2023 Biology I: Big Questions Module Summaries
Department of Biological Sciences

Does Morality Have a Biological Basis? Dr. Elizabeth Archie

Moral behavior rests upon a wide variety of actions and emotions, including altruism, reciprocity, a sense of fairness, and caring about the well-being of others. These behaviors and emotions may seem to be uniquely human traits… but are they? The more we learn about animals—from their social lives to how their minds work—the more we find that animals can be altruistic, fair, and empathetic. In this module, we will explore the biological roots of moral behaviors and emotions. Focusing on a wide range or organisms, from bacteria to birds and primates, we will consider whether and how cooperation, reciprocity, and empathy have evolved in animals, as well as the physiological and cognitive structures that have developed to support these behaviors.

Will Gene Editing Change the World? Dr. Patricia Champion

All life on earth is built from a DNA blueprint known as a genome. In 2023, anyone with an undergraduate education can edit the genome of any organism. With this great power comes an impossible responsibility. How do we use genome editing to change the world to our advantage? What impact will gene editing have on future generations and the environment? In this module we will focus on the rise of CRISPR (Clustered Regularly Interspersed Short Palindromic Repeats) gene editing technology. Using primary scientific literature and articles in the popular press, we will delve into the origins of CRISPR as a bacterial immune system, and the dynamics between bacteria and their viral predators. We will discuss how a bacterial immune system was co-opted to become a powerful gene editing tool, and how this tool continues to evolve. We will learn about how this technology is applied to answer basic research questions, edit the human genome, prevent disease and combat climate change and population expansion. At the end of this module, you will have a working understanding of the origins and applications of the CRISPR gene editing system, and an ethical, technical and practical appreciation of how gene editing has changed, and will continue to change our world.

Genetic Variation, Identity and Health: Am I My DNA? Dr. Hope Hollocher

We have been bombarded with television ads for direct-to-consumer, genetic testing kits from companies, such as Ancestry.com and 23andMe.com, to learn more about ourselves. The ads make it seem so simple – spit in a tube, send it off, and voila! – new-found truth and understanding of who we really are. These ads imply we can use DNA as the ultimate arbitrator of identity and health, suggesting a DNA testing kit can define your culture or make the perfect Valentine’s gift to learn a couple’s compatibility. However, using DNA to trace ancestry or find associations with genetic diseases is not so straightforward. What one does with the information gained from DNA testing can also be problematic. This course aims to provide students with the background and scientific tools needed to better understand what these genetic testing kits can and cannot say about our identity and health. Using a population genetics lens, we will see how genetic variation is shaped by different evolutionary processes, such as natural selection, genetic drift and gene flow, as well as the complexities underlying how genotypes map to phenotypes — all of which become important for interpreting genetic markers associated with ancestry and human health.

Blindness: Can We See Potential Gene and Stem Cell Therapies for Neurodegenerative Diseases? Dr. David Hyde

Over 300 million people worldwide suffer from a neurodegenerative disease, including 36 million people who are classified as legally blind due to a retinal degenerative disease, ranging from Retinitis Pigmentosa (affecting children) to age-related macular degeneration (primarily affecting the elderly). Nearly all neurodegenerative diseases are progressive and most treatments only slow the progression of the disease. However, there are a number of new and exciting therapies that are either recently developed or in clinical trials that restore the normal neuronal function. In this module, we will focus on retinal degenerative diseases because the retina is an accessible part of the central nervous system and is leading the way in the development of therapies for neurological diseases. We will discuss retinal anatomy and physiology, genetics of various retinal degenerative diseases, a recently approved gene therapy for Leber’s Congenital Amaurosis (a form of childhood blindness), stem cells and stem cell clinical trials for age-related macular degeneration, cellular reprogramming, and culturing of mini-retinas. At the end of this module, you should be able to understand how the anatomy/physiology/genetics of a neurodegenerative disease dictates different therapeutic strategies and what those strategies are, as well as how the science and ethical issues associated with these therapies will impact society in the future.

Hero or Villain: How Might Earth’s Ecosystems Resolve the Climate Question? Dr. David Medvigy

Climate change is impacting things that we depend upon and value, including water, energy, transportation, wildlife, agriculture, ecosystems and human health. Interestingly, the magnitude of future climate change will largely be governed by biological processes. The reason is that the element carbon plays a central role in both climate change and biology. Small imbalances in carbon-involving processes like photosynthesis and respiration can have a dramatic impact on atmospheric carbon dioxide concentrations, and hence Earth’s climate. In this module, we identify climate “heroes”, that is, those ecosystems and processes that biologically remove carbon from the atmosphere. An example of a hero is the Amazon rainforest, which has been, on net, absorbing ever-increasing amounts of carbon from the atmosphere. However, its future status as “hero” is uncertain due to increasingly strong droughts. We will also discuss climate “villains”: those ecosystems and processes that biologically increase atmospheric carbon dioxide concentration. The microbial decomposers of the Arctic represent one example. The Arctic holds a tremendous amount of ancient, fossil carbon locked in permafrost. As this permafrost melts, microbes have the potential to decompose this carbon and release it to the atmosphere: a so-called “carbon bomb”. As we follow all of our heroes and villains, we will come to understand how fundamental concepts in biology, like evolution, genetics, and others, affect the ways that scientists understand climate.

How Will Studying Biology Equip You to Fight the Next Pandemic?   Dr. Alex Perkins

COVID-19 is not the first pandemic the world has seen, nor will it be the last. Over the course of your career, the world could easily experience one or more pandemics of a similar magnitude, if not worse. As they are today, biologists of the future (i.e., you!) will play a crucial role in mitigating the harms done by future pandemic pathogens. In this module, we will explore ways that biologists—in particular, evolutionary biologists—contribute to the fight against pandemics. To help you envision how you could go from where you are today to being on the front lines against the next pandemic, this module will be divided into two halves. In the first half of the module, corresponding to your time in college, you will gain familiarity with core principles and tools from evolutionary biology, which have been developed not for the purpose of fighting pandemics but for the purpose of satisfying basic curiosity about the natural phenomena that have enabled the awe-inspiring diversity of life on earth. In the second half of the module, corresponding to your professional career, you will learn about how the principles and tools developed for basic research in evolutionary biology have been applied to fight the two deadliest pandemics of our time: HIV and COVID-19. This exploration will not be merely hypothetical, as you will learn about Notre Dame alumni who have gone on to do exactly what this module envisions you going on to do one day: leveraging an education in biology at Notre Dame to fight the next pandemic.

Humans: How Did We Get Here, and Why Are We Like This?   Dr. Michael Pfrender

The Earth's many ecosystems are home to an amazing diversity of organisms ranging from single-cell bacteria, to complex multicellular plants and animals. Among these organisms, Humans are perhaps the most intriguing of all. In this module, we will examine the evolutionary mechanisms that generate biological diversity by focusing on aspects of Human biology. In the first section of the module we will trace the major transitions in the history of life that gave rise to Modern Humans. Our understanding of Human evolution has increased enormously in the past decade revealing the surprising complexity of our history. In the second portion of the module we will explore the relationship between information in our genes and the traits that make us uniquely human. Where does the tremendous variation among people come from? What can we say about the variation in our own genomes? We will examine these topics through a combination of lectures, discussions and readings from recent scientific publications.

Natural Selection: The reason why we haven't cured cancer?   Dr. Zachary Schafer

Cancer is a disease that afflicts millions of individuals around the world. It is currently the 2nd leading cause of death in the USA and according to the CDC will likely become the leading cause of death by 2020. Despite significant research advancements over the years, why is cancer such a difficult foe to combat? This module will focus on the relationship between natural selection (survival of the fittest), cancer progression, and challenges in cancer treatment. Over the course of the module, we will learn basic tenets of biology (e.g. evolution, structure and function, information flow, pathways/energy transformations, and systems) in the context of cancer as a disease of "misbehaving" cells. Highlights include discussion of the following topics: how cancer cells adapt to diverse environments, intercellular communication, utilization of nutrients by cancer cells, cellular suicide, and why resistance to cancer therapies is such a significant problem.