Comment

Evolution Lessons From Infectious Diseases

Carl Bergstrom and Marc Lipsitch

The proponents of intelligent design and other organized opponents of evolutionary biology do not dispute the overwhelming evidence that microbes can evolve rapidly, over the course of months or even days. Instead, most skeptics focus their criticism on larger-scale evolutionary patterns, particularly the common ancestry of all living things and the generation of complexity through natural selection. So why is teaching microbial evolution critical for the public to understand evolution on both the small and large scales?

One word immediately comes to mind: disease. Disease evolution is of immense practical concern, and it happens fast. Even though the critics of evolutionary biology rarely dispute these examples of microbial evolution on human timescales, the public appears largely unaware of the importance and success of evolutionary biology in dealing with human disease.

Microbial pathogens have huge populations, undergo rapid generation times, experience high mutation rates and often face strong selection pressures — the perfect combination for rapid evolutionary change. Evolutionary biology directly helps us understand the rapid evolution of microbial pathogens.

Many emerging infectious diseases enter the human population from animal sources and then evolve the ability to be transmitted from human to human. We saw this recently and dramatically with the SARS coronavirus and we fear a similar progression with H5N1 avian influenza (so-called bird flu). Evolutionary models illuminate the processes by which diseases evolve to shift from animal hosts to humans and suggest ways of reducing the chance of that occurring.

Other microbial pathogens rapidly evolve resistance to the drugs that we use to treat them, creating enormous problems for society. Experimental evolution studies, in which bacterial populations evolve in real time in a laboratory setting, have uncovered the pathways by which bacteria develop antibiotic resistance, and thus suggest ways to counter drug resistance. Mathematical models help us predict the spread of resistant strains among hospitals, communities and farms where antibiotics are used heavily as growth supplements; furthermore, they suggest ways that we can alter our pattern and practice of antibiotic use so as to minimize subsequent evolution and the spread of drug resistance.

In yet another example, the human immunodeficiency virus (HIV) evolves so fast that the course of treating an individual with HIV is literally an exercise in applied evolution. The selection and timing of anti-retroviral drugs are chosen to best prevent, or at least compensate for, this virus' rapid ability to evolve drug resistance.

Evolutionary biology also helps us reconstruct the history of microbial transmission and evolution, which can help scientists figure out how to treat microbial pathogens. When choosing which strains to include in each year's influenza vaccine, for example, researchers consider the evolutionary histories of the currently circulating strains of the virus. Similarly, models of tuberculosis strains in San Francisco have helped researchers work out the origins of infection and the patterns of transmission in crowded urban environments, thereby guiding efforts for control and prevention.

Such examples make it clear what evolutionary biology is, what it is not, and what it can do for us. In particular, teaching about microbial evolution provides a way to engage and counter two common public misconceptions about the nature of evolutionary biology, both of which stem from the mistaken premise that evolutionary biology is limited to the study of how things came to be, over very long periods of time.

The first misconception (or deliberate sophistry, in some cases) goes roughly as follows: *Evolutionary biology deals exclusively with processes that occur only on geological timescales. Therefore we cannot do manipulative experiments in the study of evolution, and consequently evolutionary theory is not testable. Thus evolutionary biology is an ideology, not a testable scientific theory.*

Of course, it is simply false that a theory cannot be tested without conducting manipulative experiments. We can always test a theory proposed at one point in time by looking to data that become available at some subsequent time — or even by looking at the currently available data in a new way. Much of the scientific research in cosmology, for example, proceeds by this approach.

Still, this misconception remains a sticking point in public thought, and it is commonly exploited by opponents of evolution. By teaching about microbial examples where manipulative experiments are entirely possible and commonly performed, evolutionary biologists and others can illustrate that evolution is subject to manipulative experiments and head off this false criticism before it can be raised.

A second misconception is that religion and evolution are incompatible. In an October 2005 CBS News poll, 29 percent of Americans stated that it is impossible to believe in both God and evolution. The rationale goes something like this: *Evolutionary biology is a way of answering the question "How did we come to exist and how did our world come to be the way that it is?" Therefore, evolution is a set of beliefs about the world — a metaphysics — and it happens to be a metaphysics that is incompatible with religious doctrine. Therefore, one must choose between evolution and religion.*

Every step of this logic chain is wrong. Evolution is a material process of change; to access this process scientifically, we use materialist methods. Using materialist methods does not commit us to any metaphysical perspective. In other words, evolutionary biology is just a tool for doing a task — in this case, the task of generating testable hypotheses based on material phenomena to help prevent and treat infectious diseases. As it is just a tool, evolutionary biology is no more incompatible with religion than is a screwdriver!

The basic ideas underlying evolutionary biology are well-illustrated by examples from infectious diseases. Although these examples are rarely seen on the frontlines of the "evolution wars," they serve as a marvelous opportunity to educate the public about what evolution is and even about what science is. In our experience, students who have learned to understand evolution by exploring this process at the level of microbial pathogens are much more savvy when it comes to evaluating the evidence and arguments surrounding the topics of common descent and emergent complexity.

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