better understood as spatiotemporally unrestricted natural kinds or as spatiotemporally localized objects? Can we speak meaningfully about human nature? Godfrey-Smith recognizes that professional biologists also address these questions, but “distilling the philosophical upshot of scientific work is a different activity from doing science itself” (p. 4).

The book’s second project is to provide an account of the nature of biological knowledge. Chapter 2 illustrates this goal by discussing the nature of biological theories and explanations. Philosophers of science have written extensively about scientific theories and explanations. According to logical empiricists, for example, the aim of science is to discover natural laws, because laws are essential for good theories and explanations.

In contrast with this traditional conception of science, Godfrey-Smith’s approach is deflationary and pluralistic: He argues that there are three different styles of biological theorizing, which emphasize laws, mechanisms, and models. The latter two are perfectly legitimate styles of explanation but do not presuppose laws. According to his pragmatic conception, we cannot sharply distinguish laws from nonlaws (e.g., statements that are contingently true), because biological generalizations often combine elements of necessity and contingency. As a result, it is clearer to say that scientific generalizations are more or less robust (i.e., stable). Once we recognize this, it is merely a verbal choice to call a generalization a law.

One alternative to the law-based approach is that biologists explain by describing mechanisms—that is, by explaining how the parts of a system interact to bring about a new state of the system. This more-or-less reductionist approach is commonly employed in molecular biology. Ecologists and evolutionary biologists often employ a different style of theoretical explanation that makes use of mathematical models. In domains such as population genetics, we explain the behavior of an actual system by saying that it is similar, in key respects, to the idealized mathematical model.

The chapter “Laws, mechanisms, and models” illustrates three recurring features of the book. First, Godfrey-Smith’s approach is refreshingly pragmatic (rather than dogmatic). Once we’ve clarified the concept of law and recognized that some generalizations are more stable than are others, not much hinges on whether we call Mendel’s principle of segregation a law. Second, Godfrey-Smith’s approach is pluralistic. He suggests that all three styles of explanation (laws, mechanisms, and models) are useful. (Later chapters are pluralistic about species and gene concepts, too.) Finally, the book is compressed. For example, this chapter includes a brief (three-paragraph) aside on the topic of emergence. Such asides are often insightful but they tend to be suggestive rather than fully developed.

After setting out his account of biological theories and explanations, Godfrey-Smith uses the rest of the book to dig more deeply into the philosophy of nature. Individual chapters address topics such as adaptation and function, biological individuality, genes, species and systematics, the evolution of social behavior, and the concept of information.

Godfrey-Smith tells us that the book is written for two audiences: professional biologists and philosophy students. Although the book provides an excellent choice for professional biologists, it may be less helpful for philosophy students, for two reasons.

First, compared with other books on the market, this book is highly abstract. Issues are introduced in abstract terms, with few detailed biological examples. For example, the units of selection problem is initially introduced in just three pages, without a single example of what it would mean to have selection acting at the level of the gene or group. This won’t pose a problem for (most) biologists, who will track the abstract logic and fill in relevant example, but it makes the book less accessible to the true beginner. (I should add that the writing is clear; it’s just abstract rather than concrete.)

Second, many instructors of the philosophy of biology want students to understand the nature of philosophical discussion. In my courses, I want students to learn about the arguments for and against a position and to assess the strengths and weaknesses of those arguments. In contrast, this book offers a fresh way of thinking about central topics but rarely descends into the messy and difficult task of assessing the arguments that have led philosophers of biology to hold (or reject) key theses. This potential weakness can be corrected by combining this text with additional readings, but it limits the value of the book as a standalone text.

Whether or not one endorses pluralism within the philosophy of
biology, I certainly believe that pluralism is appropriate when assessing textbooks. There are many different virtues that one might aspire to in an introductory text, including brevity, clarity, insightfulness, detailed examples, and rigorous philosophical argumentation. Godfrey-Smith's text rates very highly on the first three desiderata: It provides a clear and concise introduction to the philosophical issues that arise in connection with biology. Readers will encounter stimulating and fresh perspectives on central topics, delivered by an author with a remarkable command of the field. But those who hunger for detailed examples and a richer assessment of arguments may be better served by other texts.

TODD GRANTHAM

Todd Grantham (granthamt@cofc.edu) is a professor and chair of the philosophy department at the College of Charleston, in Charleston, South Carolina.

doi:10.1093/biosci/biu206

WHY PLANT PHYSICS?


Karl Niklas and Hans-Christof Spatz, both highly respected when it comes to the structural analysis of plant tissues, have brought forward a significant addition to the literature on plant structure. Plant Physics presents a comprehensive overview of the physics relevant to the structural economy of land plants. The topics covered include a concise introduction to the principles of structural mechanics, fluid dynamics, and electrophysiology, with in-depth coverage of plant–water relations and environmental biophysics. The topics are amply referenced, and the book concludes with chapters on experimental and theoretical tools and a glossary.

But why should you have a book on plant physics on your shelf? Isn't plant structure simply the downstream manifestation of complex but familiar cellular and molecular mechanisms working within a particular set of physical constraints, or is there something more fundamental that sets plants apart?

In animals, the emergence of biological form during embryogenesis and growth is hugely complex. Signal processing, rapid nerve transmission, and muscular control must all be coordinated during development—never mind the various kinds of social interaction and consciousness that animals might enjoy. The prospect of articulating a developmental narrative that can encompass all of these processes is probably still unattainable, which forces us to deal with each subsystem individually, as its own discipline (Niklas 2012). But in the plant kingdom, development is more transparent. This is because of the constraints that the cellulolic cell wall has placed on the evolution of morphospace. In the land plants, all somatic cells are permanently trapped within a continuous fabric of rigid cellulolic cell walls, which thereby eliminates any possibility of cell migration. One consequence of the universal presence of the cell wall is that land plants, rooted in what is essentially a freshwater environment, routinely develop cellular turgor pressures that can only be considered extreme by metazoan standards. Pressures of up to 1.0 megapascal are commonplace in expanding plant cells. The plant body can be regarded as a collection of pressure vessels embedded in a more or less rigid matrix, whose properties have to be finely tuned in order to control growth. Cell division becomes restricted to the terminal meristems where new cells are formed, just as adding new floors at the top of a skyscraper creates new living space. Construction of the plant body becomes something of an engineering problem.

Furthermore, although plants and animals have similar cytoskeletal mechanisms for chromosomal assortment, cell division in the plant kingdom is functionally very different from animal cell division. In the plant kingdom, the products of mitosis are permanently bonded to one another, with the whole plant forming a single mechanically continuous structure. Cells divide by precisely orienting new partition walls, much as an architect would erect a new partition across an existing room, establishing a spatial relationship between daughter cells that can never change. Animal cell mitosis, however, involves a cell essentially pinching in two, after which the two “daughter” cells are, at least in principle, free to move independently to create new neighborhoods and to foster functional relationships in ways that are unavailable to plant cells. Morphogenesis can involve cell migration and flow. But in the land plants, in which cells are pressurized and frozen in place, the development of form becomes an architectural process, in which the permanent installation of precisely oriented partition walls is necessary to support the turgor-dependent tissue stresses that radiate throughout the growing tissues.

So while evolutionary constraints have resulted in a developmental paradigm that seems simpler than that of animals, they have also endowed plants with a suite of mechanical and biophysical tools that are largely unavailable to animals. This amounts to a unique evolutionary context, a structurally based information system that can inform developmental events with a spatial