Microbiologist explains the viruses that can wreak havoc globally

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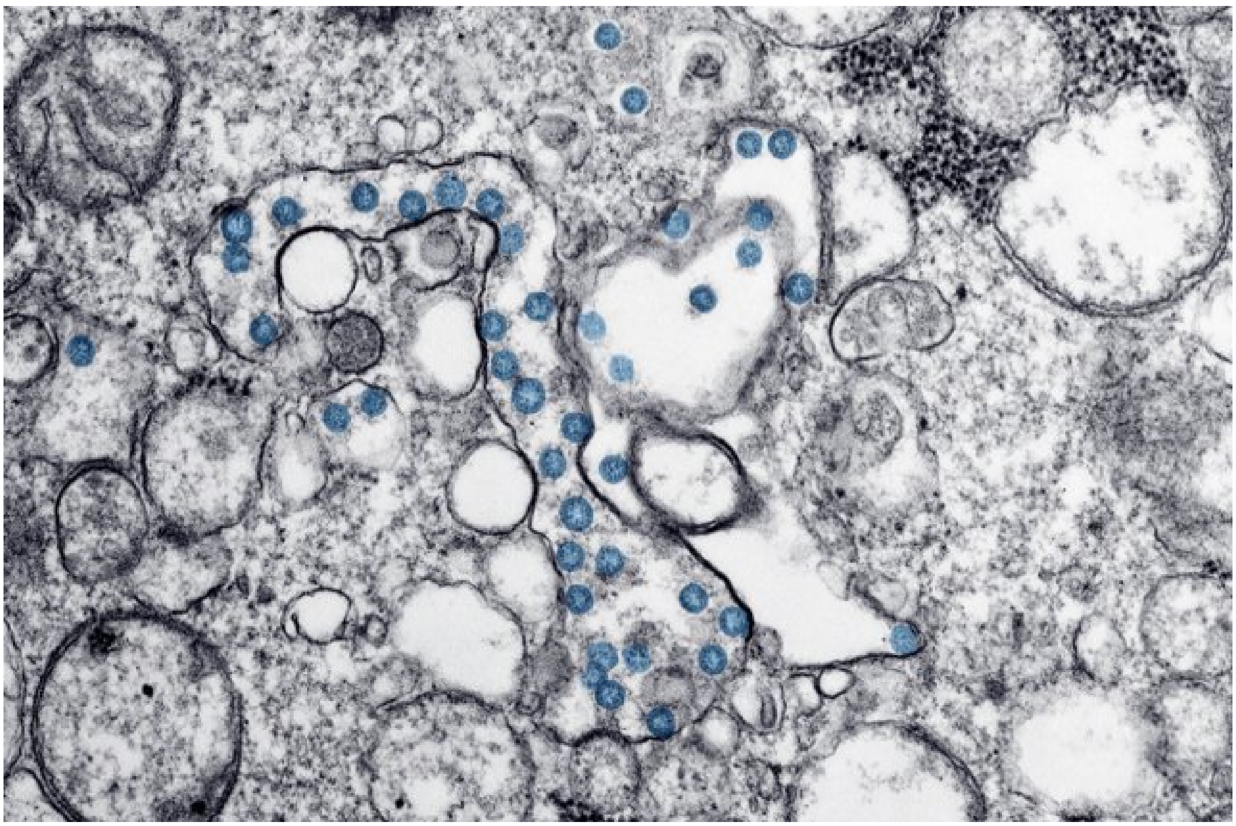

“A virus is just a piece of information,” said John Coffin. Here, an image of an isolate from the first U.S. case of COVID-19. The spherical viral particles, colorized blue, contain cross-section through the viral genome, seen as black dots. Credit: CDC

The novel coronavirus behind the COVID-19 pandemic is causing tremendous damage, killing tens of thousands of people, and upending economies as nations struggle to contain its spread. But on its own, like other viruses, it is inert, not even alive. Viruses gain their power by worming their way into living cells, quickly hijacking the cells' machinery, then reproducing like mad. Soon they are spilling out into other cells, infecting them, too—and sometimes spreading across the world.

Viruses are potent because "they evolve quickly, they are unaffected by antibiotics, they can be elusive, they can be versatile, they can inflict extremely high rates of fatality, and they are fiendishly simple, at least relative to other living or quasi-living creatures," the noted science writer David Quammen says in his 2012 book "Spillover: Animal Infections and the Next Human Pandemic."

But what exactly are viruses? John Coffin, a virology researcher at the Tufts School of Medicine, says that at root a virus is simply "a piece of information." Viruses are tiny—visible only with an electron microscope—and many contain as few as two to ten genes, compared to the 20,000 genes in each cell of a person.

A virus' "business is to make more of itself—that's its only job," Coffin says. "Causing disease along the way may or may not be good for it."

To understand more about viruses, Tufts Now spoke with Coffin, who is the American Cancer Society Professor of Molecular Biology and Microbiology at Tufts. In his research, he focuses on viruses such as the human immunodeficiency virus (HIV), which has killed more than 32 million people worldwide since the early 1980s.

Tufts Now: What exactly are viruses? How they are different from bacteria?

John Coffin: Viruses are completely different from bacteria. A bacterium is a living thing—most of them have all of the components they need for their own survival, for making more of themselves, and so on.

A virus is just a piece of information. A virus puts its information into a cell—a bacterial cell, a human cell, or animal cell, for example. It contains instructions that tell a cell to make more of the virus itself, in the same way a computer virus getting into a computer tells the computer to make more of itself. Viruses are not living things.

Its business is to make more of itself—that's its only job. Causing disease along the way may or may not be good for it actually—if it kills the cells too fast, that gives it less time to get out and go find a new host.

Are viruses alive?

They're not really living organisms—they can't carry out on their own any of the functions that we consider to be connected with life. They don't contain the ability to replicate themselves without being inside of a cell.

They have the information, but the information is dependent on having a cell to translate that information into the components that then become part of the virus particle (virion) that carries the information from one cell to the next. Many viruses are very simple, with only a couple of genes. Our cells contain over 20,000 genes, but by comparison HIV, which in a sense is a relatively complex virus, only contains nine genes. Many viruses contain fewer than that—it's a minimum of about two or three.

You've studied HIV, which has only nine genes. That might make it seem like a simple organism, yet understanding how it works is very difficult—why is that?

That's because the genes are so finely tuned—they do a lot of things. It's quite remarkable, how much viruses can accomplish with so little information. The whole genetic information for a virus like HIV would occupy about a page in a printed book. But it's all very intricate—every single letter, if you like, plays a specific role. Sorting that out is quite a difficult exercise.

Viruses mutate and evolve, making them tougher to fight. How does that happen?

As the the viral genome is being read to create new copies, the wrong letter, the wrong base, the wrong nucleotide is occasionally inserted, analogous to a typographical error. It's not all that frequently—from one in 1,000 to one in 10,000 times, say. But the virus replicates over and over and over, so those add up with time.

With a virus like HIV, it becomes very genetically diverse during infection of an individual, because HIV can replicate over and over again about once a day in an individual for years. So a lot of diversity is built up, which gives a virus a lot of flexibility. There are probably some mutations already present in the population in any infected, untreated individual that will make HIV resistant to specific drugs. That's why if you treat HIV with just a single drug, the treatment always fails after a fairly short time.

Can you explain the difference between a vaccine, which prevents infection, and an antiretroviral drug, which treats it?

A vaccine is usually a component of the virus, or a form of the virus itself. In the case of rabies or some of the polio vaccines, it is attenuated—not causing disease, but still able to grow in the body. It induces a response from the body to make antibodies, so that anytime the antibodies see that virus again, they kill off the infection before it has a chance to cause disease.

An antiviral, on the other hand, is a small molecule, a fairly simple chemical—often, for example, a component of viral DNA or RNA that is slightly altered—that disrupts the process by which the virus replicates itself.

There are millions of viruses. Why do some cause illness in humans and other animals?

There are almost as many different answers to that as there are viruses. But I can give you a general evolutionary explanation. Over long periods of evolution, you have a virus that comes into a host—a species—and spreads. One of three things can then happen.

One is that the virus can just die out for some reason—everybody can get immune, so the virus can no longer find a host, and it dies out. The second is that the host can die out. The virus can cause a pandemic that kills off a species; I'm sure that's happened many times in evolutionary history, although we don't have very much of a record of it.

The third is that the virus and host can co-evolve, so the virus doesn't cause enough disease to wipe out the host, but it's still able to replicate. Some viruses that we have around with us—like the common cold virus—are like that. They'll cause a mild disease, you recover, and the virus survives, and everybody goes about their business.

But when the virus finds itself in a new host—such as a new species—that adaptation hasn't occurred, and it might be very dangerous for that host. There are many viruses like that, such as HIV.

This coronavirus probably is, too. It could have come from a bat, and there's a recent interesting paper that suggests that part of the virus may have come from a pangolin, which is a scaly mammal eaten for food in some parts of the world.

Are there viruses that just live in us and don't cause any harm?

There are retroviruses—one of many varieties of viruses—that live in us that usually don't cause disease, but will occasionally—under certain circumstances, such as if your immune system is damaged. One example is cytomegalovirus, CMV. Many of us are infected with CMV, without consequence. But for people with an HIV infection, CMV can go crazy.

One of the things it does is infect the eye, and cause what's called retinitis, the destruction of the retina. Somebody can have normal vision on Friday and be totally, irreversibly blind on Monday. It's very common where treatment for HIV is not available—people going blind suddenly from a virus that they'd been carrying around for years and years.

How stable are viruses outside of cells?

It varies greatly. HIV, for example, has very low environmental stability—it's not passed on even by droplets or by the breath. You need really close intimate contact, blood transfusion or sexual contact.

This coronavirus, by comparison, seems to be relatively stable so that it is able to survive in the environment for hours and maybe a few days, and others are even more stable than that. Polio virus is stable even in sewage—you pick it up by drinking contaminated water. It passes through the gut, through the stomach, which is almost like pure hydrochloric acid—and the virus is still stable in that. So some are amazingly tough, and some are quite fragile.

Provided by Tufts University