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Concept article: Minireviews

Giant Viruses

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Abstract

Giant viruses are a group of viruses that have captured the attention of researchers due to their unusually large size, unique morphology, and genome organization. Despite their size, these viruses have been found to be infectious and have been shown to infect a wide range of hosts, including unicellular eukaryotes, bacteria, and even other viruses.

Subsequent studies have shown that giant viruses can also be infected by other types of viruses, which are commonly referred to as virophages which are small viruses that are able to infect and replicate within giant viruses. This discovery has raised questions about the evolution and coexistence of these different viruses, and has added a new layer of complexity to the study of giant viruses.

By exploring these unique and fascinating viruses, we hope to shed light on their diverse roles in the environment and the potential implications for understanding virus-host interactions.

Key words

Giant Viruses, Viruses, Virophages, Biological life, Evolution.

Introduction

Viruses are infectious agents that can cause diseases in humans, animals, and plants. They are composed of a protein coat called a capsid, which encloses the genetic material. The genetic material can be either DNA or RNA. The size of viruses varies from around 20 nanometers to several hundred nanometers. However, in 2003, the discovery of a new group of viruses, named Mimivirus, challenged the conventional notion of viruses' size. These viruses were much larger than typical viruses, with a size comparable to small bacteria. This discovery opened up a new field of study in virology, which led to the identification of many new giant viruses.

Giant viruses are a unique group of viruses that can reach sizes of up to 1.5 micrometers, which is about ten times larger than typical viruses. They have complex and highly organized genomes, which can range from 500,000 to 2.5 million base pairs, making them larger than some bacteria. Giant viruses also have a unique morphology, with some species having an elongated shape and a long tail-like structure.

The discovery of giant viruses has challenged the conventional notion of viruses' size and structure and opened up a new field of study in virology. The study of giant viruses provides insight into the evolution of viruses and their relationship with cellular organisms. Additionally, because giant viruses can infect amoebas and other protists, they may also have a significant impact on microbial ecology.

While giant viruses are known for their large genome sizes and complex replication cycles, they are not immune to being infected by other viruses. In fact, several studies have reported cases of giant viruses being infected by non-giant viruses.

In this article, we will explore the unique features of giant viruses, including their genome organization, replication strategies, and morphological characteristics. We will also discuss some of the best-known examples of giant viruses, including Mimivirus, Pandoravirus, and Pithovirus. Finally, we will conclude with the implications of giant virus research and future directions for this rapidly expanding field.

Methods

The study of giant viruses involves a combination of molecular biology, biochemistry, and microscopy techniques. The discovery of giant viruses is primarily based on their size, morphology, and genome characteristics. Transmission electron microscopy (TEM) is a common method used to visualize the structure of giant viruses. Genome sequencing is also an essential tool to identify the genes and their functions in these viruses.

Classification of Giant Viruses:

Giant viruses are classified based on their genetic material and the presence of certain features, such as the presence of a nucleolus-like structure, the size and complexity of their genomes, and the presence of a gene encoding an RNA polymerase. Currently, giant viruses are divided into four groups: Mimiviridae, Molliviridae, Pandoraviridae, and Pithoviridae.

Mimiviridae:

Mimiviruses were the first discovered giant viruses, with a size of up to 1.2 micrometers. They have a double-stranded DNA genome of around 1.2 million base pairs, encoding more than 900 proteins. Mimiviruses have a unique genome structure, including the presence of genes that are typically found in cellular organisms, such as genes involved in DNA repair, replication, and transcription.

Molliviridae:

Molliviruses are another group of giant viruses with a size of up to 0.6 micrometers. They have a single-stranded RNA genome of around 9 kilobases, encoding four proteins. Unlike other giant viruses, molliviruses do not have a capsid. Instead, they have a membrane envelope surrounding their genome.

Pandoraviridae:

Pandoraviruses are the largest known giant viruses, with a size of up to 1.5 micrometers. They have a double-stranded DNA genome of around 2.5 million base pairs, encoding more than 2,000 proteins. Pandoraviruses have a unique genome structure, including the presence of genes that are typically found in eukaryotic organisms, such as genes encoding histones and tubulin.

Pithoviridae:

Pithoviruses are the most recently discovered group of giant viruses. They have a size of up to 1.5 micrometers and a double-stranded DNA genome of around 600,000 base pairs, encoding around 500 proteins. Pithoviruses have a unique morphology, with an elongated shape and a long tail-like structure.

Replication Strategies of Giant Viruses:

Giant viruses have unique replication strategies, which differ from typical viruses. They can replicate in the cytoplasm of their host cells or within a specialized replication factory called the viral factory. Some giant viruses, such as Mimiviruses, have a complex life cycle, with several distinct stages, including attachment, entry, replication, and assembly. Mimiviruses also have a unique mechanism of genome replication, involving the formation of a giant virus-specific structure called the viral factory.

Unlike typical viruses, giant viruses can encode genes involved in translation, such as tRNA synthetases, and even have the ability to translate their own messenger RNAs. This feature suggests that giant viruses may have evolved from a cellular ancestor, which underwent reductive evolution to become a virus.

Examples of Giant Viruses:

Mimivirus:

Mimivirus was the first discovered giant virus, Figure 1, isolated in 2003 from a water sample in a cooling tower in Bradford, UK. It has a size of around 0.75 micrometers and a double-stranded DNA genome of around 1.2 million base pairs. Mimivirus has a complex life cycle, involving several stages, including attachment, entry, and replication. It infects amoebas and can cause pneumonia in humans.

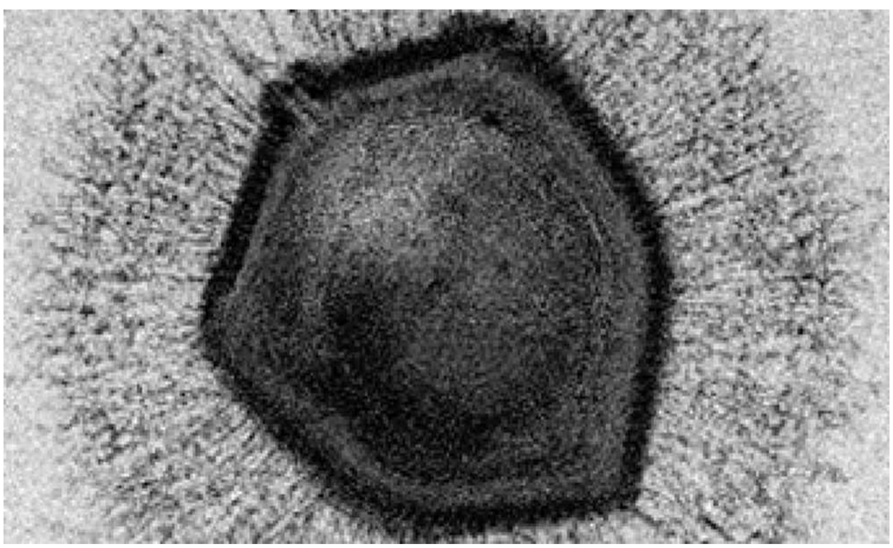

Figure 1. Mimivirus a type of giant virus. (This article is in Russian language. Use google translate to English or whatever language of preference)

https://polit.ru/news/2019/11/13/ps_mipt_olpvrii/

Mamavirus:

Mamavirus was first discovered in 2008 in a water sample from a cooling tower in Paris, France, Figure 2. It has a size of around 0.8 micrometers and a double-stranded DNA genome of around 1.2 million base pairs. Mamavirus has a complex replication cycle that involves the recruitment of host proteins and can infect a wide range of protists and even some algae.

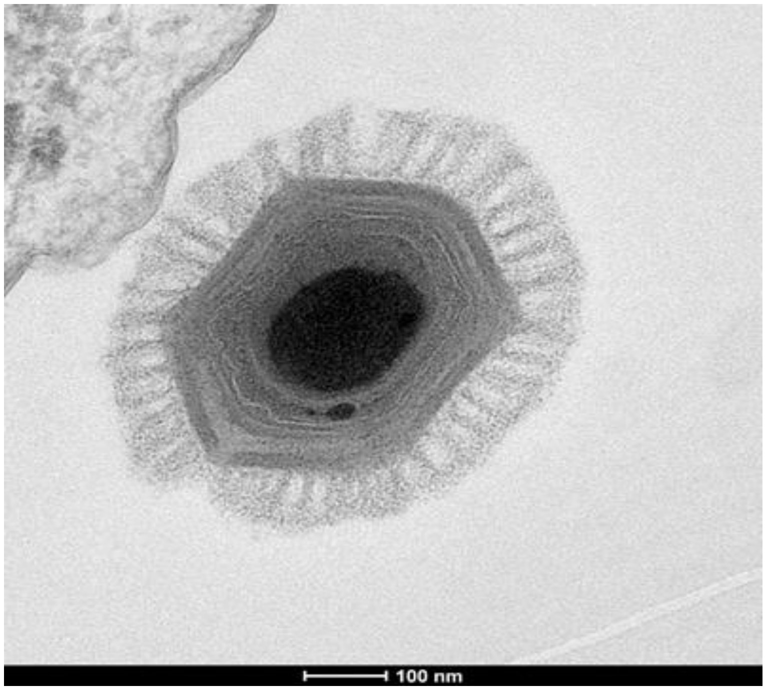

Figure 2. Mamavirus a type of giant virus.

Find here: https://alchetron.com/Mamavirus

Pandoravirus:

Pandoravirus is the largest known giant virus, with a size of up to 1.5 micrometers, Figure 3. It was first isolated in 2013 from a sediment sample in Chile. Pandoravirus has a double-stranded DNA genome of around 2.5 million base pairs and encodes more than 2,000 proteins. It has a unique genome structure, including the presence of genes that are typically found in eukaryotic organisms.

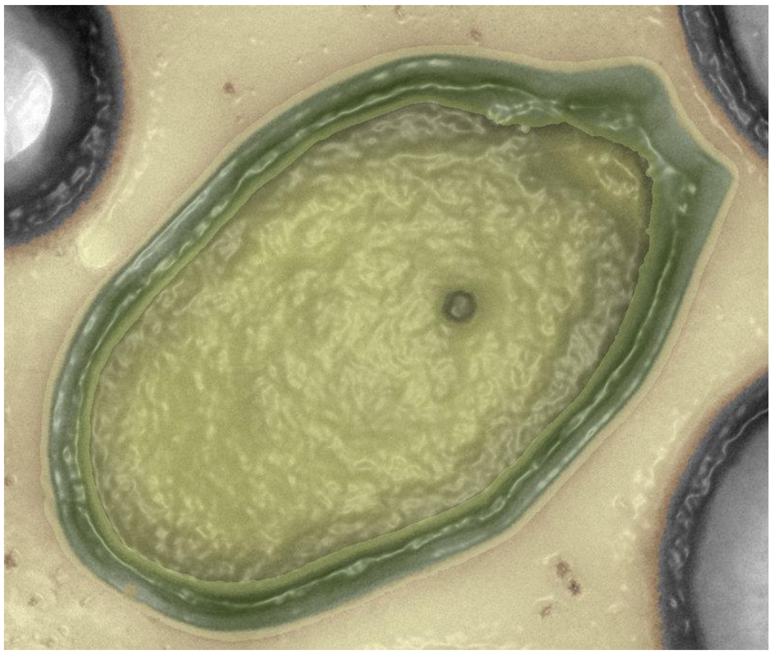

Figure 3. Pandoravirus a type of giant virus. Available here:
http://www.sci-news.com/biology/science-pandoravirus-giant-01253.html

Pithovirus:

Pithovirus was first isolated in 2014 from a Siberian permafrost sample, Figure 4. It has a size of up to 1.5 micrometers and a double-stranded DNA genome of around 600,000 base pairs, encoding around 500 proteins. Pithovirus has a unique morphology, with an elongated shape and a long tail-like structure.

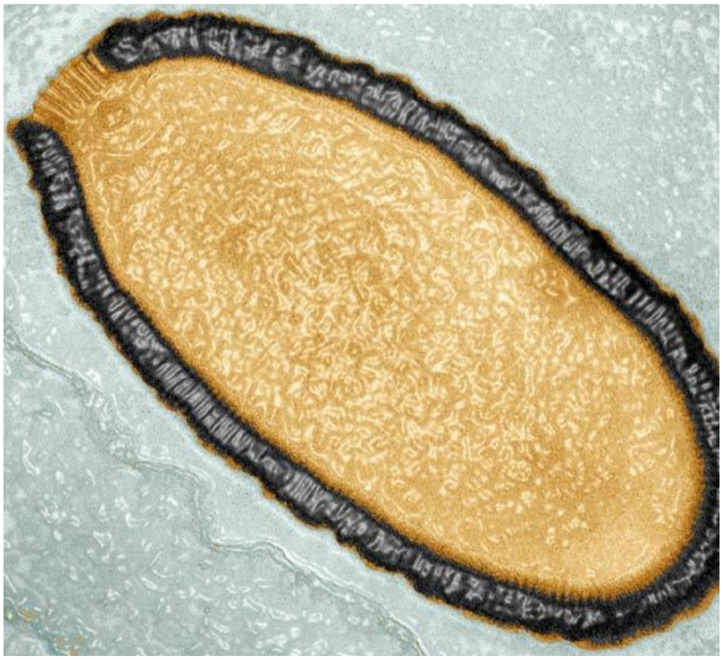

Figure 4. Pithovirus sibericum. Image credit: Julia Bartoli / Chantal Abergel / IGS / CNRS / AMU. http://www.sci-news.com/biology/science-pithovirus-sibericum-giant-virus-01791.html

Mollivirus:

Mollivirus was first isolated in 2016 from a water sample in the coastal sediments of Chile, Figure 5. It has a size of around 0.6 micrometers and a double-stranded DNA genome of around 651,335 base pairs. Mollivirus can infect amoebas and other protists and has a unique genome organization, including the presence of genes typically found in eukaryotic organisms.

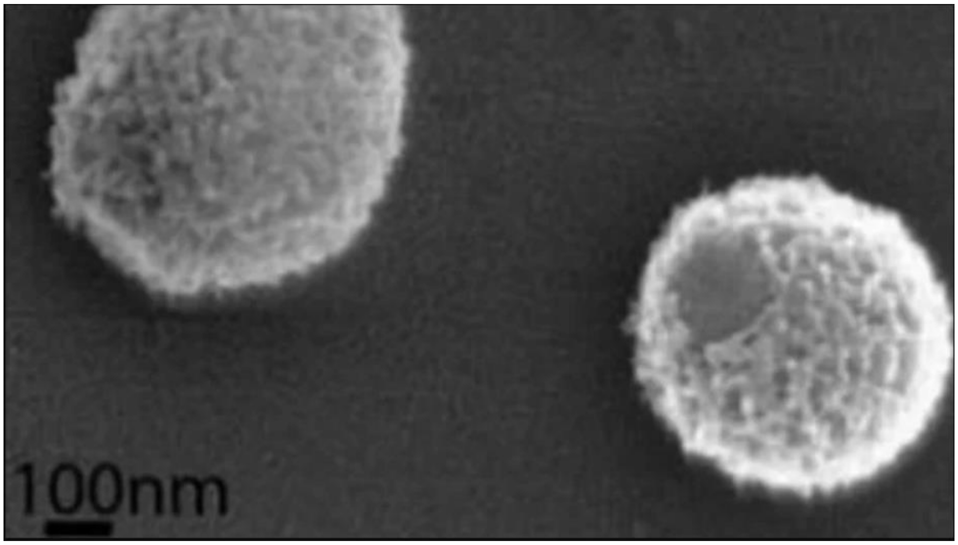

Figure 5. Scanning electron microscopy of two isolated Mollivirus particles. Available here:

https://www.smh.com.au/technology/prehistoric-frankenvirus-mollivirus-sibericum-uncovered-in-siberian-permafrost-20150909-gjial2.html

These examples highlight the diversity of giant viruses and their potential impact on microbial ecology and evolution. As new sequencing technologies and other tools continue to advance, we can expect to discover many more fascinating examples of giant viruses in the future.

Giant Viruses Can Be Infected !

While the discovery of giant viruses has challenged our understanding of the diversity and complexity of viruses, the finding that giant viruses can be infected by non-giant viruses, termed as virophages, further highlights the complex and dynamic nature of virus-host interactions. These interactions can have important ecological and evolutionary implications, as they can affect the replication and transmission of viruses in different environments and hosts.

One example of this phenomenon is the infection of the giant virus Mimivirus by the satellite virus Sputnik. Sputnik is a small virophage virus that can only replicate in the presence of Mimivirus, Figure 6. It is thought to have evolved from a plasmid or a bacteriophage and contains a small genome of around 18 kilobases. Sputnik infects the Mimivirus factory-like structures called "viral factories" and takes advantage of the host's machinery to replicate and assemble new virions.

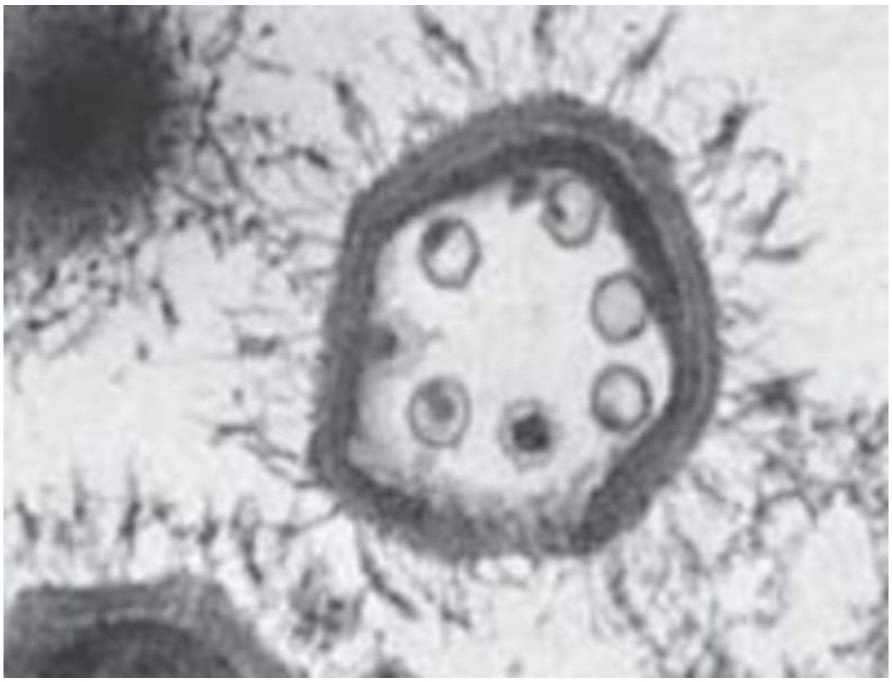

Figure 6. Sputnik virus inside the giant virus Mimivirus. Available here: https://www.nationalgeographic.com/science/article/the-virophage-a-virus-that-infects-other-viruses

Another example is the infection of the giant virus Pithovirus by the non-giant virus Mavirus. Mavirus is a small single-stranded RNA virus that can infect a wide range of hosts, including bacteria and eukaryotic cells. It is thought to have evolved from a virophage, which is a type of virus that infects other viruses. Mavirus infects the Pithovirus factory-like structures and interferes with the host's replication cycle, leading to the production of fewer viral particles.

Discussion

The discovery of giant viruses has opened up new avenues of research and has challenged our understanding of the diversity and complexity of the viral world. These viruses represent a unique branch of the virus family tree and raise questions about the origins of life on Earth and the mechanisms that drive evolution.

Giant viruses are known to infect a wide range of organisms, including unicellular eukaryotes, bacteria, and even other viruses. By studying their interactions with their hosts, researchers have gained new insights into the biology of these organisms and the mechanisms that drive virus-host interactions. The discovery that giant viruses can themselves be infected by other viruses, such as virophages, has added a new layer of complexity to these interactions and has broadened our understanding of the diversity of the virosphere.

In addition to their impact on basic scientific research, the study of giant viruses has important implications for the treatment of viral infections and the development of new medical therapies. The unique characteristics of these viruses, such as their large size and complex genome organization, make them attractive targets for the development of new antiviral treatments. By understanding the replication strategies of these viruses and their interactions with their hosts, researchers may be able to identify new targets for antiviral drugs and develop more effective treatments for a wide range of viral infections.

Furthermore, the study of giant viruses has broader implications for our understanding of the role of viruses in the environment and the impact that they have on ecosystems. These viruses are known to play important roles in the regulation of microbial populations and the cycling of nutrients in aquatic and soil environments. By understanding the ecology and evolution of giant viruses, researchers may be able to develop new strategies for environmental management and restoration.

It should be noted that many giant viruses have been discovered in extremely cold deposits, such as Siberia, at depths of up to 15 meters and with a geological age of up to 30,000 years!

These discoveries raise new questions about the nature of viruses and biological life, such as:

☛ Are viruses just dead genomic particles that only return to a kind of biological life when they occupy living cells, or are they independent life forms that require a deeper understanding?

☛ Did viruses descend from previously living cells that were severely damaged under harsh conditions, shed much of their cellular equipment, and retained their genome, becoming "viral particles" as a kind of resilience and survival?

☛ Do viruses represent a special branch in the tree of life, like the well-known major branches: "true nucleus Eukaryotes", "non-true nucleus Prokaryotes", and "Archaea or ancient"? Or should they remain outside the tree of life and be viewed as genomic particles that sometimes interact beneficially with other branches of life and at other times destroy them?

Questions still looking for scientific endeavous to answer. The existance of giant viruses represents a major breakthrough in the study of viruses and their interactions with their hosts. The unique properties of these viruses have challenged our understanding of the diversity and complexity of the viral world and have important implications for scientific knowledge, the treatment of viral infections, and the development of new medical therapies. By continuing to explore these fascinating organisms, researchers may be able to unlock new insights into the mechanisms that drive life on Earth and the potential for new treatments for a wide range of diseases.

Conclusion

Giant viruses are a unique group of viruses that challenge the conventional notion of viruses' size and structure. They have a unique genome organization and replication strategies, which differ from typical viruses. The discovery of giant viruses has opened up a new field of study in virology, with many new species identified in recent years. The study of giant viruses provides insight into the evolution of viruses and their relationship with cellular organisms.

The cases where giant viruses have been found to be infected by non-giant viruses demonstrate the need for further research to understand the diversity and complexity of virus-host interactions. By studying these interactions, we may gain a better understanding of the ecology and evolution of viruses and their hosts.

The topic of giant viruses is of relatively recent interest and it opens many opportunities for new research and promising scientific discoveries that will reflect in important developments in the understanding of the biology of life in general, as well as the phenomenon of species and genus evolution. It will also play an important role in advancing medicine and health and as tools in biotechnological applications, among others.

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