Study of giant viruses shakes up tree of life

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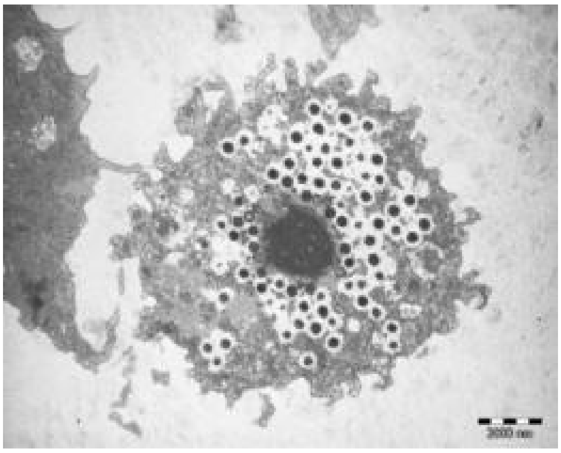

Giant viruses should be included reconstructions of the tree of life, researchers report in a new study. The mimivirus, shown here (small black hexagons) infecting an amoeba, is as big as some bacterial cells and shares some ancient protein structures with most organisms. Credit: Professor Didier Raoult, Rickettsia Laboratory, La Timone, Marseille, France

A new study of giant viruses supports the idea that viruses are ancient living organisms and not inanimate molecular remnants run amok, as some scientists have argued. The study reshapes the universal family tree, adding a fourth major branch to the three that most scientists agree represent the fundamental domains of life.

The new findings appear in the journal BMC Evolutionary Biology.

The researchers used a relatively new method to peer into the distant past. Rather than comparing genetic sequences, which are unstable and change rapidly over time, they looked for evidence of past events in the three-dimensional, structural domains of proteins. These structural motifs, called folds, are relatively stable molecular fossils that – like the fossils of human or animal bones – offer clues to ancient evolutionary events, said University of Illinois crop sciences and Institute for Genomic Biology professor Gustavo Caetano-Anollés, who led the analysis.

"Just like paleontologists, we look at the parts of the system and how they change over time," Caetano-Anollés said. Some protein folds appear only in one group or in a subset of organisms, he said, while others are common to all organisms studied so far.

"We make a very basic assumption that structures that appear more often and in more groups are the most ancient structures," he said.

Most efforts to document the relatedness of all living things have left viruses out of the equation, Caetano-Anollés said.

"We've always been looking at the Last Universal Common Ancestor by comparing cells," he said. "We never added viruses. So we put viruses in the mix to see where these viruses came from."

The researchers conducted a census of all the protein folds occurring in more than 1,000 organisms representing bacteria, viruses, the microbes known as archaea, and all other living things. The researchers included giant viruses because these viruses are large and complex, with genomes that rival – and in some cases exceed – the genetic endowments of the simplest bacteria, Caetano-Anollés said.

"The giant viruses have incredible machinery that seems to be very similar to the machinery that you have in a cell," he said. "They have complexity and we have to explain why."

Part of that complexity includes enzymes involved in translating the genetic code into proteins, he said. Scientists were startled to find these enzymes in viruses, since viruses lack all other known protein-building machinery and must commandeer host proteins to do the work for them.

In the new study, the researchers mapped evolutionary relationships between the protein endowments of hundreds of organisms and used the information to build a new universal tree of life that included viruses. The resulting tree had four clearly differentiated branches, each representing a distinct "supergroup." The giant viruses formed the fourth branch of the tree, distinct from bacteria, archaea and eukarya (plants, animals and all other organisms with nucleated cells).

The researchers discovered that many of the most ancient protein folds – those found in most cellular organisms – were also present in the giant viruses. This suggests that these viruses appeared quite early in evolution, near the root of the tree of life, Caetano-Anollés said.

The new analysis adds to the evidence that giant viruses were originally much more complex than they are today and experienced a dramatic reduction in their genomes over time, Caetano-Anollés said. This reduction likely explains their eventual adoption of a parasitic lifestyle, he said. He and his colleagues suggest that giant viruses are more like their original ancestors than smaller viruses with pared down genomes.

The researchers also found more evidence that viruses are key "spreaders of information," Caetano-Anollés said.

"The protein structures that other organisms share with viruses have a particular quality, they are (more widely) distributed than other structures," he said. "Each and every one of these structures is an incredible discovery in evolution. And viruses are distributing this novelty," he said.

Most studies of giant viruses are "pointing in the same direction," Caetano-Anollés said. "And this study offers more evidence that viruses are embedded in the fabric of life."

More information: "Giant Viruses Coexisted With the Cellular Ancestors and Represent a Distinct Supergroup Along With Superkingdoms Archaea, Bacteria and Eukarya," www.biomedcentral.com/1471-2148/12/156/abstract

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