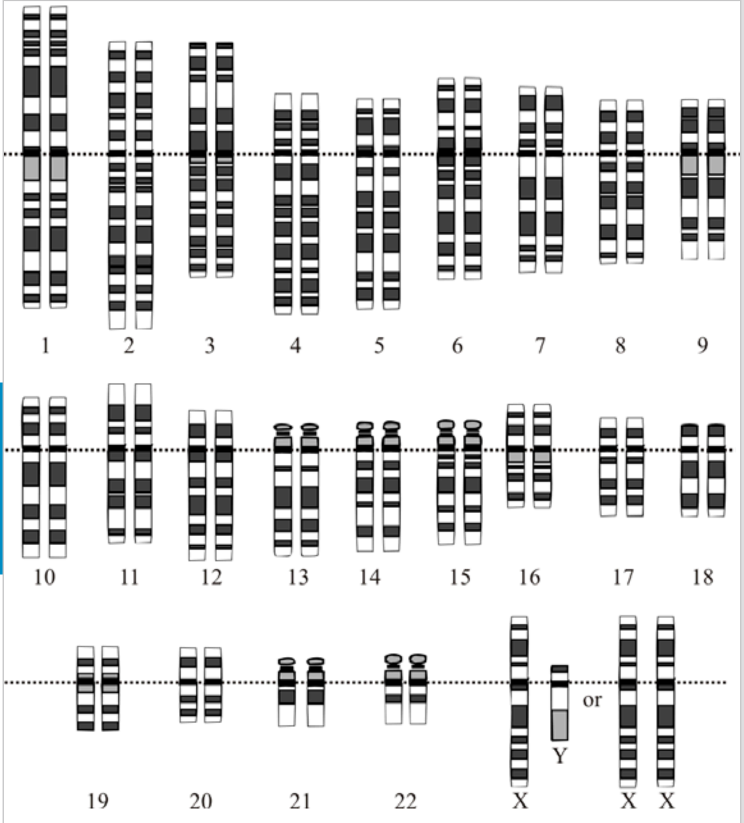
EarthDate

Fossil Viruses



Fossil viruses make up 8% of the 3.1 billion haploid base pairs of the human genome, and double that for the diploid genome. This graphical representation shows the organization of the human diploid genome into chromosomes including both the female (XX) and male (XY) versions of the 23rd chromosome pair. Chromosomes are shown aligned at their centromeres.

Credit: National Human Genome Research Institute

When scientists mapped the human genome, they found that just 2% of it controlled our own functioning. Fully 8% was the DNA of *fossil* viruses.

Paleovirologists who study fossil viruses have found that all viruses share a common single-cell ancestor from more than 3 billion years ago.

About 1.5 billion years ago, viruses changed their protein coating, allowing them to penetrate the cells of their hosts.

As multicellular life became increasingly complex, viruses got simpler, eventually giving up independent life. They threw out genes they didn't use and discarded their means of reproduction until they were totally reliant on cell hosts.

When a virus enters a cell, part of its RNA is converted to DNA within the cell's gene code.

If that cell is an egg or sperm, that DNA could be passed to the next host individual.

However, that can only happen if the virus does not kill the host.

So, if the virus is beneficial or benign—or if the host's immune system is able to defeat it and become healthy enough to reproduce—then the viral DNA can be passed down through generations.

This process has occurred enough times over millions of years for viral DNA to make up that 8% of our gene code.

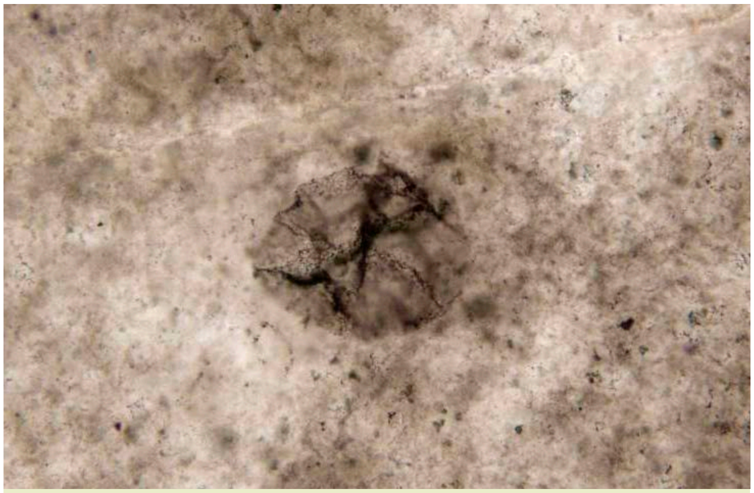
And fossil viral DNA has been very beneficial to us and all other organisms, as we'll discuss in another *EarthDate*.

Bureau of Economic Geology

Background: Fossil Viruses

Synopsis: Viruses have been around for billions of years. Scientists have never found fossilized viruses in rocks, but viral fossils are pretty easy to locate—they make up about 8% of the human genome.

- Researchers have found fossilized microbes like bacteria and fungi, but fossils of viruses have never been found in ancient rocks.
  - Their fragile structures consist of just a few strands of genetic material and protein coatings that are easily broken down as rocks lithify, so direct fossil evidence isn't preserved. Viral chemical and biosignatures, however, are still under assessment.
  - But we can find viral fossils that preserve genetic code from millions of years ago hiding in our very own genomes and in the genomes of every other living thing—from other mammals to plants to fungi to bacteria and archaea.
  - Paleovirology, the study of extinct fossil viruses, helps us to reconstruct the past history of various species and the viruses that shaped them, as well as helps us to shape effective responses to new viruses.



Viruses are too fragile to be found as fossils in rocks, but scientists *have* found fossil bacteria. This microscopic image is of a 2.5-billion-year-old sulfur-oxidizing bacterium.

Credit: Andrew Czaja

- Where did viruses come from?
  - Researchers have used a detailed study of protein folding to show that viruses and bacteria descended from a common ancestor—a fully functioning cell that lived 3.4 billion years ago and was one of Earth's earliest life forms.
  - About 1.5 billion years ago, viruses changed the structure of their protein coat, enabling them to enter host cells.
  - Eventually they diverged from cellular life and evolved into simpler symbiotic forms, throwing out genes they didn't use until they ultimately discarded their own mechanisms for reproduction, becoming dependent on cellular hosts.
  - Whereas cellular life evolved to be more complex, viruses evolved to be simpler.
- Viruses are masters of their own rapid evolution.
  - Some evolve over decades or centuries, but others—like influenza—evolve so rapidly that different vaccine formulations are required each year to bolster our immune systems.
  - Viruses also evolve zoonotically, jumping from one organism to another.
- Recent studies have shown that viruses can also cause their host organisms to evolve, and the evidence is found within the host's very own genome.
  - When researchers mapped the human genome in 2003, they found more than 3 billion haploid base pairs organized into the genes on our 23 chromosomes.
  - They were surprised to find that less than 2% of the genome carries the coding for the creation of proteins, the building blocks of life that keep our cells functioning.

References: Fossil Viruses

Human DNA is Littered with Fossils of Viruses Past | Telegraph India
Origin of the Retroviruses: When, Where, and How? | PubMed
What Came First, Cells or Viruses? | Cosmos
The Origins of Viruses | Nature Scitable

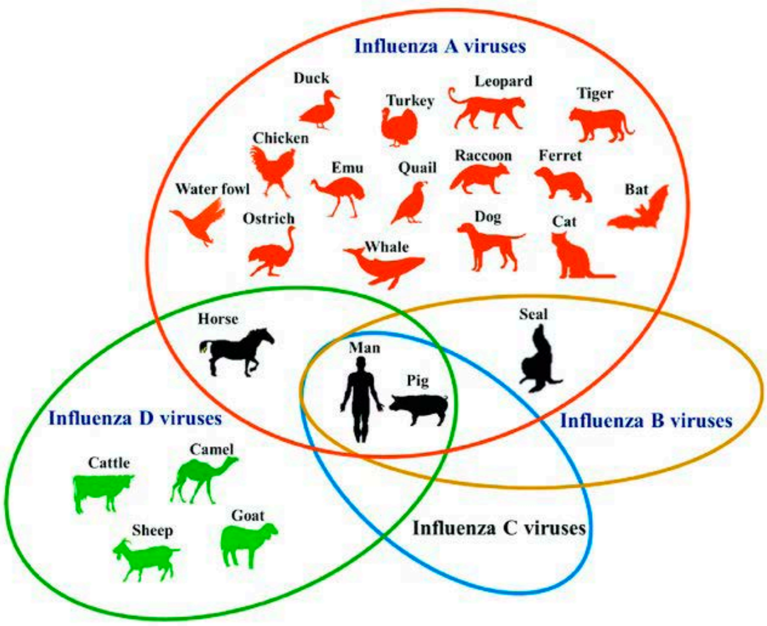
Contributors: Juli Hennings, Harry Lynch

EarthDate

Bureau of Economic Geology

Background: Fossil Viruses

- The remaining 98% of our genome consists of a tangle of old genes that don't function anymore along with strings of repetitive DNA and other elements with no obvious function.
- Within this junkyard of genetic material, researchers found that 8% of our DNA consists of forever-deactivated fossils of defeated viruses that infected our ancestors but lost the battle with our immune system. These are called endogenous retroviruses (ERVs).



Influenza viruses can affect multiple species of animals and spread from animals to humans.

Credit: Suresh Kuchipudi and Ruth H. Nissly (CC BY)

- Retroviruses are thought to have originated in marine environments more than 460 million years ago, during the Ordovician Period. They only infect vertebrates.
- When a retrovirus infects a cell, it takes over most cell functions and directs the cell to create an enzyme that converts the virus's RNA to DNA. Bits of that DNA are inserted into the host cell's chromosome using another enzyme the retrovirus directs the cell to manufacture.
- If the infected cell is a sperm or egg cell, the retrovirus becomes "endogenous," meaning its altered DNA can be passed down through generations.
- ERVs are not able to produce new viruses; they are segments of DNA left behind by the genetic engineering of a past virus.

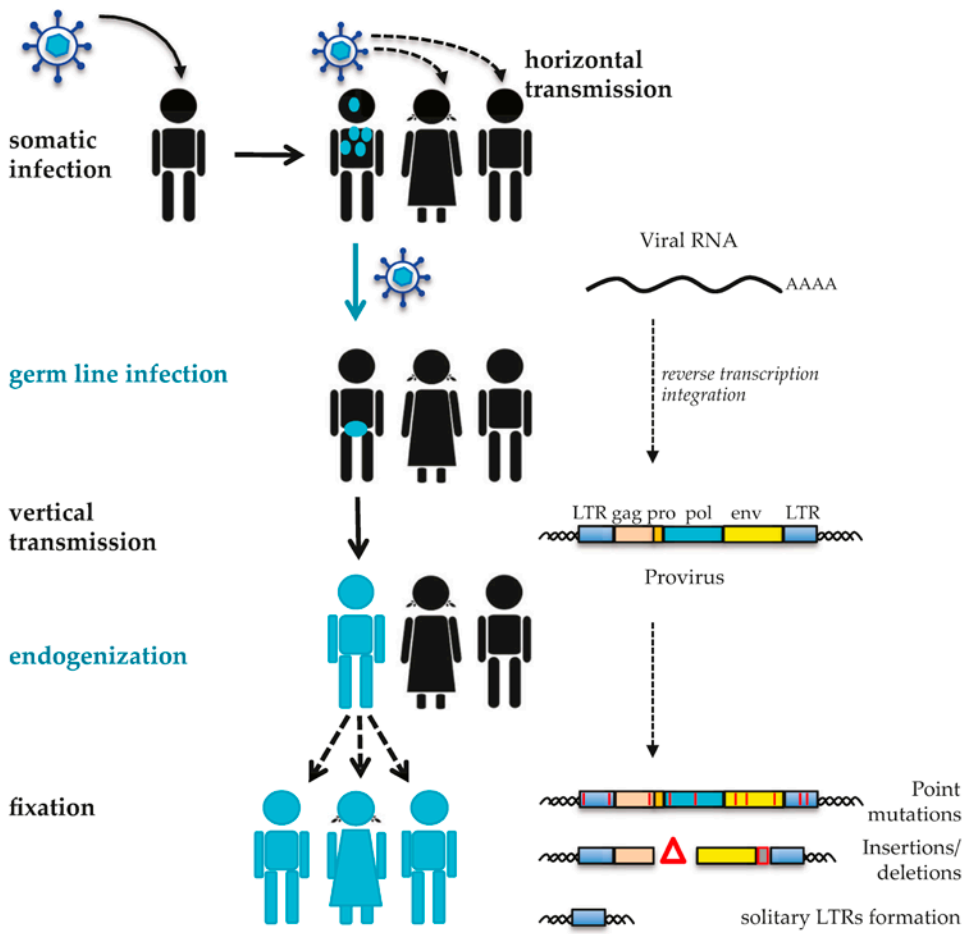
- Like other life forms, humans have been engaged in a continual battle with viruses.
  - Viruses invade, so our immune system fights back by changing the shape or composition of its proteins to defeat them. Meanwhile, the viruses struggle to evade our defensive response.
  - Pandemics and epidemics punctuate human evolution—populations either adapt or they go extinct. Endogenous retroviruses record the evolution of our proteins, revealing details of these past evolutionary conflicts.

References: Fossil Viruses

Human DNA is Littered with Fossils of Viruses Past | Telegraph India
Origin of the Retroviruses: When, Where, and How? | PubMed
What Came First, Cells or Viruses? | Cosmos
The Origins of Viruses | Nature Scitable

Contributors: Juli Hennings, Harry Lynch

Background: Fossil Viruses



This diagram shows how ERVs form. First, the retrovirus targets somatic cells, or regular body cells. People of the same generation who contract the virus are an example of horizontal transmission; they each contract the virus on their own, rather than inheriting it. Germ-line transmission happens with the virus infects germ-line cells—cells that produce eggs and sperm, giving them a chance to be passed vertically to the next generation. Children of an infected parent have a 50% chance of inheriting the virus. An EVR endogenizes when it becomes a part of the organism's genome and is capable of being inherited by offspring. EVRs become inactivated through mutations that occur during DNA replication, making them unable to produce the virus.

Credit: Nicole Grandi and Enzo Tramontano

References: Fossil Viruses

Human DNA is Littered with Fossils of Viruses Past | Telegraph India
Origin of the Retroviruses: When, Where, and How? | PubMed
What Came First, Cells or Viruses? | Cosmos
The Origins of Viruses | Nature Scitable

Contributors: Juli Hennings, Harry Lynch