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Virus Evolves

Evolutionary biology may sometimes seem like an arcane academic pursuit, but just try telling that to Gavin Smith, a virologist at Hong Kong University. For the past week, Dr. Smith and six other experts on influenza in Hong Kong, Arizona, California and Britain have been furiously analyzing the new swine flu to figure out how and when it evolved.

The first viruses from the outbreak were isolated late last month, but Dr. Smith and his colleagues report on their Web site that the most recent common ancestor of the new viruses existed 6 to 11 months ago. “It could just have been going under the radar,” Dr. Smith said.

The current outbreak shows how complex and mysterious the evolution of viruses is. That complexity and mystery are all the more remarkable because a virus is life reduced to its essentials. A human influenza virus, for example, is a protein shell measuring about five-millionths of an inch across, with 10 genes inside. (We have about 20,000.)

Some viruses use DNA, like we do, to encode their genes. Others, like the influenza virus, use single-strand RNA. But viruses all have one thing in common, said Roland Wolkowicz, a molecular virologist at San Diego State University: they all reproduce by disintegrating and then reforming.

A human flu virus, for example, latches onto a cell in the lining of the nose or throat. It manipulates a receptor on the cell so that the cell engulfs it, whereupon the virus’s genes are released from its protein shell. The host cell begins making genes and proteins that spontaneously assemble into new viruses. “No other entity out there is able to do that,” Dr. Wolkowicz said. “To me, this is what defines a virus.” The sheer number of viruses on Earth is beyond our ability to imagine. “In a small drop of water there are a billion viruses,” Dr. Wolkowicz said. Virologists have estimated that there are a million trillion trillion viruses in the world’s oceans.

Viruses are also turning out to be

astonishingly diverse. Shannon Williamson of the J. Craig Ventor Institute in Rockville, Md., has been analyzing the genes of ocean viruses. A tank of 100 to 200 liters of sea water may hold 100,000 genetically distinct viruses. “We’re just scratching the surface of virus diversity,” Dr. Williamson said. “I think we’re going to be continually surprised.”

Viruses are diverse because they can mutate very fast and can mix genes. They sometimes pick up genes from their hosts, and they can swap genes with other viruses. Some viruses, including flu viruses, carry out a kind of mixing known as reassortment. If two different flu viruses infect the same cell, the new copies of their genes get jumbled up as new viruses are assembled.

Viruses were probably infecting the earliest primordial microbes. “I believe viruses have been around forever,” Dr. Wolkowicz said.

As new hosts have evolved, some viruses have adapted to them. Birds, for example, became the main host for influenza viruses. Many birds infected with flu viruses do not get sick. The viruses replicate in the gut and are shed with the birds’ droppings.

A quarter of birds typically carry two or more strains of flu at the same time, allowing the viruses to mix their genes into a genetic blur. “Birds are constantly mixing up the constellation of these viruses,” said David Spiro of the J. Craig Venter Institute.

From birds, flu viruses have moved to animals, including pigs, horses and humans. Other viruses, like H.I. V. and SARS, have also managed to jump into our species, but many others have failed. “It’s a very rare event when a virus creates a new epidemic in another species,” said Colin Parrish of Cornell University. In Southeast Asia, for example, a strain of bird flu has killed hundreds of people in recent years, but it cannot seem to move easily from human to human.

Only a few strains of influenza have managed to become true human viruses in the past century. To make the transition, the viruses have to adapt to their new host. Their gene-building enzymes have evolved to run at top speed at human body temperature, for example, which is a few degrees cooler than a bird’s.

Influenza viruses also moved from bird guts to human airways. That shift also required flu viruses to spread in a new way: in the droplets we release in our coughs and sneezes.

“If the virus settles down on the floor, then it’s gone,” said Peter Palese, chairman of microbiology at Mount Sinai School of Medicine. Winter is flu season in the United States, probably because dry air enables the virus-laden droplets to float longer.

Up to a fifth of all Americans become infected each flu season, and 36,000 die. During that time, the flu virus continues to evolve. The surface proteins change shape, allowing the viruses to evade the immune systems and resist antiflu drugs.

Dr. Spiro and his colleagues have also discovered that human flu viruses experience a lot of reassortment each season. “Reassortment may be the major player in generating new seasonal viruses,” Dr. Spiro said.

From time to time, a new kind of flu emerges that causes far more suffering than the typical swarm of seasonal flu viruses. In 1918, for example, the so-called Spanish flu caused an estimated 50 million deaths. In later years, some of the descendants of that strain picked up genes from bird flu viruses.

Sometimes reassortments led to new pandemics. It is possible that reassortment enables flu viruses to escape the immune system so well that they can make people sicker and spread faster to new hosts.

Reassortment also played a big role in the emergence of the current swine flu. Its genes come from several ancestors, which mainly infected pigs.

Scientists first isolated flu viruses from pigs in 1930, and their genetic sequence suggests that they descend from the Spanish flu of 1918. Once pigs picked up the flu from humans, that so-called classic strain was the only one found in pigs for decades.

But in the 1970s a swine flu strain emerged in Europe that had some genes from a bird flu strain. A different pig-bird mix arose in the United States.

In the late 1990s, American scientists discovered a triple reassortant that mixed genes from classic swine flu with genes from bird viruses and human viruses. All three viruses — the triple reassortant, and the American and European pig-bird blends — contributed genes to the latest strain.

It is possible that the special biology of pigs helped foster all this mixing. Bird flu and human flu viruses can slip into pig cells, each using different receptors to gain access. “We call the pig a mixing vessel because it can replicate both avian and mammalian influenza virus at the same time,” said Juergen Richt of Kansas State University. “The mixing of these genes can happen much easier in the pig than in any other species.”

Fortunately, the new swine virus seems to behave like seasonal flu in terms of severity, not like the 1918 Spanish flu. “Right now it doesn’t have what it takes to be a killer virus,” Dr. Palese said. But could it? Dr. Palese said it was highly unlikely.

If the swine flu peters out in the next few weeks, virus trackers will still pay close attention to it over the next few months. As flu season ends in the Northern Hemisphere, the virus may be able to thrive in the southern winter or perhaps linger in the tropics, only to return to the north next fall. It will no doubt change along the way as its genes mutate, and it may pick up new genes.

The scientists will be watching that evolutionary journey with a mixture of concern and respect. “Viruses are incredibly adaptable,” Dr. Spiro said. “They have managed to exploit our modern culture and spread around the world.”