Feature

Book Review

Integrating Concepts in Biology: A Model for More Effective Ways to Introduce Students to Biology

Review of: Integrating Concepts in Biology, by A. Malcolm Campbell, Laurie J. Heyer, and Christopher J. Paradise; 2014; Trunity.com eBook; www.trunity.com/products/digital-textbooks/integrating-concepts-in-biology; ISBN-13: 978-1-63097-008-6

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Integrating Concepts in Biology (ICB) is the apt title of this groundbreaking electronic textbook (see Supplemental Material). The target audience is students seeking an introduction to biology. It is structured to focus student attention on key concepts underlying biology at all levels of organization. In contrast to the current encyclopedic model of an introductory textbook, this e-book makes effective use of electronically linked text and online resources, selects examples to explore in depth, and offers students means to deepen their understanding. It explicitly uses current ideas about student learning, supported by evidence of best practices, to help students develop as biologically literate thinkers. The authors are colleagues at Davidson College: biologists A. Malcolm Campbell (cellular and molecular biology) and Christopher J. Paradise (ecology) and mathematician/computer scientist/bioinformaticist Laurie J. Heyer. They share a common passion for innovative pedagogy and multidisciplinarity, and ICB is their laudable effort to address many of the widely recognized problems evident in introductory biology texts and introductory courses and explored in recent reports such as BIO2010 (National Research Council [NRC], 2003) and Vision and Change in Undergraduate Biology Education (American Association for the Advancement of Science, 2011).

Conflict of interest: K.N.P. attended Davidson College from 1967 to 1971 and is a loyal alumnus; all the authors are Davidson College professors, but K.N.P. has never met or corresponded with any of them.

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Understand how the structure and function of this complex series of questions and online resources that help students of ATP synthase is sketched out, but it is accompanied by a sense of how biochemists come to understand the operation of complex pathways. Likewise, the general function of ATP synthase is sketched out, but it is accompanied by a sense of how biochemists come to understand the operation of complex pathways. Likewise, the general function of ATP synthase is sketched out, but it is accompanied by a sense of how biochemists come to understand the operation of complex pathways. Likewise, the general function of ATP synthase is sketched out, but it is accompanied by a sense of how biochemists come to understand the operation of complex pathways.
read. But one can argue that learning to read more difficult texts is a skill that should begin early in a student’s career. And, although reduction in the number of terms introductory students encounter seems to be a worthy goal, what is appropriate for one instructional setting might be less so for another.

The use of hypertext and illustration is very effective. The illustrations are clear. They serve to advance points made by the text and are helpful in developing a student’s ability to visualize processes (e.g., what happens when a three-dimensional object is shown as sliced sections). Hypertext was used to give definitions of all important terms (click on the word and see the definition); to lead a student to connected sections for review or preview; and to effectively link the text with Web-based resources such as simulations, animations, movies, and appropriate examples of primary literature (although some of these articles were not open access).

The number and types of hyperlinks represented a good balance between assisting informed student discovery without simply revealing the answers. One small complaint is that it would be useful if the elements of the navigation graphic (Figure 1) were electronically linked to the corresponding chapters. Additional comments on the use of hypertext and general functionality of the e-text can be found in the Supplemental Material.

The presentation of material was, for the most part, clear and accurate. Some (perhaps inevitable) issues of accuracy or emphasis can nevertheless be found. For example, in chapter 9 (“Neurons and Muscles”) the text seems (incorrectly) to attribute resting potentials to the electrogenic nature of the Na⁺/K⁺ ATPase—whereas a linked animation correctly explains the central role of membrane permeability and ion concentration differences. Another concern arises from the designation of the term “homeostasis” as a unifying theme. Homeostasis requires biological mechanisms that serve to confine the states of some variable to a small range of values in the face of a wider range of environmental perturbation. Chapter 29 (“Population Homeostasis”) seems to lead students to conclude that population sizes are regulated homeostatically through density-dependent effects on births and deaths. Most population ecologists endorse the notion of density-dependent “equilibrium” population sizes (usually called carrying capacities) that exist for a specific set of environmental conditions. But change the broad environmental conditions and the carrying capacity immediately changes (think of the history of human populations and technologies), unlike what is observed in homeostasis. We suggest that a more globally unifying “big idea” is regulation; this broader term better allows concepts such as equilibrium, regulation, and homeostasis (a relatively uncommon condition) to be explored and distinguished from one another.

In a few other places, we disagree with the authors’ approach to a topic. For example, in the treatment of cellular energetics, we find that it is more useful to focus on Gibbs free energy and its relationship to displacement from equilibrium than on bond energies of molecules. The free-energy approach is especially useful, because bioenergetics subsumes a broad array of processes beyond chemical reactions such as ion and electrical gradients and mechanical processes. Moreover, use of this approach facilitates (and requires) that students gain a conceptual facility with equilibria (of all types) and steady states. We recommend a short essay by Richard Feynman (2008) as an accessible starting point to a guided discovery of these important topics.

As with any endeavor, ICB is a product of the vision of its authors, inevitably influenced by their training and expertise. The great strengths of ICB are at the cellular, molecular, and ecological levels of the biological hierarchy, reflecting the authors’ biological foci and the reality that most biological research is presently focused on the “small” and the “big.” The authors made an honest attempt to minimize the small-versus-large divide by seeking common themes and providing for exploration of system- and organism-level mechanistic biology (see Figure 1). But it is clear that their experience (and most successful presentation) is elsewhere.

For example, chapter 9 (“Neurons and Muscles”), which was intended to emphasize organisms, does an excellent job in guiding students through research on the regulation of synapse formation at the cellular and genomic levels. But the highest level of structural complexity discussed is between one cell and another. The authors miss a chance to explore emergent properties found in networks of connected neurons. The complexity and (often) flexibility of these networks allow neural computations related to perception (e.g., vision) and much of cognition and learning. Likewise, treatments of plant and animal physiology (chapters 12 and 15) focus heavily on processes at the cellular or molecular level. Chapter 28 (organism homeostasis) presents some interesting data regarding mammalian thermoregulation but without mentioning the roles of metabolism and circulation in temperature regulation. Temperature regulation is a subject that is often used to illustrate how interacting organ systems can achieve varying degrees of regulation. It can be used to briefly explore the salient features of these systems (“What must a pump do?” and “How is flow controlled?”) and is an ideal subject for mathematical treatments (applications of Newton’s law of cooling, surface, volume, and size) and seeing how principles from physics (e.g., diffusion and bulk flow of heat) apply to organisms. A balanced grounding in tissue/system/organism function is important to the education of beginning students.

All textbooks have problems such as the ones just mentioned. We are concerned that no content reviewers are acknowledged in the prefatory material of this text, and Trinitity uses the process of “assisted publication,” so it may be that the text was not subjected to as thorough a review as a traditional textbook backed by the resources of a major publishing house. However, since the electronic format permits updating at the authors’ pleasure, mistakes can be easily corrected as users offer feedback.

**ICB, OTHER INTRODUCTORY TEXTS, AND THE PARABLE OF THE BLIND MEN AND THE ELEPHANT**

Each biologist has his or her own perspective as to how students should be introduced to biology, much as in the ancient parable wherein each wise but blind man attributed different characteristics to the elephant. One approach is to admit that other views are useful but, nevertheless, select a particular perspective. The three BSCS high school biology texts launched in the 1960s are good early examples of this
The more common path has been to examine the “elephant” from every possible perspective and pedagogy and produce a textbook that theoretically would meet all needs. Given the costs of traditional publication, there is logic in producing a book that has the greatest adoption potential. Thus, traditional textbook writers have compiled increasingly massive compendia, with multiple authors and expert advisors, richly detailed illustrations, numerous study questions, boxed features on applications and ethical issues, and examples of applications of mathematics and chemistry, along with an array of electronic resources and instructional aids. For example, the widely adopted introductory biology textbook that we use at Holy Cross (Sadava et al., 2014) has more than 1300 pages and uses multiple authors and advisors, each an expert on some range of topics.

This thoroughness is often overwhelming for both students and faculty members. Students become lost in the detail and bombardment of terms and fall prey to frustration or boredom. Instructors provide study guides to help students focus, leading students to minimize their reading and concentrate on slides presented in class, which reflect what the instructors believe to be most important.

ICB was partially designed as an antidote to the expansive text, and it effectively facilitates a path to teaching and learning that takes advantage of recent educational research promoting the benefits of student-centered active learning. For these reasons and because of its inherent strengths as a text, it is a significant contribution. But is it for everyone? The answer, of course, is no. We have a different take on what topics should be presented and how. For instance, we believe that it is not just theory and experiment that motivate students; many thrive and grow from knowledge of biological diversity. Other differences that matter to us, such as how to explain biological energetics or the importance of good treatments of organismal biology, we touched upon earlier. We also place more importance in the value of terminology than do the authors of ICB. So, at our institution, we are moving along a largely parallel but different path as we strive to make education more exploratory, active, and integrative—a path that owes much to that advocated by Freeman et al. (2011). We look for textbooks with treatments that include these perspectives. A second issue is how the introductory course fits into the entire department’s curriculum. Coadaptation of introductory and advanced courses is required for a coherent student experience.

These quibbles and reservations aside, we believe that in the hands of motivated and skilled instructors, ICB represents the core of an approach that is likely to excite and engage students more than does a more traditional course. The text and supplemental materials are effective tools to anchor courses of guided self-discovery of biology and the scientific process. This approach is more likely to motivate students to develop a usable knowledge foundation and problem-solving skills, and it should also facilitate the development of their metacognitive skills (NRC, 2000). A study done at Davidson College the first year that the ICB version of first-semester introductory biology course was offered in parallel with a more traditional version showed that student performance was similar across approaches on factual content but that ICB students performed better and showed more improvement on tasks involving data interpretation and had a better conceptual understanding of biology as a discipline (Barsoum et al., 2013). Moreover, even educators who choose not to adopt ICB would likely benefit from studying its intent and execution. It exemplifies an innovative and enlightened new direction in education that is worthy of emulation by those who see the biology elephant with different perspectives. If we may conclude with a personal reaction, reviewer K.N.P. would have been overjoyed to have experienced the ICB approach when, a mere four-plus decades ago, he took introductory biology in the very same rooms as the students of Campbell, Heyer, and Paradise do today!

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