The Changing Image of Biology

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THE current science education reform movement has been underway since 1970. Since then, hundreds of local, state and national committees have proposed curricula simply by making science courses more rigorous or updating the subject matter. The result has been a list of concepts, principles and theories regarded as "standards" because they are to be learned by all students. A renewed emphasis has also been placed on teaching science as inquiry.

Neglected in reform efforts so far, however, has been the changing face of the science of biology itself. Because of changes in the nature of science and its social implications, the time has arrived to *reinvent* school science curricula. The purpose of this article is to summarize the new image of biology and its future, and to relate the new biology to science education.

Changes in the Ethos, Culture & Practice of Biology

Over the past 50 years a mosaic of changes has taken place in the nature of biology. Today, more than 50% of all research scientists are employed in industry rather than in a university. In both settings, however, the focus is on strategic or applied research and on practical applications rather than on the traditional seeking of new theories, laws or principles. Strategic research is problem-oriented and considers elements of risk.

The Explosion of Biology Knowledge

How many research fields characterize today's science is unknown. One indicator is the number of research journals: The number is believed to be around 80,000, of which 29,000 are new since 1979. The largest number of research journals is in the biological sciences, where there are 20,000, and this number excludes journals in the medical and health fields (*Chronicle* 1990).

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Classifying Science Knowledge by Discipline

Throughout the past 400 years science knowledge has been classified by disciplines. Biology, chemistry, physics and earth sciences have been the framework for the teaching of science in schools and colleges. The tremendous increase in science knowledge has led in the past to the fractionating of disciplines into research fields. Currently these fields are being hybridized into new fields of research, each having distinctive characteristics, modes of research, language, and theoretical structure. The American Chemical Society in 1991 stated, " ... like a species that has moved into open niches, evolved, and diversified, chemistry can no longer be regarded as a discrete scientific field. Its methods, concepts, and practitioners are penetrating virtually every nook and cranny of science and technology" (Keer 1991). The same observation is true of biology.

One characteristic of today's science is the shift in dominance from research in the physical sciences to studies in biological fields. At the same time, biology research has moved away from evolutionary biology toward the adaptive biological and social behaviors of human beings. The new biology is carried out more in human and social contexts, and data are more qualitative than quantitative in nature. The intellectual skills required to do research in today's biology are mostly those of problem solving.

Biology as a single discipline no longer exists, but is divided into fields. Some of today's biology fields are found in Table 1.

Team Research

The revolution taking place in the sciences has changed the practice of biology. One characteristic is the development of team research. Owing to the hundreds of new fields of research and their complicated nature, it is beyond the capacity of one person to advance the resolution of most problems. Today, 95% of research reports are multiauthored; at the beginning of the century the number was 5%. A study of published science reports in 1991 found an average of 5.3 authors; no research report had fewer than four authors (ISI 1993). It took 17 years of cooperative experimental work on the part of 440 physicists to provide convincing evidence that the

Table 1. A partial listing of today's biology fields.

biogeography	biobehavior
bioengineering	bionic technology
biopolitics	chronobiology
geomicrobiology	gerontology
human biology	ergonomics
biosafety	bioclimatology
biomathematics	biorhythmics
paleobiology	microbiology
paleobiogeography	immunology
biogeology	human ecology
ecological genetics	ethnobiology
astrobiology	biomaturation
geobiology	biopsychology
bionutrition	biorganic chemistry
cultural anthropology	bioecology
environmental chemistry	archaeobiology
bioenergenetics	biodiversity
pathobiology	pharmacology
biophysics	microbial ecology
global systems	computational biology
biochemistry	sociobiology
biogeochemistry	human gene therapy
genetic engineering	bioethics
chemecology	biomethanogenesis
biochemical engineering	biosensors
bioinformatics	environmental biology
biogerontology	population biology
neuroscience	biotechnology
bioinorganic chemistry	behavioral neuroscience
molecular genetics	biomechanics
paleoecology	bionomics
human engineering (ergonomics)	neurochemistry
biomedicine	biomedical engineering
organometallic chemistry	photobiology
bioelectrochemistry	neurobiology
molecular biology	cell biology
structural biology	

In addition, there are more than 300 other named fields of today's biology.

top quark actually exists. Team research is based on a point of view that the pooling of minds for collective reasoning provides a broader and more insightful outlook on problems than that of an individual.

Students Today

The context for a human science curriculum is the student at varying ages of development from kindergarten through grade 12 (Hurd 2000). The biological and social needs of individuals vary with age. Every science curriculum reform effort of this century has listed as a goal "meeting the needs of students." What these needs are at varying grade levels has yet to be identified. The present emphasis on standards is stated in terms of the principles, theories and facts of science as they exist today, rather than in terms of the adaptive needs of students as they grow up, mature and live. Biology curricula are sought that are at the center of our culture and its trends toward the future, and that view humans as unique animals. This will require a curriculum that integrates aspects of the social, physical, humanistic and behavioral sciences.

The Future of School Biology

The character of most biology courses today is obsolete. Efforts to bring about change are focusing on the study of life in the context of human beings and their growth and development. This appears to be the best way of attempting to integrate the hundreds of fields of biology. At the same time it is essential to consider a curriculum framework that recognizes we are living in a knowledge-intensive age, a world of rapid change that is changing both the personal and cultural evolution of human beings.

We are now at the beginning of a new biological revolution, one that emphasizes biotechnology and medicine. The subject matter of new K to 12 biology is structured in terms of significance in human affairs. It appears that the new biological revolution will have an even greater societal impact than the technological revolution of the 20th century. "This new biological revolution will require profound decisions with respect to the ethical, legal and social issues that are sure to arise, decisions that will affect our personal lives and society in ways we have not seen before" (Carrano 1999).

The new dimensions of biology will have aspects in ethics, legal affairs, and perhaps moral conditions. Research in today's biology has become more an art than a mode of inquiry. Since the beginning of the current reform movement in science education (1970), the call has been for a reinvention of science courses to match science itself. The fractionation of biology into thousands of research fields means that the evolutionary model is a view of biology limited to the physical evolution of living organisms, no longer adequate to represent the culture of biology. As Albert Einstein once commented, "The significant problems we face cannot be solved at the same level of thinking we were at when we created them." Proposals for a new biology have centered on a curriculum characterized as human biology or life science replacing the century-old evolutionary and career-oriented curricula.

Students need a biology curriculum that is centered on human beings and the realities of life and living. This approach includes relating biology to the common good of humankind, accenting areas such as wellness, the environment, human ecology, and other applications of biology. For the student a human biology curriculum is one that can be lived and will result in a richer, more satisfying life.

References

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