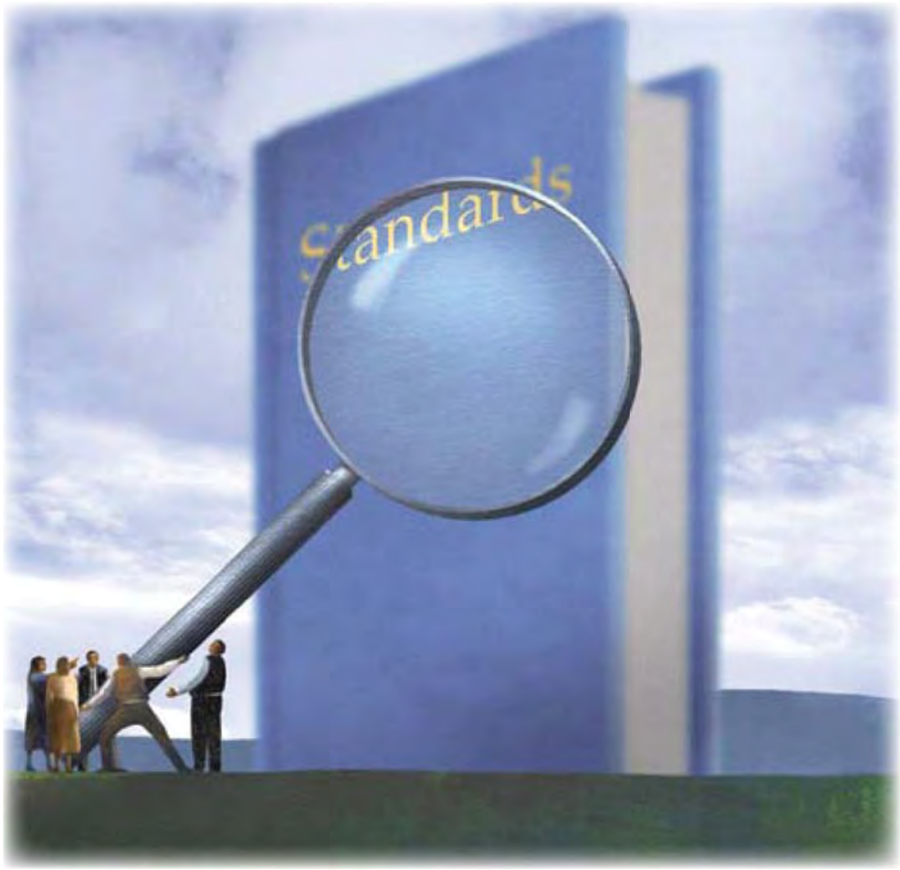
No Contest

Up Close, Typical State Biology Standards Don't Have the Content or Coherence of the International Baccalaureate



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BY PAUL R. GROSS

Since the beginning of the standards movement, national and state science standards have been padded with politically correct matter having little to do with the substance of scientific knowledge. According to philosopher of science Noretta Koertge, this invasion can be traced to the 1996 National Science Education Standards. They were developed by the National Research Council and have served as a model for the states. Koertge doesn't blame the national standards; she merely notes that they created the opportunity:

> [The National Science Education Standards] note that learning about science as process is not enough. Understanding of content is also required.... But one of their goals opens wide a door [for] ... political correctness [to] ... intrude. This is the requirement to present Science in Personal and Social Perspectives. "An important purpose of science education is to give students a means to understand and act on personal and social issues." What might this mean in practice?[1]

In practice, it could mean almost anything except the actual content of science. As she notes, the national science education standards *do* recognize content as important. But they don't resist the politicized formulas and prescriptions for science, nor the sociological turn, that came into prominence during the 1980s and 1990s. Since then, many 18-wheelers, loaded with cargo other than science content, have barreled through the wide-open door.

Despite optimistic predictions that flagrant politicizing of science would doom these initiatives to an early demise, at least in K-12, the incursion succeeded. K-12 education standards, which precede and give direction to everything from teaching to professional development to textbook and assessment writing, ought to be "standards of scholarship and intellectual responsibility."[2] But, of course, there has always been right- and left-leaning political correctness intruding, even into the science classroom. Science

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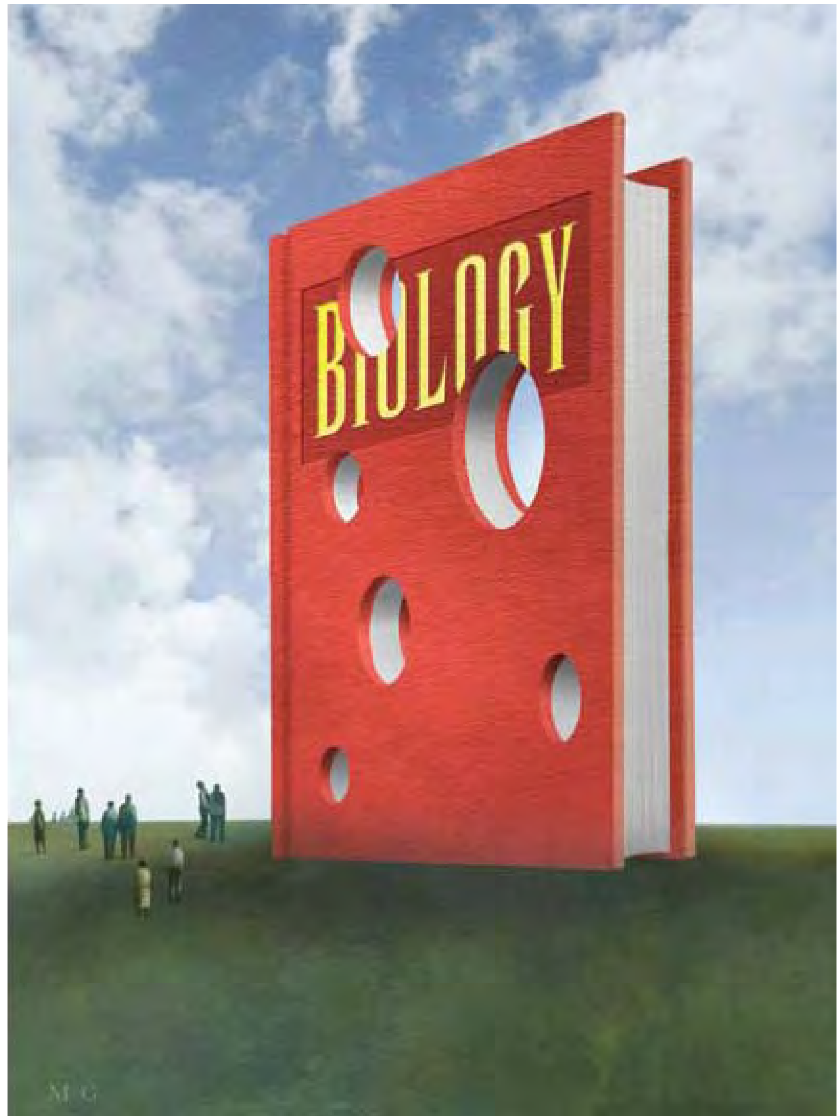


education and science standards have not been immune from the culture wars of academe and society. And the comments in this article, which focus on biology standards, do apply in general to the rest of natural science.

Conservative political correctness for science, which today as in the 1920s is most clearly visible in reference to biology, is mainly a pervasive anti-Darwinism.* Currently, the attack protests against viewpoint discrimination (a catchphrase conservatives borrowed from the left). Unfair discrimination is claimed to be implicit in the teaching of evolution without equal time for favored alternatives: "scientific creationism" or "intelligent design." But, as good science, both of those fail. As has been demonstrated time and again, they are *not* good science but something else: bad science or, at best, a kind of theology.[3] Since the mid 1990s, anti-Darwinism has grown faster and with greater threat to national scientific literacy than have any of the left's intrusions.[4]

But individual anti-science attacks from the right, damaging as they might well become to our already deficient national science literacy, have not so far survived for very long. Vigilance has routed them, one at a time, sometimes in the courts (as in *Kitzmiller v. Dover School District of Pennsylvania*). Unfortunately, the same cannot be said of intrusions from the left. Their target is the alleged "narrow," "authoritarian" insistence in traditional science study on content and "factoids," as opposed to something else: something higher, more analytical—*science process*, for example. This vaulting of process over content has become established nationwide. Its promoters have succeeded because their basic claim resonates with the intuition of most nonscientists. This is that the processes of science are distinct and separable from its content, that *the processes are of equal or greater importance, and that they, as well as content, must be taught in the science class.*

So conceived, "process" includes not only some necessary and appropriate history of science, and some simple but serious definitions of inquiry and methodology, but also much deliberation on the cultural, social, and political origins, and the social consequences, of both. "Process" becomes, as it were, sociological. This emphasis comes with a rider: so far as actual science content is concerned, as some standards documents proclaim, "less is more." The claim is that with emphasis on process in the science classroom, and with diminished specific content (but pursued in depth), we shall raise science literacy and expand proficiency, providing experiences of "rigorous" science for every child. Thereby it is implied, for example, that the child with no glimmering of elementary solution chemistry, of microbiology, limnology, or hydrology can learn (enough of) those sciences, for practical purposes, without actually studying them. How? Well—still for example—by participating team-wise in a science classroom simulation, with role-playing, of a town council hearing on pollution by local industry of the water supply.

Unfortunately the results of nationwide, objective testing of students (e.g., the NAEP assessments) have not yet—after decades of process emphasis—demonstrated any noteworthy increase in proficiency. Nor have they shown any significant closing of the achievement gaps between various groups of students.

Rating the Standards

Are the state standards as bad as all this suggests? Yes, although with some happy exceptions. Most are strongly influenced by national standards publications (e.g., from the National Research Council and the American Association for the Advancement of Science). But the failures cannot be directly attributed to these

*Conservative intellectuals, many but by no means all of whom dislike evolution and wish it could be kept quiet, like to justify this wish, in print, as a decent respect for tradition. So doing, they forget that after more than 150 years, richer and sounder than ever, evolutionary science is among the very strongest of our intellectual traditions.

models. The national standards are sound where they deal with content (although there is not enough of it at the necessary levels of detail). Their emphases on process are adopted enthusiastically by the states and usually expanded; but the same state standards often do *not* match the quality of the already somewhat attenuated content in the national models.

States write their own standards, most of them organized idiosyncratically, dense, and long-winded as to process. They stress learning by doing, praise "hands-on, minds-on" classroom work; but they focus more on those "personal and social issues"—in chic pedagogical language. They reduce science content even further. And it is often clear that there has been insufficient input from scientists. There is far too much plain error and misleading content.

Most standards suffer from excessive length, obsession with process and pedagogy, and inadequate attention to the kind, amount, and organization of the subject matter: science content.

How can I assert all this so confidently? In 2005, I was lead author of *The State of State Science Standards*.[5] There were five other referees. Most of us are working scientists and teachers (two are biologists). One is a distinguished philosopher of science, also a dedicated teacher. Together, we examined 50 sets of science standards (49 states** plus the District of Columbia), employing well-defined criteria that allowed quantifiable judgments. Prominent among those were explicit measures of content and the approach taken to its teaching.

The result: 15 states flunked, with a letter grade of F. Seven more earned a reluctant D, "just passing." Nine were awarded a C. To be sure, 19 states earned an A or B. And the "A" documents (California, Indiana, Massachusetts, New Mexico, New York, South Carolina, and Virginia) were excellent, in places outdoing the national models on content and in the organization of content for sequencing by grade and (in high school) course. But overall, for the 50 standards, the result was disheartening and no advance over earlier reviews.

Except for those heartwarming "A" documents, most standards suffer from excessive length, obsession with process and pedagogy (including discovery learning, cooperative learning, paeans to constructivist theory and practice, relativist praises of peoples' and indigenous science), and inadequate attention to the kind, amount, and organization of the subject matter: science content. Such standards *cannot* ensure that what happens in the classroom follows from the stated expectations of the standards—that is, systematic alignment, all the way from standards to tests and portfolios.

Biology in State Standards

To illustrate the findings of what has been done well and poorly in state standards, I've sampled a few summaries from the 2005 review of life science standards (remembering that they represent well the handling of the other natural sciences taught in school). It is neither necessary nor appropriate to identify the states referred to in these excerpts from the experts' reviews. State standards are in continuous revision, and there were some remarkable changes, up or down, between the prior and the new set. Thus what was found for a state in 2005 may not be true in 2008. The point is to identify what is right when it was provided in the standards, and what was wrong in far too many of them.

Starting with the (too few) "A" standards on biology, here is a sample expert comment to stand for their content and backup:

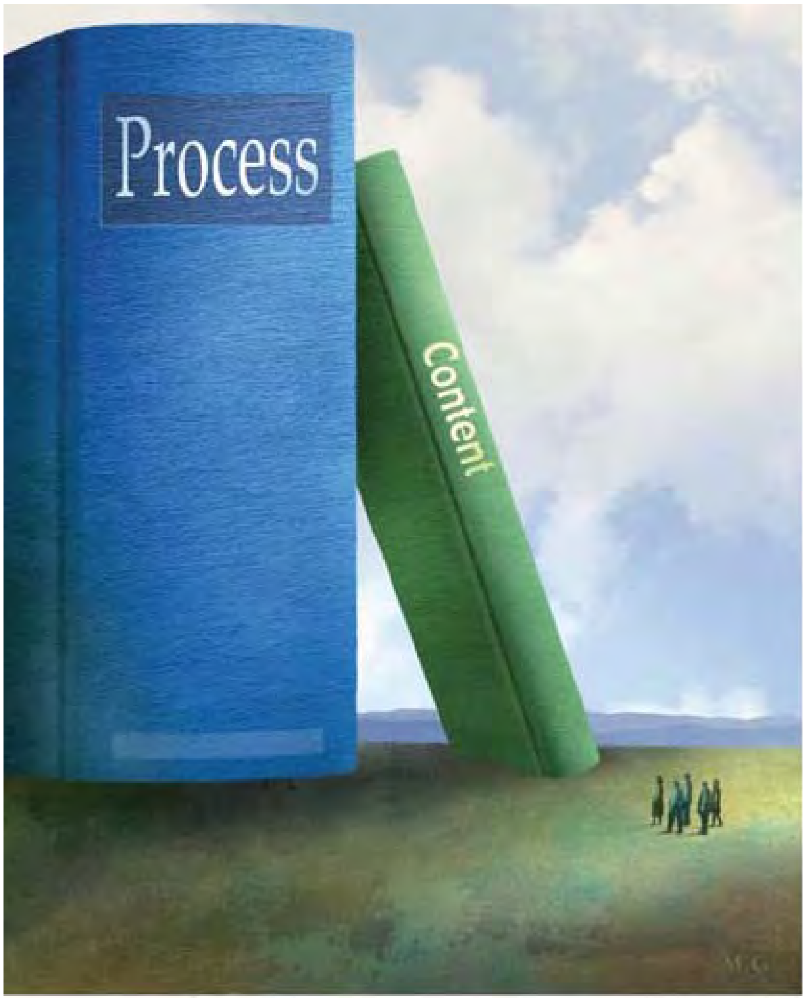
> Life science treatment is sophisticated. It begins in kindergarten, but grade 1 already introduces material that is both serious and interesting to children: "Conduct simple experiments/investigations related to plant needs by changing one variable (food, air, water, light or place to grow) at a time. Students do not need to know the term *variable*." Interweaving of science content with process continues through grade 6. In middle school, cell [sub-organismal] biology is balanced by [community and population] ecology. Genetics begins, and so does the real study of evolution. The high school program opens with the history of discovery in biology! This, to keep things balanced, is matched in the program by biotechnology. Evolution has its appropriate place and is presented without the usual glosses and misunderstandings. The standards draw evidence from a variety of sources, including the fossil record, radiometric dating, genetics, biogeography, comparative morphology, and embryology....

In those seven "A" standards, carefully written, explicit guidance is provided for follow-through, from the standard itself through curriculum design, lesson planning, laboratory and library projects, and by implication to assessments. This need not yield a hundreds-of-pages document. It can be done with less print and paper than is now the norm, if the standards-makers know what they want to do in each science discipline, know what they are talking about, and engage a competent editor.

In 2005, the "A" standards were alone in providing such guidance. Elsewhere there were gaping holes in the depiction of modern biology and, just as frequently, misdirection and mistakes in the content presented. Here are a few observations on several of the inferior standards (of which, remember, there were at least 20 out of the 50) from the experts who reviewed them. The first sample finding discusses standards that earned a D, the rest are for "F" standards.

> For the life sciences, treatments of fundamentals—mitosis, meiosis, and cell division; basic embryology; the genetics of

**At the time, Iowa did not have science standards. It has since adopted a rather disappointing set of science standards.



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evolutionary change—are rather weak, and grade-wise progression is often in the form of mere repetition.

For example, we find: "Evolution vs. Creation: two approaches to help explain the origin of life; the former based on Darwin's Theory of Evolution and the latter on divine intervention".... [Darwin said nothing about the origin of life.*] In modern biology, origin of life is a quite independent discipline and its success, or lack of it, has no effect on the theory of evolution. For grade 7, we find "Have students review the evidence that support and refute [*sic*] the theory of natural selection. The review can be done through textbooks, the Internet, and journals." Despite the implications of this statement, there has been to date no "evidence" that "refutes" the "theory of natural selection." Natural selection occurs....

Treatment of the life sciences is similarly scant.... "The student will understand the theory of biological evolution. Observe and explore the characteristics of plants and animals." That is for 5-year olds[!].... The problem of this entire [standard-writing] undertaking ... is a pervasive vagueness combined with hortative turns of phrase. In grade 2, for example, students will "brainstorm questions that can be investigated." In grade 5, they will be expected to "know that science and technology are human endeavors related to each other, to society, and to the workplace." [Why stop there? Are they not related to beekeeping, ballroom dancing, Mesopotamian architecture...?]

The[se] Content Standards, Benchmarks, and Performance Standards all produce the same letdown: they are too general, and they begin with verbs like analyze, infer, investigate, and evaluate, which are used as though they had no specific meaning.

High school biology is supposed [in these standards] to emphasize biological knowledge in a social/ecological context—biological concepts as they relate to human well-being and the common good. Fair enough; curricula can be built on such themes. But neither the concepts nor the connections are sufficiently spelled out to guide a curriculum or lesson planner. Without [cogent and comprehensible statements of the concepts and] the connections, good intentions [in the social/ecological context] are more self-congratulation than guidance.

There is no more depth in the standards for biology [than in the previously discussed standards for physical and earth/space sciences], exemplified by these selections, for Grade 12: "State the relationships between functions of the cell and functions of the organisms as related to genetics and heredity." Or, "Understand the impact of energy on organisms in living systems," and "Apply the underlying themes of science to develop defensible visions of the future." Local specialists and teachers needn't worry about biology content in planning to comply with such standards.

Simply put, these standards are not serious about science education. They put political correctness—be it anti-evolution or an excessive emphasis on scientific process—over science content. As a result, they are of little value to teachers, assessment writers, and others who are concerned with students' scientific literacy.

If states decided to get serious about science education, what would a no-nonsense, comprehensive, serious approach to science look like? Many models exist—including the seven "A" states discussed above. But for a truly world-class model, states might turn to IB, the International Baccalaureate.†

* "Origin of life" is an active branch of science centered mainly in biogeochemistry and geophysics. Evolutionary biology is concerned with *the history of life on Earth after it got started*. Darwin's theory was concerned with the latter and had nothing to offer about the former. For a useful reference on this question see **www.csuchico.edu/~curbanowicz/DarwinDayCollectionOneChapter**.

IB's Biology Syllabus Is Clear and Specific

See for Yourself with This Excerpt on Cell Theory

1.1.1 Discuss the theory that living organisms are composed of cells.

Skeletal muscle and some fungal hyphae are not divided into cells but have a multinucleate cytoplasm. Some biologists consider unicellular organisms to be acellular.

1.1.2 State that a virus is a non-cellular structure consisting of DNA or RNA surrounded by a protein coat.

1.1.3 State that all cells are formed from other cells.

1.1.4 Explain three advantages of using light microscopes.

Advantages include colour images instead of monochrome, a larger field of view, easily prepared sample material, the possibility of examining living material and observing movement.

1.1.5 Outline the advantages of using electron microscopes.

In comparing electron and light microscopes, the terms *resolution* and *magnification* should be explained. Scanning and transmission electron microscopes should be mentioned briefly, but the principles of how they work need not be discussed.

1.1.6 Define *organelle*.

An organelle is a discrete structure within a cell, and has a specific function.

1.1.7 Compare the relative sizes of molecules, cell membrane thickness, viruses, bacteria, organelles and cells, using appropriate SI units.

Appreciation of relative size is required, such as molecules (1 nm), thickness of membranes (10 nm), viruses (100 nm), bacteria (1 μm), organelles (up to 10 μm), most cells (up to 100 μm). The three-dimensional nature/shape of cells should be emphasized.

1.1.8 Calculate linear magnification of drawings.

Drawings should show cells and cell ultrastructure with scale bars

(e.g., |——| 1 μm).

Magnification could also be stated, e.g., x250.

1.1.9 Explain the importance of the surface area to volume ratio as a factor limiting cell size.

Mention the concept that the rate of metabolism of a cell is a function of its mass:volume ratio, whereas the rate of exchange of materials and energy (heat) is a function of its surface area. Simple mathematical models involving cubes and the changes in the ratio that occur as the sides increase by one unit could be compared.

1.1.10 State that unicellular organisms carry out all the functions of life.

1.1.11 Explain that cells in multicellular organisms differentiate to carry out specialized functions by expressing some of their genes but not others.

1.1.12 Define *tissue*, *organ*, and *organ system*.

IB Biology

The IB program, a rigorous, internationally monitored two-year (junior-senior) curriculum, is mature (40 years old) and highly organized. Curriculum design is under continuous review by experts, many of them university faculty in relevant disciplines. The courses are meant to reflect and, if appropriate, to substitute for, introductory college courses in each subject. Teachers of IB courses must, for example, be trained by IB, and their performance as assessors of student work is monitored.

Using biology, then, as our test object, and in light of the findings on state biology standards already discussed, what can be observed about the IB version of that key science subject?

First, no ambiguity is allowed on what is to be learned and understood. In the standard level IB course, which is comparable, time-wise, to a good American high school biology program, five major subjects are covered: Cells, the Chemistry of Life, Genetics, Ecology and Evolution, and Human Health and Physiology. Associated with these (they are the main sub-disciplines of modern biology) are highly specified and clearly stated aims and objectives. Associated with each of those, for each main topic and in an orderly way, are full sets of "action verbs," together with attached content statements. The action verbs are the same as the terms "analyze," "understand," "know that," etc., so often used vaguely and interchangeably in the state standards documents. In the IB biology course, however, they are very carefully defined so that teacher and student know exactly what each term requires the student to do—annotate, calculate, compare, define, distinguish, outline, etc.

The first topic, "Cells," will serve as a sample of syllabus detail. Under Cells, there are three subheads: Cell Theory, Prokaryotic Cells, and Eukaryotic Cells. Seven hours are specified for teaching all of these. Each subtopic then specifies a number of subdivisions. Cell Theory, for example, has 12 subdivisions (which you can see in the box above), each structured as a sentence beginning with an action verb, which is followed by a brief but carefully written explanation of what that action requires and the appropriate (credit-worthy) results. There is no mandate to teach these topics in the order or with the specific emphases of the curriculum guide, but it is clearly expected that everything will be covered at some time during the IB biology experience. Anything touched upon in the syllabus is liable to appear on an exam at the end. So both the clarity of purpose and program organization are excellent.

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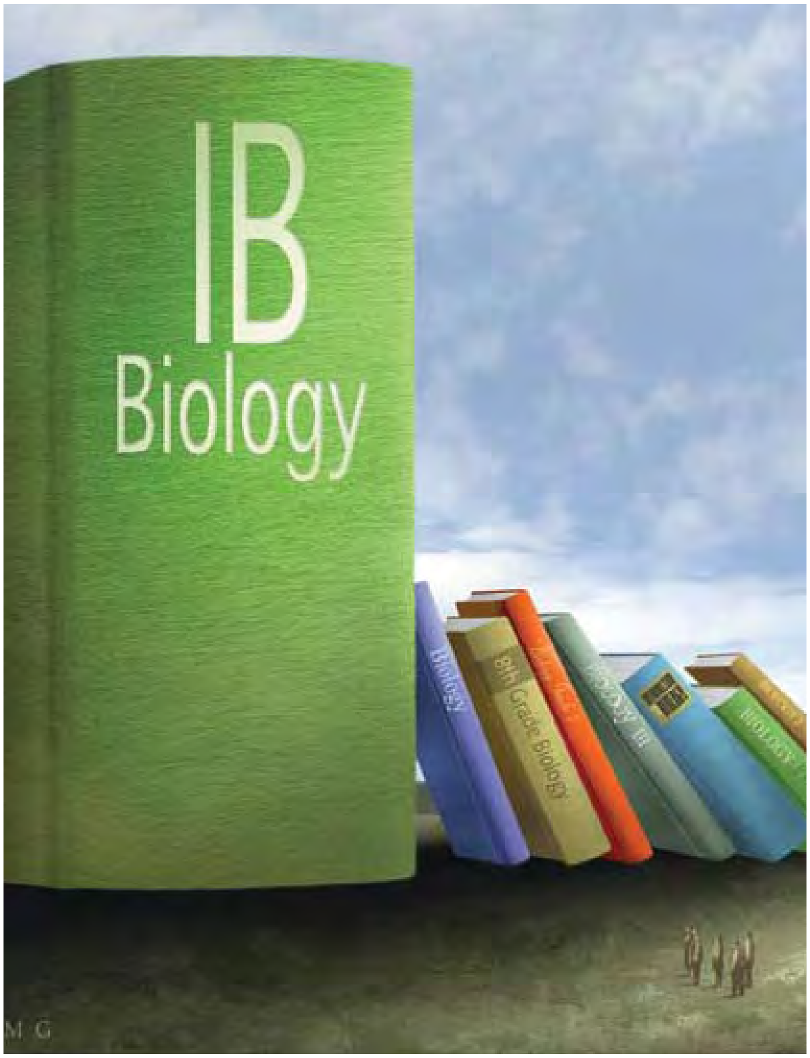
†Some readers may wonder why I chose to highlight IB over Advanced Placement (AP). Although AP does offer a strong biology program, it does not have as many quality control mechanisms as IB. The International Baccalaureate Organization exerts much tighter quality control over the syllabi, as well as the mounting and grading of assessments, so that results from schools all over the world are intercomparable. For a recent review of AP and IB, see *Advanced Placement and International Baccalaureate: Do They Deserve Gold Star Status?* at **www.edexcellence.net/institute/publication/publication.cfm?id=378**.

To learn more about the International Baccalaureate, see **www.ibo.org**.



No state needs to have third-rate standards when there are already first-rate ones available to be copied or at least adapted conscientiously to local need.

There is little that seems to cover all the "process" that is so dominant in states' standards. In fact, more than enough process is captured in the full IB Diploma Program, but it is taught as a very general, independent course dubbed Theory of Knowledge. Every IB student takes it. There, process can be dealt with in appropriate disciplinary context. The biology course is, as it should be, for biology; the same goes for the other IB "Experimental Sciences."

All proceedings of the IB biology course are set forth in the *Introduction* and the *Curriculum Guide*. There is room for some innovation in sequencing and practical work, but it is plain that a specified body of knowledge and skills, elaborately documented in these course materials, is to be acquired by each student, and tested. One would have to concede that this is teaching to the test, and with a vengeance; but a student who absorbs this specified body of knowledge and skills will acquire a good command, at the average first-course level for a good American college, of the current state of the science.

Student achievement is measured by a linear combination of grades from two independent evaluations. Written tests are graded *externally* by trained examiners, and are worth 76 percent of the total course grade. An internal assessment is graded locally by the teacher (but centrally monitored by the International Baccalaureate Organization). It covers practical, interdisciplinary, and independent student work. This is a system of assessment that leaves nothing to chance or favoritism (or its inverse). Credit is available for good work in biology and for nothing else.

The issue of conceptual or "higher-level" learning, so central to our arguments about what should be in a set of standards, disappears, handsomely as it should, when an objective reader who knows biology reads these tests. They require plenty of "free response" or essay or analytical-thought answers. But not one of the many questions in the several tests that make up an IB assessment can be answered as a pure exercise in *conceiving*, or of *process*. Every such question must first be understood; the meanings of its words, its technical terms, and its graphics, when those are present, must be known. The contexts of their use must be recognized. And once they are, the needed conceptual manipulations can be undertaken or will, often, fall out of the definitions, the "factoids," making up the question's language.

This is the cogent answer to fashionable handwringing about conceptual learning versus "mere facts." *For real knowledge of a science subject, the two are never really distinguishable. Concepts are manipulations of facts. Facts are certainties brought into existence by concepts.*

Is the IB approach for every student? Probably not. But nobody has offered a good reason why our state standards should not move in the direction of excellence and detailed guidance exemplified by IB's best features. The political reasons offered for incompetent standards produced in too many states have no evidentiary support. No state needs to have third-rate standards when there are already first-rate ones available to be copied or at least adapted conscientiously to local need. ☐

Endnotes

[1] N. Koertge (2007). "Political Correctness in the Science Classroom." Paper prepared for the American Enterprise Institute Conference, "Reforming the Politically Correct University," November 14, 2007. Available online at **www.aei.org/docLib/20071115_Koertge.pdf**.

[2] See Boghossian, P. A., "What the Sokal Hoax Ought to Teach Us." *Times Literary Supplement*, December 13, 1996, p. 14-15.

[3] Forrest, B. and Gross, P. R. (2007). *Creationism's Trojan Horse*. New York:Oxford University Press.

[4] Gross, P.R. (2000). *Politicizing Science Education*. Washington, D.C.: Thomas B. Fordham Foundation.

[5] Gross, P. R. et al. (2005). *The State of State Science Standards*. Washington, D.C.: Thomas B. Fordham Institute. Available online at **www.edexcellence.net/institute/publication/publication.cfm?id=352**.