Are Viruses Alive

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Viruses are one of the most common biological units on the planet and have had an immense effect on all organisms. Viruses are often associated with numerous diseases that can arise from their reproduction in a cell— such as COVID-19. While viruses are responsible for countless diseases, the significance of viruses far surpasses illness; viruses have played a vital role in evolution. According to Rossmann (2013), viruses have facilitated the transport of genes between different organisms, leading to new gene combinations that have catalyzed countless advantageous developments. Due to the immense importance of viruses, and the impact in which they can have, the field of virology has grown exponentially over the last one hundred years.

While the understanding of viruses has drastically increased over this period of time, there is still debate on one key question; are viruses alive? The accepted answer to this question has changed multiple times since the discovery of viruses, with most of the current scientific community subscribing to the idea that viruses are not alive. This point of view is not ubiquitous though, as new discoveries and theories in the field of virology have introduced unique arguments in the debate on viral life (Forterre, 2016). Despite events like the discovery of giant viruses and the creation of the virocell concept, under the current definition of life, it is impossible to classify viruses as living organisms. Therefore, because viruses rely on cells to evolve and adapt to their environments, they are unable to conduct metabolic processes without the aid of a cell, and they lack certain structural elements that all other living organisms share, they cannot be considered alive.

Literature Review

Viruses are microscopic biological units composed of DNA or RNA surrounded by a protective protein layer known as a capsid (Meštrović, 2022). Many viruses also have an envelope, or a spiky layer that surrounds the capsid (Crosta, 2020). While there are some universal similarities between viruses, there is also an abundance of diversity between viruses. The Baltimore Classification System separates viruses into seven main groups based on the kind of nucleic acid that they contain and the number of strands present (Shaffer, 2019). In each class of viruses, there is additional variance based on the physical size of the virus as well as the size of the genome (Louten, 2016). For example, viruses can range in size from 20 nanometers to over 1,000 nanometers in diameter; the genome of viruses can range from 7,000 base pairs to well over 2,000,000 base pairs (Louten, 2016).

Viruses are intracellular parasites that are only able to reproduce through the usage of cellular machinery (University of Hawaii, 2022). Forterre (2016) noted that viral reproduction is completed during two phases; there is an extracellular phase where the genome inside the virion (a single viral particle) remains inactive until it makes contact with a cell that it can utilize and an intracellular phase where the virion takes control of the cell and creates more virions using the cellular organelles. During the intracellular reproduction phase, viruses with an RNA genome introduce their own genetic material into the host cell's genome (Louten, 2016). Because of this exchange in genetic material, it is estimated that around eight percent of the human genome comes from viral genes (University of Hawaii, 2022).

According to Rossmann (2013), viruses were first discovered in the late nineteenth century by Dmitri Ivanovsky during his studies on the Tobacco Mosaic Disease; but it was not until the experiments of Wendell M. Stanley in 1935 that the size, shape, and properties of viruses were discovered. Following the experiments of Ivanovsky and Stanley, the newly established field of virology began to drastically expand. Meštrović (2022) defined virology as the study of the taxonomy, disease-producing properties, cultivation, and genetics of viruses. Some notable improvements to the modern understanding of viruses were Watson and Crick's discovery that viruses may have icosahedral symmetry in the 1950s, the determination of viruses' three-dimensional structures during the 1970s, and the usage of cryo-electron microscopy with X-ray crystallography to study enveloped viruses in the 1990s (Rossmann, 2013). Recently, there have been three major discoveries that have altered the understanding of viruses. It was found that viral particles and genes outnumber cells and cellular genes by up to two degrees in magnitude, evolutionarily related viruses that affect all three domains of life were discovered, and giant viruses like Mimivirus and Pandoravirus were found in Amoeba (Forterre, 2016).

Giant viruses were first discovered in 2003 and have challenged the definition of viruses (Claverie & Abergel, 2016). The discovery of these viruses was delayed, as they filter differently than traditional viruses. They were often mistaken for an intracellular parasitic bacterium, but since the discovery of the Mimivirus, multiple other giant viruses from unrelated families have been uncovered (Claverie & Abergel, 2016). These viruses are unique because they have a genome to volume ratio more like a cell, more genetic material than some simple bacterium, and are larger in size than some bacterium (Claverie & Abergel, 2016).

When viruses were first discovered, they were thought of as living organisms that resemble small prokaryotes; however, this was quickly abandoned for the idea that viruses are a missing link between the inert world and living organisms (Moreira & López-García, 2009). This idea was proven to be incorrect upon the accumulation of evidence that viruses are molecular parasites (Forterre, 2016). Currently, it is believed that viruses are not alive because they are polyphyletic, the important genes responsible for metabolism and translation have a cellular origin, and there is no structural continuity in viruses (Moreira & López-García, 2009). Some individuals believe that viruses should be considered alive because DNA viruses undergo transcription, viruses are composed of the same macromolecules that make up living organisms, and adherence to the virocell concept would add more life-like qualities to viruses (Forterre, 2016).

The virocell concept is a theory proposed by Patrick Forterre that would solve many of the problems that arise from calling viruses alive (Moreira & López-García, 2009). When a virion enters a cell, it creates a virus factory that allows the replication of new viruses. If the virus factory found in the intracellular phase of viral reproduction is considered the organism rather than the virion, then viruses display all the characteristics of life (Forterre, 2016). The virus obtains a cellular structure and a metabolism that would make the virus an autonomous organism (Forterre, 2016).

Life is an extremely important process that is fundamental to all organisms. All humans have at the very least a simple understanding of being alive, but the intricacies that separate chemistry from a living organism are often overlooked. This is because defining life is an extremely complex task, as the earth contains a plethora of diverse organisms. There is not a single, all-encompassing definition to life, but most definitions include five key points. All living organisms use enzymes to speed and mediate reactions, store hereditary information, have an evolutionary history and adapt to their environments, maintain homeostasis, and have some form of cellular organization (University of Hawaii, 2022). This definition can be interpreted ambiguously, leading to some confusion when it comes to viruses. Placing more weight on the first three points would mean that viruses are alive but focusing on the last two points would provide evidence against the inclusion of viruses (University of Hawaii, 2022).

Cellular organization refers to the arrangement of the components that make up a cell (University of Hawaii, 2022). All known life forms are either prokaryotic –composed of one cell—or eukaryotic –composed of numerous cells functioning together—but they all share three major components: a cell membrane, cytoplasm, and organelles (University of Hawaii, 2022). All organisms have a metabolism as well. Mandal (2021) defined metabolism as all the chemical reactions that occur within an organism and allow that organism to survive. Metabolic pathways can either be catabolic, meaning they release energy through the breakdown of compounds, or anabolic, meaning they consume energy to build larger compounds (Mandal, 2021).

Confirmation

The first reason that viruses cannot be considered alive is that the virus's ability to evolve and adapt to its environment is reliant on cellular intervention. It is clearly established in the definition of viruses that a single virion is unable maintain homeostasis and it lacks proper cellular organization; however, viruses technically cannot evolve by themselves either. The Viruses' ability to evolve and adapt is a reoccurring subject in the debate on viral life, but the way that viruses evolve renders the logic behind the argument faulty. While it is true that viruses have changed over time, all evolution in viruses occurs from the influence of cells and natural selection (Moreira & López-García, 2009). All viral reproduction takes place within a hijacked cell through the usage of cellular machinery. Any evolutionary differences that arise between viral strands are entirely reliant on the reproductive processes occurring within the cell, and the virus's ability to infect that cell. If a virus is unable to infect a cell, no new virions will be created, and no evolution or adaptation will occur (Moreira & López-García, 2009).

Viruses evolve and adapt in a way that mirrors nonliving entities, like computer malware, more than living organisms. Like viruses, computer malware can slightly alter its code with the aid of external influences (Wassenaar & Blaser, 2002). Computer malware spreads like viruses, travelling between hosts and changing based upon the defense mechanisms that they are faced with, rather than by their own accord (Wassenaar & Blaser, 2002). Computer malware was invented by people and has no sincere basis in the argument for life. Therefore, even though evolution and adaptation are major features that all living organisms share, being able to evolve and adapt does not necessarily provide evidence that an entity is alive.

Viral evolution not only fails in providing evidence of life, but it also creates more discrepancies between virions and living cells. Viruses have inconsistent evolutionary patterns because of the way that they evolve. All cellular life shares certain genes and has the same nucleic acids; this is because all cellular life shares a common ancestor (Moreira & López-García, 2009). Unlike living organisms, there are no genes that are shared in every virus, and different viral lineages do not even share the same nucleic acids; this is because viruses have multiple evolutionary origins (Moreira & López-García, 2009). Viral evolution is an interesting concept, but it does not support the notion that viruses are alive.

The second reason that viruses should not be considered alive is that they rely on the cell to conduct metabolic processes. All bodily functions require energy to take place; no matter how big or small an organism is, they must have some way to produce energy. Energy is created through an organism's metabolic processes. Every living organism has their own metabolism, but viruses do not. Viruses are metabolically inert, meaning that the virion itself has no ability to produce the energy required to complete any tasks. The only way viruses can generate the necessary energy to replicate new viral copies and synthesize enzymes is through cellular metabolic events (Sumbria et al., 2021). Cells produce viral copies and enzymes using their own metabolism while they are being controlled by a virus. In the absence of cells, viruses lack the energy needed to conduct any reactions. The fact that viruses are unable to conduct their own metabolic processes provides further evidence that viruses are not alive, because metabolism is a major feature that living organisms share. According to the University of Hawaii (2022), every organism that is considered alive possesses the ability to use enzymes to speed and mediate reactions; viruses technically use enzymes to speed and mediate reactions, but the metabolic processes that create these enzymes are only found in cells. Because viruses lack the metabolic processes needed to create these enzymes and mediate reactions, they are entirely reliant on the cell to fulfill this characteristic of life; therefore, this feature of life cannot be assigned to viruses.

It is apparent that viruses are unable to conduct metabolic processes autonomously, but it is also important to note that all metabolic viral genes have a cellular origin (Moreira & López-García, 2009). Certain viruses like the cyanobacterial phages contain genes that code for metabolic pathways like the photosystems; however, recent experiments have shown that these viruses acquired them from host cells, as they are not seen anywhere else in the viral lineage (Moreira & López-García, 2009). This same line of thinking applies to the genes found in the Mimivirus that code for protein synthesis. Even though there are some genes that may be important to metabolic processes within viruses, there is still no evidence that any virus has ever had the ability to conduct a metabolic pathway without help from a cell.

The last major reason that viruses cannot be considered alive is that viruses lack important structural elements that all other living organisms share. Structure is an essential aspect of life, as all living things share one major structural feature. The University of Hawaii (2022) asserted that all living organisms maintain some sort of cellular organization. Cellular organization is an extremely loose term, as eukaryotic organisms like humans consist of trillions of cells working together, while prokaryotic organisms like bacteria are composed of just one cell. Even though viruses are composed of proteins, lipids, carbohydrates, and nucleic acids, the molecules that make up cells, it is impossible to classify a virus as a cell (Moreira & López-García, 2009). Even the most complex viruses--like the Mimivirus which is larger than the smallest known bacteria-- still lack a membrane, organelles, and cytoplasm (Rossmann, 2013). These three components are necessary to fulfill cellular structure, organization, and the ability to maintain homeostasis.

Cellular membranes are primarily composed of a lipid bilayer; they are essential to cells because they serve as a barrier between the cell and its environment, they aid in cellular recognition, and they allow for the transfer of material in and out of a cell (University of Hawaii, 2022). Cellular membranes are essential in maintaining homeostasis, without membranes cells would not be able to survive. Viruses do not have a membrane, but they do have a protective coating called a capsid. At first glance, these two structures are quite comparable, but a capsid is quite different from a membrane. Capsids are composed of proteins rather than lipids, and they are responsible for protecting the genome of the virus and aiding in the infection of a cell (Rossmann, 2013). Viral envelopes are a more comparable structure to cellular membranes, but envelopes are not universal across viruses, and they function slightly different (Crosta, 2020). Viral envelopes are also composed of lipids, but envelopes have a cellular origin and they function more like a capsid, improving a virions ability to infect a cell (Crosta, 2020). Despite certain similarities, the capsid and the envelope both fail to fulfill the role of the membrane.

In addition to membranes, all cells have cytoplasm and organelles (University of Hawaii, 2022). Cytoplasm is the jelly-like substance that occupies the inside of a cell. This substance is the site of many reactions and contains various components such as organelles. Viruses are simply composed of genetic material encompassed by a capsid, so there is no comparable structure to the cytoplasm found in cells. Viruses also completely lack organelles. Cells can contain numerous kinds of organelles to fulfill a variety of tasks. Eukaryotic cells tend to have larger amounts of more complex organelles, but all prokaryotes still have organelles (University of Hawaii, 2022). Because of the simplicity of the viral structure, there is yet again no comparison that can be made between this cellular component and a viral counterpart. Because viruses lack a proper membrane, cytoplasm, and organelles, it would be impossible to classify them as cells; therefore, viruses lack any sort of cellular organization.

Counterarguments

Looking exclusively at a typical virus, they simply do not fulfill enough of the requirements needed to be considered alive. At best, viruses only fulfill three of the five requirements, but considering the reliance on the cell, only one requirement is autonomously possessed. There are other exceptions to the rules of life though. For example, bacterial endospores are considered alive even though they do not display all five characteristics of a living organisms throughout their entire life cycle; while dormant, these cells can survive for millions of years, only maintaining their structure, hereditary information, and their evolutionary history (Berman, 2012). This means that like the virus, they would fulfill only three of the five requirements. Bacterial endospores can be considered alive because, unlike viruses, bacterial endospores display all five characteristics when they are not in their dormant state, without the aid of another cell (Berman, 2012). The bacterial endospores independence in displaying the characteristics also shows why they can be considered alive and viruses cannot. The importance of independence is shown by mitochondria and chloroplasts. These organelles are not considered alive even though the endosymbiont theory provides evidence that they were once independent cyanobacteria that possessed all the characteristics of life (Martin et al., 2015). Just like viruses, their reliance on the cell makes it impossible to consider them living, regardless of the characteristics they display.

Viruses can be interpreted as living organisms through the adherence to the virocell concept. When the virion itself is considered the organism, its reliance on the cell removes characteristics of life; however, if the virus factory found in the intracellular phase of viral reproduction is considered the organism rather than the virion, then the reliance on the cell would contribute all the necessary characteristics needed to be considered alive (Forterre, 2016). If this concept were adopted, the debate on viral life would be over, but the logic behind the concept is flawed. It would be unfair to except a definition of an organism that requires components from another organism. Classifying the infected cell as a virus would be like classifying a person infected with a tapeworm as the tapeworm (Moreira & López-García, 2009). The presence of a parasite does not affect the classification of the host organism, just like the presence of a virus does not affect the classification of the host cell.

The last major argument that is brought up in the debate on viral life is the recent discovery of giant viruses (Forterre, 2016). Giant viruses have challenged the current definition of viruses, as they resemble cells much more than typical viruses in both size and morphology

(Claverie & Abergel, 2016). Giant viruses have immense genomes that contain essential elements for protein synthesis, a process that is exclusive to cells; these unique characteristics may signal major viral evolution, or a cellular origin (Claverie & Abergel, 2016). Giant viruses are an interesting topic, and they may cause a change in the definition of viruses, but they still do not provide evidence of viral life. The four known classes of giant viruses appear to have independent origins, they are still reliant on cells to reproduce, and their metabolism is still reliant on cellular intervention (Claverie & Abergel, 2016). There is still a lot to be discovered in the field of virology; it is possible that there is a missing link that would prove giant viruses have a cellular origin, but under the current understanding of the topic, there are no viruses that fulfill the characteristics of life.

Conclusion

Viruses play a massive role in the lives of all organisms. Viruses can function in ways that are beneficial or neutral to life on earth, but viruses can also be extremely detrimental to an organism's health. Viral diseases have caused countless deaths and were responsible for the recent global shutdown. To better understand these molecular parasites, and develop methods to avoid future pandemics, it is important that all aspects of virology are explored thoroughly. As for the question on viral life, given the current information in the field of virology, viruses cannot be considered alive. Because viruses rely on cells to evolve and adapt to their environments, they are unable to conduct metabolic processes without the aid of a cell, and they lack certain structural elements that all other living organisms share, they do not properly fulfill the necessary characteristics to be considered alive. While this may temporarily provide a perspective on the debate on viral life, new information should be calculated into the argument to ensure that viruses are properly classified. To better evaluate viral life, continued research should be conducted on the topic of giant viruses, as their complex nature may alter the definition of viruses as well as the outlook on the characteristics that prevent viruses from being considered alive. The debate on whether viruses are alive may appear trite, but thoroughly understanding all aspects of these particles is essential in effectively combatting them.

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