Kambadur Muralidhar
Department of Zoology
University of Delhi
Delhi110 007, India.
Email: kambadur@hotmail.com

Biology as an Integrating Natural Science Domain A Proposal for BSc (Hons) in Integrated Biology

In this article, I present arguments in support of teaching biology as one of the integrating natural science domains at the higher secondary school and the undergraduate levels and not as phylogenic group-based subdisciplines like botany, zoology and microbiology or functional subdisciplines like genetics and biochemistry. This is possible only if we conceptualize biology and try to understand its philosophical underpinnings.

Introduction

Natural Science differs fundamentally from humanities and social sciences in the sense that Natural Science has a clear objective which is understanding nature. Both form and function have to be understood. Natural science has a unique scientific method or rigour with which it works. Natural science is amoral – neither moral nor immoral. Scientists have made value judgments on science and one such currently accepted value of science is that it must serve human welfare. Therefore, when we teach science we teach both basic and applied aspects. Our day-to-day lives are influenced by science and so does national development and progress. As nation building requires trained manpower, capacity building and serving, knowledge bank of the society is the immediate goal of academicians within the ambit of the ultimate goal of understanding the structure and functioning of nature. Let us try to understand the nature of biology.

Nature of Biology

Biology, the science of life, is a historical science. It gives us the history of life on earth. It is good to understand the living state from a physical perspective. It is a non-equilibrium steady state. Systems at equilibrium do not and cannot perform work. The law of thermodynamics states that every system moves towards

Keywords
Biology, undergraduate teaching, conceptualised biology, reductionist biology.

equilibrium spontaneously. Hence, living is a metaphor for preventing oneself from reaching equilibrium. This is made possible by constant input of energy into the system. Energy is obtained by the breakdown of chemical bonds in dietary components. Energy is utilized and transformed as osmotic, metabolic and mechanical work. Environmental factors (physical like O_2 tension, temperature, etc; chemical like pollutants, dietary toxins, etc; biological like other organisms) constantly disturb the steady state. Organisms sense and respond to environmental factors to get back to steady-state. Sensitivity and response to environment, growth and reproduction are the cardinal features of living organisms.

Biology addresses three questions. How did life originate and living creatures evolve? Can we understand internal (physiology) and external (behaviour) living processes through physics and chemistry? What has biology contributed to human welfare?

Biology addresses three questions. One, how did life originate and living creatures evolve? Two, can we understand internal (physiology) and external (behaviour) living processes through physics and chemistry? Three, what has biology contributed to human welfare? There are various theories of origin of life – some untestable and others testable. We are far from creating in a test-tube, the simplest of life forms *de novo* from non-living material. However, we have learnt to manipulate and engineer existing life forms into newer forms.

Evolution from the Darwinian point of view is more or less an accepted idea by all biologists. All the currently living organisms are related, to varying degrees, to all the organisms that ever lived in the past and to those that ever will live in future. The relatedness in structure and function is because of shared genetic material that directs all living processes. The functioning of the genetic material (genes and non-genes) results in all of the physiological, developmental, behavioural and evolutionary phenomena. While some details of this translation of genotype to phenotype are known, some other aspects are not yet understood. What is known of the translation as well as of the processes (physiological, developmental, behavioural and evolutionary) constitutes the bulk of biochemistry and biophysics. Among many things, what is still unknown is the mechanism that incorporates the concepts of time and space in these processes. Whether it is gene expression

When we add humans as study material to biology, an entirely new dimension to biology appears.

or growth or behaviour, both intensity and duration appear to be involved. How do biological systems sense among other things, time and space?

From the days of Rene Descartes, anthropocentrism has been the key approach for both generation of knowledge and utilization of knowledge. When we add humans as study material to biology, an entirely new dimension to biology appears. Human biology and human evolution is of utmost importance to the human race. Three aspects are worth discussion. One, like in plant, animal and microbial science, there has been considerable progress in human biology. Two, there are problems to be answered from epistemological, ethical and philosophical perspectives and three, evolution of the human brain and its higher cognitive functions is the most challenging aspect of understanding biology. It is important to note that the observer and the observed become one and the same here. The highest form of knowledge becomes self-knowledge. Biology, metaphysics, culture and philosophy merge at this level.

Growth of Biological Knowledge

The history of biology as a branch of human knowledge is hardly 3000 years old at the most. Progress in any branch of knowledge much more so in science, depends upon the availability of tools and techniques. When observation (through eyes) was the only tool, branches that could grow were taxonomy, behaviour and natural history. For centuries, this was biology. For the convenience of handling data, zoology and botany were diversified. When the microscope became available, other disciplines such as histology and microbiology were born.

The history of biology as a branch of human knowledge is hardly 3000 years old at the most.

When biologists started breaking down the organism to smaller and smaller components, reductionist biology took roots, whereby biochemistry, cell biology, molecular biology, biophysics, genetics, and physiology grew and flourished. Phenomenal progress in the advent of tools and techniques, not to speak of instrumentation made this possible. In the 20th century, while physics and chemistry continued to flourish as natural sciences relating laboratory work to natural phenomena, biology became more and more an experimental laboratory science, delinked from natural history. Funding agencies also contributed to this misery. How did this affect university departmental structure with regard to teaching of biology? More than a dozen departments exist teaching some fragment of biology (e.g. Zoology, Botany, Microbiology, Genetics, Life Sciences, Medicine, Biomedical Science, Biochemistry, Biophysics, Physiology, Anatomy, Pharmacology, etc.). This is academically an unsound and unhealthy development. While research can only be done in a small focused area, teaching has to be at a discipline level. What is a discipline? A set of self-sustaining concepts and techniques and questions constitute a discipline. Physics, Mathematics, and Chemistry are disciplines. Fragments of biology are not disciplines. Precisely for this reason in the last 3-4 decades there has been talk of interdisciplinary sciences and areas of research and teaching! The fact is people created disciplinary boundaries for fragments of biology, created departments in their names and perpetuated a tunnel vision of biology. I am reminded of the elephant and four blind-folded men describing it! It is time we dismantle all these departmental structures and create a single department and a single discipline of Biology. We must integrate both vertically (Physics, Chemistry, Mathematics and Biology) and horizontally (Zoology, Botany, Genetics, Biochemistry, and Microbiology). Information transfer cannot replace understanding and concept-driven teaching. This is more so at the undergraduate level.

While research can only be done in a small focused area, teaching has to be at a discipline level.

Undergraduate Teaching in Biology

Because of historical accidents, we are faced with at least a dozen biology related undergraduates degree courses (e.g. Zoology, Botany, Microbiology, Biotechnology, Bioinformatics, Sericulture, and Genetics). A fundamental flaw in these courses is a misunderstanding of what is undergraduate level education. Put in simple words, it is a transition from 4-5 discipline study stage (high school) to one discipline study. At the undergraduate level, the student should get exposed to a set of courses leading to conceptual and broad understanding of a single core discipline

We must integrate both vertically (Physics, Chemistry, Mathematics and Biology) and horizontally (Zoology, Botany, Genetics, Biochemistry, and Microbiology)

Box 1. Course Structure for a BSc(Hons) Biological Sciences Programme

I Year (Foundation Course) Course Title	II Year Course Title	III Year Course Title
Physics	Biodiversity and Bioprospecting	Bioenergetics
Physics Laboratory	Metabolism and Tissue Function	Genome Biology and Evolution
Chemistry	Ecology	Differentiation and Morphogenesis
Chemistry Laboratory	System Physiology and Behavior	Growth and Reproduction
Biology	Biology Laboratory I	Biology Laboratory I
Biology Laboratory	Biology Laboratory II	Biology Laboratory II
Mathematics for Life Sciences	Bio-organic and Bio-inorganic Chemistry	Chemistry and Biology of Biomacromolecules
Laboratory: Electronics and Modern Instrumentation	Chemical Science and Biomaterials	Chemical Physics of Membrane
Laboratory: Analytical Techniques	Chemistry Laboratory	Biochemistry Laboratory
Laboratory: Computer Science and Informatics	Biology Laboratory III	Computational Biology Laboratory
Environmental Science	One Elective Subject from:	One Elective Subject from:
Technical Writing and Communication in English	Geosphere-biosphere Interactions (Paleobiology)	Molecular Paleontology
	Human Biology	Human Biology

Based on a new undergraduate course in integrated biology at Sri Venkateswara College, University of Delhi.

with all its ramifications (e.g., Philosophy, Social Science, Literature, Physics, Mathematics, Biology, Chemistry, Geology, and Economics) (*Box* 1). If one is clear about the aims of undergraduate education, it would be fairly simple to see sense in what has been said just now. Undergraduate education (between 18-21 years of age) should help in developing an integrated personality through combination of self learning, formal teaching and extra-curricular activities. It is a period of formal education where physical, mental (technical), cultural (emotional) and spiritual development should be realized to its maximum potential in each student. The experience should enable the students to either go further for employable training leading to jobs or for higher education, teaching and research. Truly motivated and talented students should pursue research and higher teaching. Post-graduate education should be integrated with research. Limited intake and quality output should be mandatory for research departments.

Undergraduate education should help in developing an integrated personality through combination of self learning, formal teaching and extra-curricular activities.