Of Pathogens and Men: Professor Johannes Foufopoulos

Daniel Urcuyo
College of Literature, Science, and the Arts, University of Michigan, Ann Arbor, Michigan, 48109

Introduction

Dr. Johannes Foufopoulos is an Assistant Professor at the University of Michigan. He is currently teaching in the School of Natural Resources and Environment as well as in the Department of Ecology and Evolutionary Biology. He received his Bachelor's degree in Biology from the University of Illinois-Urbana-Champaign and his Master's and PhD in Zoology from the University of Wisconsin-Madison.

His research interests include conservation biology as well as the ecology and evolution of infectious diseases. Along with his research interests in the effects of habitat fragmentation and global climate change on species extinction, he also studies the impact diseases have on wildlife populations and the processes leading to disease emergence.

To better understand the impact of pathogens affecting both wildlife and humans we caught up with Professor Foufopoulos.

Parasites and pathogens differ in their impact on the host. What role does the virulence of a pathogen play in its survival?

What we experience as virulence is basically the rate at which a pathogen/parasite extracts resources from the host and uses them to reproduce or do whatever it needs to do in order to get transmitted. It is a fundamental parasite trait because it determines whether the parasite survives by being transmitted from one host to another. Because multiple pathogen strains generally compete against each other, either inside a single host or within a population of hosts, at first glance it would seem that each parasite should evolve to extract the maximum amount of resources from the host, i.e. evolve the highest possible virulence. The problem is that as virulence rises, the host is likely to die more quickly, meaning that there is a shorter time period available for the pathogen to transmit itself to another host. So, simplifying matters a bit, there are tradeoffs between virulence and time available for transmission. Dependent on what this relationship looks like for different transmission modes, there exist different optimal levels of virulence. For example, sexually transmitted pathogens tend to be on average less virulent because if they make their host too sick, he/she will not go out and have sex and as a result the pathogen will not get transmitted.

What appears to have happened in the last few hundred years is that virulence for most human pathogens has decreased. There are several possible explanations for this, including humans just being able to deal better with infection because of improved living conditions. But perhaps the most interesting hypothesis postulates that reduced virulence may be the inadvertent outcome of effective medical treatments. Essentially, each time you choose to go to the doctor and you receive antibiotic treatment, the pathogen population that infected you gets wiped out. When you have different strains that have varying levels of virulence, those patients infected with the most virulent strains are also most likely to go to the doctor, get treated and thus eliminate their infection. So essentially all the truly virulent strains, the ones that really make their host sick, suddenly are at a disadvantage because they are being treated and are not being transmitted anymore. So the only strains that now survive are the ones that do not make you sick enough for you to choose to go to the doctor. Since only the least virulent strains now survive to replicate, the disease as a whole becomes progressively less virulent.

This is one of the interesting unintended evolutionary developments that no one really thought about when they developed drugs. When we first developed antibiotics, the basic idea was that we would be eliminating infection, but what we apparently ended up doing, by applying selective pressure, was to make some pathogens less virulent.

What are humans doing to promote the spread of infectious diseases?

Humans are right now engaged in a broad range of actions that promote disease; perhaps most important among these are particular activities that disrupt the environment, therefore facilitating the emergence of new pathogens. Despite their name these are generally pathogens that are already existent in natural ecosystems. Although sometimes they can be newly evolved pathogens, in general these are organisms that have been around for long periods of time. When we disturb the natural environment we put ourselves in contact with them and suddenly we have an epidemic in humans. If you look at all the new emerging diseases that have hit humanity in the last twenty years or so, almost all of them have been zoonotic. This means that these are pathogens that normally circulate in some kind of animal host population in nature and then were able to switch hosts and are now infecting humans. This has often been the result of our interference with natural ecosystems. AIDS is a good example. HIV, the causative agent of AIDS, is really just "the revenge of the vanquished." HIV entered the human population as the result of the intense hunting of chimpanzees, which are the virus's regular host species. We are currently in the process of cutting down the central African rainforest while at the same time hunting chimps - who are also our closest relatives - to extinction. We are literally eating the species to extinction - there are very few chimps left right now—just a few thousand. They are in precipitous decline and from an ethical perspective, I wonder what that says about

humans— the fact that we are butchering and eating our closest relatives at a time when we have plenty of alternatives. But essentially what happened was that in the process of us eating our way through the chimp population, we contracted one of their pathogens, which was HIV.

Similar things occurred for other zoonotic pathogens. SARS, for example, produced a major outbreak about five years ago when it was introduced into the human population in Chinese wet markets, which are basically wildlife markets where people bring various kinds of live animals for sale. These places are hotbeds for cross-species infection because you have many different species crammed together in tight proximity in truly abhorrent conditions. People just butcher the animals and often eat them right there, under very unsanitary conditions which then promote the transmission of all kinds of pathogens. So it was not surprising that humans were exposed and infected with this new group of viruses called coronaviruses, one of which causes SARS.

Another example is West Nile Virus, which causes bird disease and that one careless traveler apparently brought in from the Middle East. The whole North American epidemic started in New York City in the vicinity of JFK International Airport. A traveler probably brought in an infected bird which then transmitted the virus to the local mosquitoes, and from there the infection spilled over into the resident bird populations. The pathogen then spread rapidly and has now become established over most of North and Central America, has been reported from over hundred species of birds, mammals and reptiles, and is estimated to have caused the death of several million native birds.

Environmental degradation is another major problem. It is a problem in many regions of the planet because it stresses local wildlife and makes it more susceptible to existing parasites. This in turn can have effects on human health as well, because the more prevalent a pathogen is, the higher the probability that it will spill over into the human population. Therefore if we want healthy wildlife and human populations—these two things are intimately interconnected—you need to make sure the ecosystems are in good shape. If we can not find it in our hearts to protect the forests, oceans and grasslands because they are beautiful and we care about them, we have to at least do it because it is in our own narrow health interest. Whenever people do not do that, they end up ultimately undermining their own health and their own wellbeing. You have to think long-term and you have to be prudent.

To summarize, international trade and transport, habitat degradation, and trading of bushmeat are all human activities that promote the emergence of new pathogens. A wealth of data has demonstrated that they are some –but not all- of the main processes that have led to the emergence of new diseases.

In what way does your research examine these issues?

Much of my research currently focuses on two projects. The first project looks at avian malaria in bird populations in Colorado. We are studying this because avian malaria is a very common pathogen in bird populations. It is not a disease that humans can contract, but it is a pathogen that can cause serious conservation problems. It is responsible for the extinction of endemic species in Hawaii after it was first introduced there by Europeans. The native birds in Hawaii had never been exposed to avian malaria and had therefore no resistance to the disease. Humans accidentally brought mosquitoes to Hawaii and later on introduced malaria-infected game birds and avian pets. The mosquitoes transmitted the disease from the exotic, largely resistant birds to the native species which died by the thousands; this led eventually to the extinction of many species. Many of the unique Hawaiian birds became extinct because people were not thinking about the long-term implications of their actions.

We study avian malaria to understand how it affects birds. In Colorado it is a native parasite so it is not an organism that is new or introduced. In general, in nature there is some sort of dynamic balance between parasites and their hosts. However, if the host population is stressed because the environment is being degraded—there is not enough food for example—then it is not going to have, among other things, enough resources to maintain a competent immune system. As a result, the balance can shift in favor of the parasite and you could end up with a serious epidemic. If you truly want to understand diseases in natural ecosystems, you really need to understand the stressors that the hosts face, and this is one of the main topics we are currently investigating. For example, we are examining how food availability, in particular, shapes the balance of the host-parasite interaction.

The other project we are working on is looking at small populations of lizards that live on islands in the Mediterranean Sea. There are a great number of different islands, and because lizards can not swim, they are stuck on these islands. The reason they are found there today is because sea levels a few thousand years ago used to be much lower, and all the islands used to be connected. When sea levels rose, the lizards became isolated on the hilltops, which are now islands, so there exist all these populations that differ in their size due to their period of isolation. Because both of these characteristics, population size and duration of isolation shape the genetics of a population, these populations differ greatly in their levels of genetic diversity. The larger and the younger the island, the less inbred the population is, which has implications for their ability to mount an effective immune response against parasites. In particular, we are looking at the relationship between mites, the worms that live in the gastrointestinal tract and lizard malaria. For example, we examine how lizard malaria changes between different island populations of hosts that have differing levels of genetic diversity.

Why is this interesting? It turns out that one of the main mechanisms by which humans impact natural habitats is through habitat fragmentation. For example, when humans enter a large forest expanse and put a road through it or develop the area, they end up fragmenting the habitat and the wildlife populations living there. Then these fragmented populations start facing all kinds of problems: loss of genetic diversity, edge effects, etc. In addition, they are not able to deal very well with the regular parasite communities that they have always harbored. So one of things we are trying to figure

out in the Mediterranean lizard project is how fragmentation affects the outcome of host-parasite interactions in these organisms.

What can the average college student do to suppress the impact of diseases?

There are two different ways to answer this question. On the immediate, trivial level, it would be to wash your hands and go to the doctor and that type of thing, but that is pretty obvious. I think the issues we are facing are actually much bigger. These are large problems that have to do with what choices we make as a society. In turn, these societal choices are ultimately the result of individual values and choices, and only a society of informed citizens is likely to do the right thing, so being informed and remaining politically and socially engaged is going to be key for any student who cares about these issues. Right now we are entering an age of unprecedented environmental change, and this is going to have important health implications. As far as scientists can tell, environmental changes are going to be massive, and people will be surprised by what will be happening to the planet over the next fifty years. One of these things is going to be shifts in global climate. From a health perspective a warming climate will, among other things, likely allow a number of tropical pathogens to enter the temperate regions of the United States and Europe.

One of the most important things students can do to reduce the impact of infectious diseases in the long term, is to make sure the planet and its climate remain in good shape. For example, it is crucial that we try to limit our activities that accelerate global climate change. We all need to start thinking about our carbon footprint—how our activities generate CO_2 and then change the climate—because this will have implications for our health in terms of infectious diseases. It is going to be a nasty wake-up call if people in the U.S. suddenly start contracting malaria or yellow fever again. Malaria used to occur in Michigan. It was eradicated from the U.S. because the relatively cool climate enhanced the effects of good public health practices. However if the climate warms up enough, we could see the disease return again with a vengeance as some computer models predict is likely.

What does this mean in practical terms? We need to drive less, turn the lights off, fly less, and reduce overall consumption. Two of the most effective practical things students can do is give up eating meat (which has a huge carbon footprint) and choose to have one less child - the planet can simply not support the current human population. More humans translate into more damaged natural environments, a ruined climate, as well as higher probabilities of disease transmission. So these are two simple things that in the long term are going to make a big difference.

The interesting thing is that if you ask people, no one wants to damage the climate, destroy the rainforest or cause species extinction. But the truth is when you go to the mall and you buy that nice little pair of sneakers or that CD you do not really need, you are really contributing to global warming and to species extinction. Those sneakers did not fall from the sky. They were manufactured from oil and leather from somewhere, most likely Latin America or Asia, where it is cheap to produce them. They were made from oil that had to be pumped out of an oilfield, shipped in an accident-prone supertanker across the ocean and processed in a polluting refinery. The leather came from a cow that likely fed on a cleared piece of tropical rainforest. Ultimately, it does not matter what you say but rather what you do - you vote with your wallet. Each time you go and shop at the mall, you promote extraction and destruction of the natural environment. Everything is connected. The key for promoting environmental and human health – and the two are intimately interconnected – is to limit our impacts on the environment.