10-1973

The Other Side of Biology

John J. Janovy Jr.
University of Nebraska-Lincoln, jjanovy1@unl.edu

The Other Side of Biology

By JOHN JANOVY, JR.

Department of Zoology
University of Nebraska
Lincoln, Nebraska 68508

A scientist of world renown recently retired. He had been a participant in many scientific expeditions to far corners of the globe, in many international meetings, a charter member and past president of the leading international society in his field, and was a prolific and respected author. He made his professional name classifying parasitic worms and dealing with their phylogeny in relation to host geographic distribution. His place was taken by a younger man, also a classifier of worms. The difference between the two men is that the younger man, a tenured associate professor, is *now enrolling* in courses in calculus, advanced statistics, and computer programming, taught by fellow faculty in departments often considered unrelated to his own. In the same department with the young taxonomist are five physiologists and cell biologists. Among the five are a senior faculty member with over half million dollars in federal money for cancer research and an associate professor who is also a NIH Career Development Scholar in developmental biology. The five have one characteristic in common: within the past three or four years all have taken regular courses in advanced chemical techniques and computer programming. There is much talk about the merging of physical science technology and mathematics with biology, but these professional "practicing" biologists are demonstrating first hand what the talk is all about. In some cases, they are forced into formal advanced training because of the demands of their graduate students for research opportunities in modern biology. In other cases they have arrived at points in their own research where no more progress can be made without the use of tools previously considered outside the realm of biology. These faculty will expect future graduate students to be handy with these tools. Unhandy students will be rejected. The above situations are true at the University of Nebraska, where basic biology ranks somewhere below basic football. At institutions where the relationship is reversed, the expectations of faculty regarding potential graduate students are likely to be magnified many times.

The cruelest lesson for potential biology graduate students may lie in the years ahead, when as fresh Ph.D.'s they begin searching for their first secure job as well as the opportunity to put their many years of training into use. In 1972, few advertised academic positions drew less than 200 applicants. Every search committee in the country has probably had the experience of turning away dozens of qualified applicants, each of whom had more formal training in physics, chemistry, and mathematics than some graduate students in their own departments are willing to take. The person hired is likely to be the one who not only has the formal training, but has demonstrated his or her ability to apply the physical, chemical, and mathematical concepts to biology. After all, the new faculty member will probably be teaching introductory biology; and a glance at one of the best selling introductory texts reveals extensive material on everything from chemical bonding and thermodynamics to the chemical basis of mutation and energy flow in ecosystems expressed in molecular terms (see Curtis, 1968). The search committee can either hire a person who is comfortable with these concepts, or it can hire someone who is not. In the latter case, the department will have purposefully opted for a teaching program that is behind the times (see Kornberg, 1969). If such departments exist, they make an effort to keep it secret. And the topic of discussion here is the *introductory course.* The demands for familiarity with the concepts of chemistry, physics, and math only increase at higher levels.

This demand is exemplified by the graduate admission practices of a large midwestern state university biological sciences department, where, in general, high verbal and quantitative GRE scores will override a poor score in advanced subject matter, but even students with high advanced scores are not admitted unless they also show high verbal and quantitative ratings. This department is obviously looking at graduate students on some basis other than advanced knowledge of its own subject matter. Graduate admission policies of other universities reflect the same thing by requiring a specific set of courses in chemistry, physics, and math on the undergraduate level. Graduates who are admitted without these courses must take them without credit before starting graduate studies, and are not eligible for financial aid until the courses are satisfactorily completed. Universities try to choose graduate students with high potential. What these policies say, in effect, is that these departments feel that potential is best revealed by proven skills with the "tools" of science rather than by extensive knowledge of the accomplishments of science. Biology has few unique tools; mostly it has borrowed from the physical sciences and mathematics.

Historically, the involvement of the physical sciences and mathematics in biology became visible with the birth of molecular biology, an area conceived and nurtured by men like André Lwoff (Monod and Borek, 1971) and devastatingly popularized by its leading folk hero, James D. Watson, co-winner of the Nobel Prize for elucidation of the "genetic code." Not since the publication of Darwin's theory of evolution has a concept had the impact of this discovery upon the field of biology in general, as well as society's impression of what it can do with the biological sciences. In one five-year bracket, encompassing approximately the years between 1958 and 1963, virtually all general biology and most genetics texts were rendered obsolete. Within the last five years developments in molecular biology, stemming from the genetic code concept, have started reaching the popular literature in the form of predictions about the possibilities of genetic engineering to cure hereditary diseases, production of special biological types, etc. (Toffler, 1970). The lesson for the purposes of this article is that the original work of Watson involved the fusion of the fields of physics, chemistry, and mathematics, while the classical biology directly involved in the original work consisted of learning how to grow the material necessary to get the DNA! Watson himself, primary engineer of the discovery, recognized the situation early and took time in the middle of a productive career as a microbiologist to learn the mathematics and physics necessary to carry his research to its logical end (Watson, 1968). However, if the competition for basic biological science positions ten years from now will include new doctorates who *started* their graduate training with a strong math and physical science background, then will those who plan to wait until the middle of their professional careers to acquire these tools be in the running? Probably not.

The effects of the use of math and physical sciences by biologists are obvious in the original literature. For example, *Experimental Cell Research*, one of the leading and more distinguished outlets for modern biology, should be expected to be biased toward chemical and physiological studies. It is not surprising, therefore, that in a recent issue, out of 38 regular length papers, 24 dealt with nucleic acid and/or protein synthesis, six with chemical action or site of action of various compounds, three with ultrastructure, and one with electrophysiology. Only four of the 38 could be considered classical in that they were not concerned *primarily* with chemical reactions, the control of reactions, or ultrastructure. However, even these four papers involved lines of investigation leading directly to the study of reactions or ultrastructure.

Close to the other end of the spectrum of interest lie such publications as the *Transactions of the American Fisheries Society* and the *Journal of Parasitology:* "organismal" in their approach, the former by its title admitting interest in applied biology and the latter long a major outlet for species and life cycle descriptions. However, in a recent issue of even the *Transactions*, three of 19 regular length papers assumed an understanding of chemistry or theoretical statistics well beyond that normally acquired by the average biology master's candidate, and probably also well beyond that normally acquired by the average doctoral candidate. The *Journal of Parasitology* presents only a slightly more classical facade. In a recent issue four of 24 regular length papers contained chemistry, physiology, or statistics sophisticated enough to require advanced training to understand the paper, and six of the 19 research notes contained a similar level of chemistry or statistics.

The rudest awakening, however, may lie for the budding professional biologist in one of the hottest "new" fields, one which combines social concerns, politics, and brute emotionalism with biology: the field generally known as "Ecology." The University of Nebraska has for several years received applications for more potential graduate students interested in "ecology" than in all other recognized areas of biology. At the faculty level, funding is now available for ecologists even while it is drying up for molecular biologists (excluding cancer researchers). It should be of little surprise, therefore, to hear bar room conversations between molecular biologists decrying the current national emphasis as a retreat from the significant and sophisticated back into the classical and applied. There is a distinct population of molecular biologists who harbor an unshakable image of an "ecologist" as one who counts plants in a square or who does junior-high-level chemistry on a rack of water vials, usually for gross sums of federal research money. Where such images originate is difficult to discern, but it is fairly certain that they are not supported by the ecological literature. The winter issue of *Ecology* (now in its 53rd year) included as a part of more than one third of its papers differential equations, multivariate analyses, or computational programs more sophisticated than *any* of those in *Experimental Cell Research.* As if this were not enough, witness the startling but merciful inclusion of a generic and specific index in Florkin and Schoffenfiels' (1969) short but powerful text on the biochemical aspects of ecology! At the present rate, the field of ecology faces a serious "technology transfer" problem in the very near future, due primarily to the general inadequacy of the political public, and its scientific advisers, to deal with current research in the field.

The lesson from these elementary observations on some rather typical journals is obvious: the journals concerned with cell biology *assume* a primary reader concern with chemical reactions and the control of reactions, and tolerate classical approaches as long as they point toward biochemical problems. The journals with long traditions and deep roots of classical biology, while maintaining their roles as outlets for organismal level observations, have nevertheless begun to serve as the vehicles by which investigators make known their applications of the techniques and philosophies of chemical and mathematical biology to the problems of organismal level relationships. And the publication representing the most popular field of biology has outclassed them all in its move to sophistication in mathematics and the computational sciences! Of course we have not mentioned "new" journals, e.g. the *Journal of Theoretical Biology,* now in its 13th year, which if measured against potential reader ability, properly belongs in the mathematics library rather than the biology library!

One of the last bastions of classical biology, and likely classical science in general at the graduate level, is the language requirement for a doctoral degree. The language requirement has come under assault from a variety of sources, including molecular biologists who feel more of a need to acquire skills of chemistry than the skills of German grammar. The sympathy for removal of the language requirement has not been great, particularly among older faculty who, after all, lived through foreign language courses. The sympathy for substitutions, however, is great, even among older faculty who are successful scholars in their own right. The substitutions that are being made are typically computer science and biochemistry, with an occasional program utiltizing statistics without the accompanying computational courses. The substitutions are even called "research tools" in graduate school bulletins.

"Ontogeny recapitulates phylogeny" is a shibboleth that not only dignifies its current strong proponents as historical figures, but also has been somewhat of a casualty of the sophisticated approaches to all of biology forced upon us by the leadership of people like J.D. Watson. Biologically, those classicists who study trees instead of forests like to point with pride to the downfall of this phrase as a guiding philosophy, evidence, they feel, of the increase in acuity that has occurred in their particular disciplines. Molecular biologists, if they know the phrase, regard it as a peculiar trapping of a group that has not chosen The Way. The merits of the concept as a guide to the study of biology may indeed have been rendered vulnerable by the increased sophistication of science since World War II. However, even practitioners of sophisticated sciences must realize that as "ontogeny recapitulates phylogeny" loses respect as a biological principle, it gains validity as an indicator of the manner in which the education of individuals proceeds.

There is abundant evidence that the professional development of the individual scientist recapitulates not only the cultural development of man as a species, but also the historical development of his particular discipline. In many fields of zoology, for example, this means for the individual an early exposure to and fascination with animals, perhaps as a child at the zoo, subsequent random and unsophisticated experiences with "discovery" in high school and as an undergraduate (these often involve descriptive zoology typical of that practiced in the 1800's and early 1900's), serious discovery involving training in use of tools of the trade as a graduate student, and finally serious efforts to synthesize at the boundary between known and unknown in his discipline. History shows that individuals who are unable to draw upon a broad range of synthetic materials are rarely able to cross that boundary more than a few steps, while individuals who are able to put together ideas built from the strongest tools available, regardless of their area, are those who go the furthest into unknown territory. The latter are those who establish the paths along which many subsequent scholars follow. For the biologists of the 1970's and 1980's, this means that those who establish the paths will be those who forge their tools from mathematics, chemistry, and physics.

Literature Cited

Curtis, Helene. 1968. Biology. Worth Publishers, New York. 862 pp.

Florkin, M., and E. Schoffenfiels. 1969. Molecular Approaches to Ecology. Academic Press, New York. 203 pp.

Kornberg, A. 1969. Current problems in gene action and science education. In: Biology and the Physical Sciences, S. Devons, Ed. Columbia University Press, New York. 379 pp.

Monod, J., and E. Borek, Eds. 1971. Les microbes et la vie. Columbia University Press, New York. 312 pp.

Toffler, A. 1970. Future Shock. Random House, New York. 505 pp.

Watson, J. D. 1968. The Double Helix. Atheneum, New York. 226 pp.