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What Every Undergraduate Should Know about Evolution (and Why)

RICHARD M. KLIMAN AND NORMAN A. JOHNSON

In 1860, the year after publication of Darwin's *The Origin of Species,* the wife of the Bishop of Worcester reportedly said, "My dear, descended from the apes! Let us hope it is not true, but if it is, let us pray it will not become generally known." Although she might have been disappointed with today's United Kingdom, the bishop's wife would be comfortable living in today's United States. A November 2004 Gallup poll found that 45 percent of respondents were young-Earth creationists. Another 38 percent were theistic evolutionists—they accept that humans have evolved over millions of years, but believe the process was guided by God. Only 13 percent accepted a fully naturalistic model of human evolution.

It is time that science faculty explicitly advocate teaching the theory of evolution to all students enrolled in a college liberal arts curriculum. The reasons, however, have little to do with content knowledge. Because of distribution requirements, many nonscience majors have taken biology courses, and they generally learn about Darwin's insights, some of the more easily understood evidence supporting them, and perhaps some applications. However, as biology educators, we may not be making the most important points about evolution. Here we present four answers to the question of what every liberal arts graduate should know about evolution—an idea that is often met with skepticism or outright hostility.

Among the goals of a liberal arts curriculum are to instill in students an understanding of the various "ways of knowing" and to familiarize students with specific ideas that have a broad impact on our understanding of human nature and natural phenomena. Thus, the first thing all undergraduates must recognize about Darwin's theory of evolution is that it changed the way humans view their place in the universe. Western philosophers have contemplated for centuries the place of humans and the definition of humanity. The materialist philosophy that humans arose by natural forces is not universally held. But one need not accept an idea to recognize its impact. From a strictly philosophical standpoint, all college graduates should be familiar with Darwinian evolution.

The other things all students must know about evolution relate to improving students' understanding of the practice of science as a way of knowing. For example, do most liberal arts graduates understand that to develop a widely accepted theory is the greatest of all accomplishments for a scientist? As scientists, we recognize that theories vary in their breadth of explanatory power and empirical support, but a handful are supported by unparalleled evidence and resonate throughout at least one major discipline. Among these major theories are evolution, thermodynamics, molecular orbitals, gravity, relativity, quantum electrodynamics, and plate tectonics. One would be hard-pressed to find an observation or hypothesis in biological science unrelated in some way to evolution.

All major scientific theories rely heavily, if not exclusively, on inference. This is the second thing all students must know about evolution, and about science in general. The results of experiments are directly observed, but the direct targets of investigation are not. To this end, it might be useful to present students with another, less controversial example. Molecular orbital theory describes the behavior of electrons and the bonds that unite atoms into molecules. Though neither has ever been observed directly, electrons and bonds are universally accepted by scientists because they have broad explanatory power and because the theory describing their behavior makes empirical predictions that are repeatedly confirmed. If chemists did nothing but mix sodium hydroxide with hydrochloric acid (not recommended), they would have difficulty attributing the consequent formation of very warm salt water to rearranged bonds. Fortunately, chemists have done many more experiments, most of which are far more elaborate and thoughtful, that have led to refinements in the theory.

Students need to be reminded that, in high school and college, they were probably not presented with any of the critical evidence supporting molecular orbital theory. They might not even have learned about molecular orbital theory in high school. They probably would not understand the rationale of experiments that support molecular orbitals; certainly none of those experiments allowed for direct observation of electrons or chemical bonds. In fact, undergraduates are presented with considerably more evidence for evolution than they are for the other major theories. It is crucial that they understand that the inferential nature of the evidence is not unusual.

The third thing all undergraduates must know about the theory of evolution is that, like all important theories, it has continually faced evidence that could potentially shift the paradigm. We're referring to data and ideas that are consistent with the facts and logic at hand, but that force scientists to reconsider ideas in which they have invested considerable time and energy. Biologists were quick to accept common descent as a cornerstone of evolutionary theory. Students should be made aware, however, that adaptation by natural selection, one of the most powerful scientific ideas ever proposed, met significant resistance, and not just because of religious opposition. Years after Darwin's death, Mendel's rediscovered principles of inheritance seemed incompatible with Darwin's theory of natural selection. Mutations studied in the laboratory or greenhouse seemed to have only large effects, yet Darwin had suggested that the natural variation that had evolutionary importance was usually subtle. Not until the 1920s and 1930s did biologists reconcile natural selection and classical genetics into a mathematically rigorous component of evolutionary theory.

Natural selection was challenged a few decades later by Motoo Kimura, who argued that most observed changes at the DNA level are selectively neutral. Initial hostility toward Kimura's ideas ultimately dissipated because Kimura's ideas worked; they helped make sense of molecular data, and they drove several new lines of experimental inquiry. As Einstein refined the scope of Newtonian mechanics, Kimura refined Darwinian evolution.

Students should know that scientists dismiss intelligent-design creationism not because, as some creationists suggest, scientists have too much invested in natural selection. Intelligent design is rejected because it has not led to any productive understanding of nature. If we assert that something is intelligently designed, that's the end of the story. But if we have evidence that something has evolved, then we have a starting point for further study. Indeed, evolutionary biologists are continuously seeking data that will either support or refute earlier conclusions. Students must understand that scientists' most dearly held ideas are constantly tested.

The fourth thing all college students should know about evolution is that it is increasingly relevant to their lives. People still die in large numbers from infections by pathogenic microorganisms that relentlessly evolve resistance to antibiotics. Insects evolve resistance to every poison we invent. An enterprising high school student, with an understanding of natural selection and the colossal breeding potential of insects, could easily predict the consequences of large-scale monoculture and overuse of insecticides. We spend billions of dollars trying to keep up with the bugs, and for the most part all we gain is the need to wash our vegetables more thoroughly.

The relevance of evolution is not limited to variation within species. Model organisms—mice, yeast, fruit flies, and the like—aren't chosen just for their convenience. Because of common descent with modification, we share many more characteristics (including a four-chambered heart and a pancreas) with mice than we do with fruit flies, so mice are better models for heart disease and diabetes. We can learn a surprising amount about eye development from fruit flies. But we can still learn a lot from yeast; we share more characteristics with yeast than we do with bacteria or, for that matter, plants.

Why is it easier to treat tuberculosis or anthrax than it is to cure malaria? Bacteria cause tuberculosis and anthrax, while malaria is caused by a protist. Because the protist is a closer relative, it's harder to find drugs that hurt it without hurting us. It's harder still to treat trichinosis, because the pathogens that cause the disease are animals. Because the trichinae are so closely related to us, unique targets for poisons are harder to find.

If the goal of a liberal arts education is to foster appreciation for the ways that we understand our world, all college graduates should understand these things about modern evolutionary theory. If biology instructors successfully foster a passion for knowledge and learning, perhaps some students will even take it upon themselves to read *The Origin of Species* and contemporary books on evolution. Ultimately, it will be less likely that, as school board members, legislators and judges, they will be swayed by rhetorical arguments used by creationists.

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