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Biology: The Science of Life

Course Guidebook

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Professor Nowicki has been awarded fellowships from the Mary Flagler Cary Charitable Trust, the Alfred P. Sloan Foundation, and the John Simon Guggenheim Foundation. He also is the recipient of the Robert B. Cox Distinguished Teaching Award from Duke University. ■

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Biology: The Science of Life

Scope:

Biology—the "science of life"—matured as a discipline in the previous century and will surely be the branch of science that most affects our daily lives in the next. Our expanding knowledge of how living systems work at all levels of scale, from the function of biological molecules to the integration of global ecosystems, is providing us with tools we can use to control and manipulate those systems to our benefit—allowing us to grow more food, design better medical treatments, build better products, and even to change the fundamental nature of the world in which we live. As the social, economic, and political significance of biology continues to grow, however, people are confronted with an ever-increasing set of practical questions. What does it mean to say that the human genome has been "sequenced" and why should we sequence the genomes of other species? How is an organism "genetically modified" or "cloned," and what are the benefits—or potential costs—of doing so? What are "stem cells," and how can they contribute to human health and welfare? Why is HIV/AIDS so difficult to treat? What will happen if vast tracks of tropical rainforest are cut down? Why does it matter that the temperature of the Earth is rising? Our ability to answer these kinds of questions and, thus, to be informed consumers, citizens, and decision-makers depends on our understanding of how living things work, an understanding that is difficult for non-specialists to gain given the tremendous explosion of knowledge in this field over the last few decades.

Understanding biology also satisfies our natural curiosity about the living world around us. Why do children look like their parents? What causes plants to bend toward light? Where are memories stored? Why do some birds have very long tails? How did life on Earth begin? Answering these kinds of questions, whether they are passing fancies or profound inquiries into our very being, also depends on understanding the principles of biology, but here again, it is daunting for the average educated person to sort through a swelling mountain of relevant data and theory without guidance.

This course provides the background and guidance needed for the curious listener to explore in depth the fundamental principles of how living things work; in so doing, it offers the tools needed to understand not only the science of life, but also the impact and importance of the many ways that advances in the biological sciences touch our lives. It presents this material at the level of a typical first biology course taken by university science students, but without assuming prior background in biology or science in general. It also presents material in a conceptual format, emphasizing the importance of broad, unifying principles—facts and details are offered in abundance, but in the context of developing a framework listeners can use to work with information and to understand issues in biology they may encounter in the future. Finally, the course takes a historical approach wherever possible, explaining how key experiments and observations led to our current state of knowledge and introducing many of the people responsible for creating the modern science of biology.

The 72 lectures of this course are divided into three main sections, with each section organized around a major unifying theme in biology. Lectures 1 through 24 explore the theme of "Information and Evolution" in living systems. This exploration begins by asking how life might have arisen spontaneously on the newly formed planet Earth and by describing the hierarchical organization of living systems as we know them today. This discussion leads to the question of how living things reproduce, the most enigmatic aspect of which involves explaining how information about the structure of complex biological molecules called *proteins* can be stored and transmitted. The solution to this problem is found in the structure and function of an equally complex molecule, DNA. The lectures go on to explain what DNA is, how we know it is the genetic material, how DNA stores information about proteins, and how this information is copied and passed on from parents to offspring. One important conclusion of this discussion is that the DNA of an offspring is almost never exactly the same as that of its parents, a fact that means species inevitably change over time, that is, that life evolves. This conclusion leads to an analysis of how Darwin came to his theory of natural selection, followed by an in-depth examination of evolutionary mechanisms and a discussion of how those mechanisms are thought to be responsible for generating the enormous diversity of species we see on the planet today.

Lectures 25 through 48 turn to the second organizing theme of the course, "Development and Homeostasis." This dual theme focuses on the consequences of being an organism made of more than one cell. Many organisms, such as bacteria, are single-celled, but other kinds of organisms—including ourselves—are made up of a large number of cells, with different cell types specialized to perform different functions. This series of lectures begins by considering how different cells having the same genome can turn on or off subsets of the genes they possess, a necessary prerequisite for producing different types of cells from a single fertilized egg, and by examining how cells communicate, necessary for the different cells in an organism to integrate their activities. Against this background, the lectures then explore, in more detail, patterns and mechanisms of animal development, the remarkable process through which one cell formed by the union of a sperm and egg yields a complex, multicellular organism, potentially having trillions of cells of hundreds of different types, all arrayed in precise spatial positions relative to each other. After discussing how a multicellular organism is "built," the lectures then turn to the question of what is needed for a multicellular organism to maintain itself and coordinate its parts, a question that frames the concept of *homeostasis*. This discussion answers a number of questions, including how organisms maintain a constant physiological state, such as a particular body temperature; how chemical signals called *hormones* and specialized cells called *neurons* transmit physiological information across great distances in a body; and how the body is defended against attack by disease-causing agents. The section culminates with the idea that an animal's behavior—even in the simplest case of detecting and responding adaptively to the environment—may be viewed as a kind of highly derived homeostatic mechanism enhancing an organism's ability to survive and reproduce.

The third major theme of the course focuses on "Energy and Resources," the subject of Lectures 49 through 72. This section begins at the level of cells and molecules, showing how living things obtain, store, and deploy the "power" they need to survive and illustrating how this energy ultimately all comes from sunlight. Next, the lectures turn to consider the implications of how energy and other resources necessary for life are distributed and used at progressively higher levels of biological organization, from the level of whole organisms, to populations of organisms, to communities of different species, and finally, to the level of ecosystems, including the entire biosphere. Because the amount of energy and other resources available to organisms may be limited, there often is not enough to go around, a fact that plays a major role in determining the distribution and abundance of different species on the planet. This point sets the stage for introducing fundamental principles of the discipline of ecology and for showing how these principles fit in the broader context of how living systems function and how they change over time.

The course concludes by considering the fact that, just as biologists are on the verge of a truly revolutionary understanding of the "science of life," we are at the same time facing an unprecedented crisis in the loss of biodiversity—potentially a loss of much of the natural world—because of the unprecedented success of a single species, our own. The final lecture discusses the origin of this crisis and considers what is being done, and what still can be done, by biologists and citizens alike to preserve the wonders of the living world around us. ■