# Helping Nonmajors Find out What's So Interesting about Biology

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# Education

# Helping nonmajors find out what's so interesting about biology

What should college students who are not science majors learn about biology? At our school and many others, it has been traditional to provide such students with a survey course in general biology, perhaps with an emphasis on information that will help them make decisions in the future about such things as nutrition, health care, and environmental issues. This approach was simply a variation of the way we teach biology to biology majors. We offer majors a year-long survey course to provide an overview of the discipline, followed by advanced courses that explore more narrowly defined topics in greater depth. Although there are obviously differences in the extent and depth of coverage of material in introductory courses for majors and nonmajors, the underlying philosophy in each case is that the best introduction to biology is a broad, though often shallow, sampling of the many biological subdisciplines.

We have become concerned that this approach is particularly unsuitable for nonmajors for at least three reasons. First, although we will have several more opportunities with our majors to revisit in depth what they have learned in the introductory courses, it is unlikely that nonmajors will ever take another biology course. Thus, they will not have a chance to explore any particular topic sufficiently to feel that they have understood it thoroughly. Second, given that survey courses typically present an array of currently accepted biological facts in a doctrinaire manner, we felt that, however well they learned the information during the course, because they have no context for organizing their knowledge the students would not remember much of this information beyond the end of the semester. Indeed, our experience with the majors convinces us that, by their second year, most of them have forgotten large amounts of what we thought we had taught them their first year. It is unlikely that nonmajors will remember any better. Finally, we were convinced that a general survey of biological facts and information does not convey to students a sense of why biologists find their subject so exciting nor does it provide them an understanding of how we try to learn about the world of living organisms.

We have therefore taken a different approach with a course we recently developed at Pomona College for nonmajors, choosing a few important topics that we could explore extensively and providing a historical and social context to help students understand how these ideas are related to their personal interests and concerns. We thereby aimed to provide students with an appreciation for what science is and how it is practiced as well as an understanding of how some of the most central ideas in biology were developed and tested.

Because we wanted to explore biological ideas in serious depth during the course of one semester, we chose only two—the two ideas that we believe provide a unifying framework for all of biology: the hereditary mechanism, which explains why there is continuity of appearance and function over generations, and the idea of evolution, which explains how life forms have changed over Earth's history. Because these two ideas are logically related, they provide an ideal framework for such a course. We called the course "DNA and Evolution."

## Design of the course

There is no textbook designed for a course like this one. Instead, we relied on three kinds of readings. First, we wanted a general introduction to each of these ideas, their history, and their implications that was written for an intelligent reader who had no special science background. We chose *Darwin for Beginners* (Miller and Van Loon 1982) and *DNA for Beginners* (Rosenfeld et al. 1983), which are part of a series published by Readers and Writers Press. Despite their deceptive titles, these books present rather sophisticated treatments of these ideas, yet at the same time are highly accessible. Students enjoyed their readability and wit, and the cartoon-style format provided students with memorable (though, regrettably, sometimes offensive) visual representations of ideas, people, and events.

Second, we wanted students to understand first-hand the process of discovery. Therefore, we asked them to read some original writings. We included chapters from Darwin's *Origin of Species* (1859), Mendel's *Experiments in Plant Hybridisation* (1868), the Avery et al. (1944) account of transformation, and Watson and Crick's (1953a,b) original formulation of the DNA double helix.

Finally, we wanted the students to read some modern-day commentary by practicing scientists on these ideas and their implications. Therefore, we assigned articles from *Scientific American* (Anderson and Diacumakos 1981, Beadle 1948, Crick 1954, 1966, Mirsky 1968, White and Lalovel 1988), as well as writings for a lay audience by Stephen Jay Gould (1976, 1985), Richard Lewontin (1982), E. O. Wilson (1975), Evelyn Fox Keller (1983), Lois Wingerson (1990), and Douglas Futuyma (1983).

The class had an unusual format for a nonmajors science course. Of three one-hour class periods each week, two were devoted to lectures given by one of us. The third period each week was a discussion. We di-

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vided the 30-person class in half, and each of us led one of the discussion sections. Students were required to come to each of these sessions with a question to write on the chalkboard, either a question about the reading or lecture or a question they derived from their own experience or the news. These questions formed the basis of the discussion. The questions were occasionally forced ("What did Darwin mean by the term 'sport' on page x?"), but the questions and the discussion that ensued inevitably led to lively talk and the asking of many more thoughtful questions. For example, an African American student who had a Caucasian ancestor wondered about the chances that any of her children would be born with blue eyes. Another student exclaimed one day, "You mean I have the same genes in all the parts of my body? Why do they look so different?" thus articulating one of the major questions in developmental biology.

This discussion format offered two advantages over a course consisting solely of lectures. First, it enabled us to monitor students' understanding of the material covered in lecture and to adjust the pace and content of the lectures accordingly. Second, and perhaps more important, it enabled students to pursue issues of interest to them in greater depth than we might have chosen to do. For example, a discussion of the mechanics of meiosis and mitosis became a consideration of the consequences for human health of unequal segregation of chromosomes or unequal crossing over. Letting the students determine the direction of these discussions created for them a personal involvement with the subject matter and led to animated and engaged sessions that often extended beyond the allotted class time.

This format also allowed us to deemphasize the importance of examinations in determining students' grades in the class. There were four examinations, with short essay-style questions; students were permitted to drop the lowest grade of these four. In addition, students received a grade for their participation in discussion sections, determined by how often their participation consisted of mere attendance, the bringing of discussion questions to put on the board, or engagement in the classroom conversations. Finally, we provided students with positive incentives for completing the rather heavy reading assignments by giving them a few extra-credit points each time they turned in a page-long summary of that day's assignment. The sum of these measures determined a student's grade, which was based not on a curve, but rather on a fixed scale that we published in the syllabus. This way students felt encouraged to cooperate with their fellows and could gauge how much effort they needed to invest in the course to earn the grade they hoped to receive.

## Lecture topics

The lectures themselves were structured in a historical sequence. The course began with a section on evolution, in which lectures covered the history of evolutionary thought before Darwin, how Darwin developed his ideas, and how the scientific community reacted. A discussion of the problems with Darwin's theory—the absence of a known hereditary mechanism—led naturally into a discussion of Mendel's experiments and theory. This material took four weeks to cover. We then undertook a description of mitosis and meiosis and a discussion of how chromosomes came to be identified as carriers of the genetic material. We moved on to describe during the next four weeks ideas about the chemical nature and function of genes, from early work to modern interpretations.

Throughout our presentations, we made sure to include the contributions of novices and women to the development of biological ideas. For example, we told students how Alfred Sturdevant was a 20-year-old undergraduate when he devised the method of using recombination frequencies to order genes on chromosomes. Students heard about geneticist Harriet Creighton and Barbara McClintock's studies correlating cytological and genetical crossing-over and read Evelyn Fox Keller's explication of that work in her 1983 book *A Feeling for the Organism*. Rosalind Franklin's role in the discovery of the structure of DNA was explicitly addressed. We also talked at some length about the role of chance and serendipity in scientific discoveries, trying to explode the myths that science is only the province of genius and that discovery can only come from relentless, single-minded submersion in the subject.

Once the chemical nature of DNA was understood, we then attempted in lecture to make clear the connections among all these threads—DNA, heredity, and evolution—and to place these ideas in a wider political and social context. We discussed environment's effects on phenotypes and some of the ways ideas about human heredity have been misused. We covered, for example, a brief history of the eugenics movement (Allen 1983). We discussed sociobiology and the controversy surrounding it. We introduced the debate between evolutionists and so-called creation scientists by asking students to read chapters from Gish (1973), thus clarifying the difference between science and religion, and giving students some basis for sorting out their feelings about these issues. We were careful to emphasize that there is no inherent contradiction between a belief in evolution and a belief in a god; students were surprised to learn how many clergy of different religions are opposed to the teaching of creation science in public schools. Finally, we talked about the uses to which the new genetic technologies are being put: in vitro fertilization, genetic engineering, and DNA fingerprinting in court disputes. In every one of these cases, we confronted ethical issues head-on and never pretended that science and scientists were or should be removed from a social context.

It was our purpose not to impose a particular viewpoint on students but to make clear that citizens who are concerned about these ethical issues need to understand clearly the science involved and also that scientists should be, indeed most are, sensitive to the ethical issues raised by their work. Because science is often taught to undergraduates as if it were an entirely self-contained field of inquiry, separate from all others, we also wanted to emphasize that biology is relevant to, even inseparable from, many of the issues that touch our students' lives.

## Results and their implications

In our judgment and that of our students, this course was a great success.

Student evaluations included comments such as these: "I have already recommended this class to other students; I hope you teach it again!" "I had a good time and learned a lot." "It has made me feel that I am not scientifically illiterate."

Students found the discussion sections especially valuable, saying that they understood the material much better after a discussion. One first-year student commented that she had gotten into a conversation with some biology upperclass majors who were taking a class in genetics and that they were amazed at how much she knew about molecular genetics merely from taking this course. Students were very pleased with the inclusion of social, ethical, and political considerations; they consistently ranked the material on eugenics as the most interesting, with creationism and genetic engineering close seconds.

We are persuaded that by focusing on a few ideas in depth, students have an opportunity to develop a sense of mastery of the material and confidence in their ability to understand significant biological ideas. Reading and understanding original sources helps reinforce their confidence and, we hope, their willingness to continue studying biology on their own. One student continues to bring us articles she has clipped from newspapers and magazines. We also believe that students learn more readily and retain much more of what they learn than they would have from a broad survey course. Last, we think that examining these ideas within their social and political contexts motivates students to understand the biology and appreciate its relevance to their other concerns.

The course as we have constructed it provides students with several experiences that are normally lacking in science courses offered to nonmajors—the opportunity to read original literature, the ability to choose the topics for discussion, and consideration of a historical, political, and social context for the biology. We think that these are the main ingredients in the success of the course.

We realize that not only are these elements typically absent in courses for nonmajors, but they are lacking in majors courses as well. Every general biology or genetics course includes a description of Mendel's work, but how many require a reading of his elegant paper? How often is Darwin read in evolution courses? Should we not give our majors a better feel for the history of our discipline, not only a recounting of the successes, but an examination of the wrong turns and blind alleys as well?

Our majors are required to take many nonscience courses to make them better-rounded citizens, but we take no cognizance of that in our biology courses for them. Although we professional biologists recognize the complex interplay among biology, other sciences, and other disciplines including politics, economics, ethics, history, and philosophy, we seldom take the time to help students make connections for themselves between what they are learning in their biology classes and what they learn elsewhere, both inside and outside classrooms. It is assumed that these connections will happen automatically, but our discussions with graduating seniors and our reading of senior theses convinces us that students typically do not make such connections without guidance.

We understand that time spent on these issues is time not spent on biology per se. We, like other biologists, are so concerned about simply including in our courses the biology that students should know that we are little inclined to make room for anything else. Nevertheless, we believe that the increased sense of immediacy and relevance students gain from a broader view of our subject more than compensates for the loss of biological detail.

Finally, it is often the case that not until graduate school do biologists begin to feel, or to be made, responsible for their own education. At the undergraduate level we, their teachers, often force-feed the information we think is necessary for them to succeed in graduate or professional schools. We give them little opportunity or incentive to choose the content or direction of courses; at best, we allow the braver students the chance to interrupt a lecture to ask a question.

The price of this policy is to make students dependent on us for the judgment of what is important or not, what is interesting or not; they often therefore lack the confidence that they can distinguish the important from the trivial. We think it would be better to give students opportunities to exercise their own judgment with supportive, but critical, guidance from us, through discussions in which they choose the topic, grappling with original literature in courses or journal clubs and designing and executing their own experiments in laboratories. Our colleagues in the humanities often permit or encourage students to contribute to the selection of course content, but such encouragement is uncommon in the sciences. Although we recognize the valid reasons for these differences, we think ways can be found to give students more of a sense of responsibility for, and investment in, what they learn.

## Conclusions

Our efforts to present biology to nonbiologists more effectively have led us to design a course that explores a few topics in depth, emphasizing the connections between biology or biologists and the rest of society. The success of this course indicates to us that it would be well to consider incorporating some of its elements into courses designed primarily for biology majors, and we have begun discussions toward that end.

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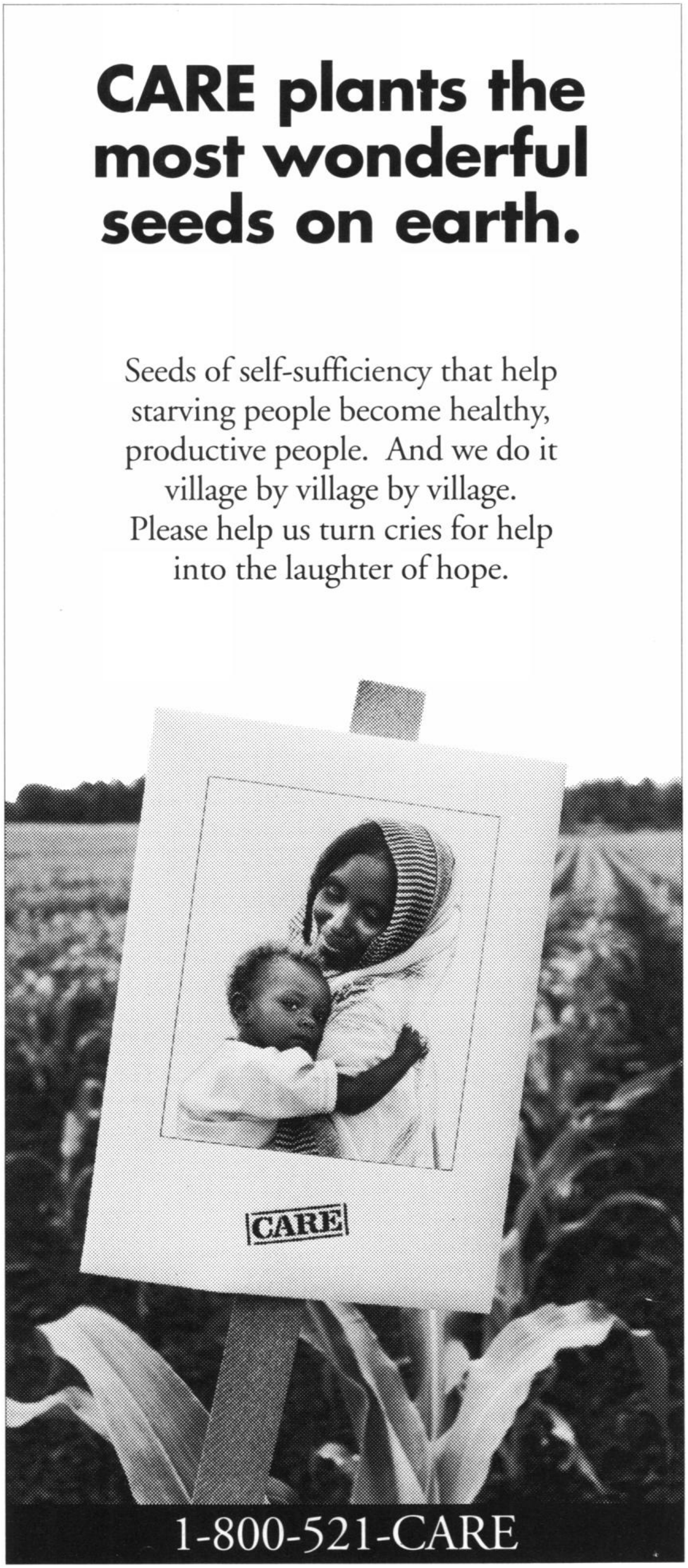


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