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Viruses and Evolution: The Role of Viruses in Big History

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Abstract

The role of viruses within Big History is an important field in understanding the process of evolution; however it is not yet extensively studied. This is due both to the fact that viruses, being microscopic infectious agents, have left limited physical traces in the geological record, and because there is no clear agreement on the place of viruses in evolution. The article aims to explore the role of viruses in the context of evolutionary development within the framework of Big History. It provides an overview of current perspectives and challenges associated with understanding the position of viruses in the broader narrative of evolutionary history.

A virus is defined as 'any of a large group of submicroscopic infectious agents that are usually regarded as non-living extremely complex molecules'. The term 'agents' is commonly used in virology due to the difficulty in finding a universal term to describe these unique entities. A virus is not an organism, in our usual sense of the definition, nor is it a chemical compound since viruses have an overly complex structure and behavior that sets them apart. In the field of evolution, viruses pose a perplexing puzzle piece that does not neatly fit into the larger picture.

Undeniably, viruses are the most pervasive entities on Earth. However, despite their ubiquitous presence, only a little over 6,000 virus species have been comprehensively described in the existing body of knowledge.

In the paper, the author observes evolution and the origin of viruses, including regressive, protobiont hypotheses, as well as the symbiotic theory, which, according to some researchers, was the factor that led to the three cellular domains of life that we know today.

The paper also delves into a fascinating aspect of evolution: the unique position of viruses, which exist on the edge of disorder, displaying high instability yet remarkable adaptability. This raises the question of whether viruses can be

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considered alive or not, leading to an intriguing debate. We also explore the question of whether viruses can be classified as parasites, which may seem simple at first glance but in fact it is a complex and contradictory topic.

The author discusses the role of viruses from an energetic perspective, recognizing their significance in information and energy dynamics within ecosystems. Viruses exert a substantial influence on energy flows in intricate ecological systems. The paper considers viruses from the perspective of information evolution, because in some respects viruses can be regarded as pure information particles. The author also argues that viruses can be considered as basic information agents that transmit genetic information and are thus the basic molecular tool of evolution. Moreover, this tool is beginning to be used by humans for the genetic alteration of many organisms, including ourselves.

It is important that viruses will no longer be considered only as dangerous pathogens, since infectious viruses make up only a small part of their genus. We argue that breakthroughs in virology in the coming decades could be no less important as a breakthrough in understanding the nature of bacteria, both pathogenic and beneficial.

The paper also examines viruses as a complex self-regulating system drawing comparisons to other complex systems such as computer viruses, cancer, and languages. It emphasizes the remarkable similarities between these systems and explores possible explanations for these similarities.

Keywords: *viruses, Big History, evolution theory, complex systems, protobionts, mutualism, symbiosis, parasites.*

The role of viruses within Big History is an important issue. However, it is not yet extensively studied. This is due both to the fact that viruses, being microscopic infectious agents, have left limited physical traces in the geological record, and that there is no clear agreement on the place of viruses in evolution. In this paper I will explore the role of viruses in the context of evolutionary development within the framework of Big History. It aims to provide an overview of current perspectives and challenges associated with understanding the position of viruses in the broader narrative of evolutionary history.

What are Viruses?

Even though we hear about viruses on a daily basis, it is not easy to define what a virus is. The classical definition of a virus is that it is a submicroscopic infectious agent that replicates only inside the living cells of an organism. According to the Merriam-Webster dictionary, a virus is 'any of a large group of submicroscopic infectious agents that are usually regarded as non-living extremely complex molecules'.[1] The term 'agents' is often used in virology, be-

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[1] URL: https://www.merriam-webster.com/dictionary/virus.

cause it is hard to find a common word for viruses. A virus is not an organism, as we used to understand it, nor a chemical compound as it has a very complex structure and behavior. One of the biggest problems regarding understanding viruses is that they are very different from everything we know. For the theory of evolution viruses also present a problem. They are like a piece of a puzzle that does not fit into the whole picture. It is clear but at the same time it is hard to realize is that there is an unimaginably large number of viruses, probably more than stars in the universe. Astronomers estimate that the universe could contain up to one septillion stars which in numbers is 10 to the 24th power.[2] An estimated 10 nonillion (10 to the 30th power) individual viruses exist on our planet, enough to assign one to every star in the universe millions of times over (Wu 2020). This number is so large that our brain is incapable of understanding it. Undoubtedly, viruses are the most widespread agents on Earth. However, at present only over 6,000 virus species have been described in detail.

This may also seem unexpected that the vast majority of viruses on Earth are marine viruses, the diversity of which is almost astronomic. A teaspoon of seawater typically contains about fifty million viruses. Most of them are bacteriophages which infect and destroy marine bacteria and control the growth of *phytoplankton*.

Viruses are not only the most widespread but also the most changeable of all known forms of life. The presence of viral diversity and its importance is evidenced by the fact that each new sequenced virome includes new sequences. Like every new wave on the seashore, every virus is different from the other. At the same time viruses prove not only that they are very widespread but also demonstrate a great diversity in size. There are smaller viruses, for example MS2, the size of which is about 27 nanometers. Other viruses, such as the mimiviruses, are so large that they are actually larger than some of the smallest cells we know.

Alive or Not?

Probably the most debatable question about viruses is whether they are alive or not. They are often considered non-living because, firstly, they do not have the metabolic activity that is required to maintain cellular structures, and secondly, they cannot reproduce without a host organism. The seemingly simple question of whether or not viruses are alive raises a fundamental issue: What exactly defines ‘life?’ ‘A precise scientific definition of life is an elusive thing, but most observers would agree that life includes certain qualities in addition to an ability to replicate. A living entity is in a state bounded by birth and death’ (Villarreal 2008).

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[2] URL: https://www.nationalgeographic.co.uk/science-and-technology/2020/04/there-are-more-viruses-than-stars-in-the-universe-why-do-only-some-infect-us.

'Living organisms are thought to require a degree of biochemical autonomy, carrying on the metabolic activities that produce the molecules and energy needed to sustain the organism' (*Ibid.*). On the other hand, not all living cells have metabolic activity, many include potential dormant states that are practically considered alive but are no less inert than viral particles outside their hosts. In these dormant systems, no growth or detectable *metabolism* will take place over very long periods of time. Are these dormant agents alive? For example, a seed or a spore. 'A seed might not be considered alive. Yet it has the potential for life, and it may be destroyed. In this regard, viruses resemble seeds more than they do live cells. They have a certain potential, which can be snuffed out, but they do not attain the more autonomous state of life' (*Ibid.*).

As for reproduction, it is even more complicated, since there are different types of reproduction. But it would also be a mistake to argue that every organism is independent in propagation, since sexual reproduction intrinsically needs another organism for genetic exchange. There is a reason to believe that the cell nucleus itself is of viral origin, which means that reproduction emerged as an isolated system.

Parasites or Not?

According to the generally accepted definition, a virus is an 'obligate intracellular parasite'. Although it is not so obvious, viruses maintain many types of relationships with their hosts, from mutualism to pure *parasitism*. A parasite usually uses the host for resources, typically food, and does not need the host to replicate. Viruses do not need any food; they use the host for replication. Viruses are only active in the intracellular state. This means that they are inside the cells of a body, taking control of that cell's mechanisms and stealing its energy.

There is another important question: Can an organism be defined as a parasite that does not harm its host? We believe it is more reasonable to consider such relations as cooperation. Another quite surprising fact is that most of known viruses are persistent and *innocuous*, not pathogenic (*Ibid.*). According to some data only one virus of 20 is infectious.

> They take up residence in cells, where they may remain dormant for long periods or take advantage of the cells' replication apparatus to reproduce at a slow and steady rate. These viruses have developed many clever ways to avoid detection by the host immune system – essentially every step in the immune process can be altered or controlled by various genes found in one virus or another (Villarreal 2008).

Although there is a dualistic question (Are viruses parasites or not?), any parasite, as any other organisms, originates from the emergence of the replicators. With a virus being a possible source of the genetic material for all other organisms, can we really oppose viruses to more complex parasites?

‘In fact, viruses can have beneficial effects on their hosts, creating a symbiotic relationship. And this might be far from anecdotic. Many examples of viruses that provide functional benefits to their hosts are known to create a mutualistic tie’ (Solé and Santiago 2019: 117).

> Other remarkable examples include a long-term coevolution between a large class of viruses (*e.g.*, the *polydnaviruses*) and their host wasps. These wasps are parasitoids: they are different from standard predators, since they lay their eggs inside the *larvae* of their prey species, which develop inside the body of the living *larvae* by eating them from inside. The normal outcome of this should be an immune response capable of encapsulating the injected eggs and inhibiting egg development. However, the endogenous virus carried by the wasp egg suppresses this response. The coevolutionary ties are very strong and some authors have questioned how appropriate it is to consider the polydnavirus as a real virus (*Ibid.*: 118).

Evolution of Viruses

Viruses have shaped the evolution of cells, organisms, ecosystems and even the biosphere. From an evolutionary perspective, self-replication became one of the most important landmarks of life. We know that viruses are non-cellular structures, consisting of a piece of DNA or RNA surrounded by a slim protein coating.

Although all living organisms on the globe have a DNA genome, viruses are the only organisms that still use RNA as a genome. This can mean that viruses could have separated from DNA organisms or preceded them. Viruses are the *quintessence* of genetic information. It is their main and often only function, with incredible variability. Just as within the web of life, viruses directly exchange genetic information with living organisms. Genetic information is the key to understanding viruses. Viruses are literally part of the genome of all organisms. For example, there are over 60,000 proviruses in the human genome.[3] From the energetic point of view, viruses are an important part of information and energy flows. They strongly influence energy flows in complex ecosystems. ‘Viruses live at the edge of disorder, where high instability but also *adaptability* occur’ (*Ibid.*).

Viruses are probably one of the main sources of mutation in organisms and thus a locomotive of entire evolution. As is well known, mutation is a crucial component of evolution because genetic variability is the fuel on which natural selection operates to adapt populations to their environment.

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[3] URL: https://bigthink.com/health/human-virus-herv-genome/.

Viruses are found infecting all forms of life and have probably been around since the first cells arose, or perhaps even before them. Tracing back the origin of viruses is a titanic, almost impossible, *endeavor* because they do not form fossils.

Viruses are perhaps the first organisms which developed a mechanism of reproduction up to the level which is capable of life. The amazing diversity of reproductive mechanisms among viruses demonstrates specialization of viruses in reproduction.

There are many theories of the origin of viruses. Some of the most well-known are listed below:

1) *The regressive hypothesis.* It suggests that *viruses were once small cells that parasitized larger cells*. Over time, as the parasite became more dependent on the host cell to complete its life cycle, genes not strictly necessary for their acquired *parasitism* were lost.

2) *'Vagrancy hypothesis, or the escape hypothesis. The second classic hypothesis for the origin of viruses states that some viruses may have evolved from pieces of DNA or RNA that 'escaped' from the genome of cells*. The escaped DNA could have come from plasmids (pieces of naked DNA that can move between cells) or from transposons (molecules of DNA that replicate and move around the cellular genomes to different positions)' (Solé and Santiago 2019: 177).

3) *Protobiont hypothesis.*

> 'This is also called the virus-first hypothesis and suggests that viruses may have evolved from complex molecules of protein and *ribonucleic* acids at the same time as cells first appeared on Earth, and would have been dependent on cellular life from the very beginning. In the primitive precellular soup, as in any other replicating system, parasites would have also evolved that grew at the expense of other more complex molecular systems' (Solé and Santiago 2019: 179).

As we mentioned before,

> 'some researchers think that the cell nucleus itself is of viral origin. The advent of the nucleus – which differentiates eukaryotes, including humans, from prokaryotes, such as bacteria – cannot be satisfactorily explained solely by the gradual adaptation of prokaryotic cells until they became eukaryotic. Rather the nucleus may have evolved from a persisting large DNA virus that made a permanent home within prokaryotes' (Villarreal 2008).

As a complex system viruses are similar to other complex systems.

Computer Viruses

Computer viruses are similar to biological ones, and not only in name. Similarly, in the same way that flu viruses cannot reproduce without a host cell, computer viruses cannot reproduce and spread without a file or a document.[4]

While some computer viruses can be playful in intent and effect, others can have profound and damaging effects. This includes erasing data or causing permanent damage to your hard disk. Worse yet, some viruses are designed with financial gains in mind.[5]

Viruses can hide disguised as attachments of socially shareable content such as funny images, greeting cards, or audio and video files and replicate themselves by modifying other computer programs and inserting their own code.

Both biological and computer viruses are capable of mutations. ‘However, we know that most mutations affecting a virus genome are harmful, impeding or threatening their replication potential. How many mutations in man-made counterparts are lethal? None. Thus, there is a sharp separation between these two types of viruses’ (Solé and Santiago 2019: 195). And Darwinian natural selection does not work within computer viruses as it does in nature.

Viruses in Big History

Despite the fact that viruses are tiny objects, their role in Big History may be more significant than it might be expected.

First, they show that not everything in Big History has similar patterns and fits into one narrative.

Secondly, they demonstrate that even such basic phenomena as life, death, reproduction, parasites and others are in fact very conditional. Viruses as a transitional link between all these phenomena show that reality is much more diverse and complex. In the evolutionary phases of Big History we place them between the chemical *abiogenic* and biological (see Fig.).

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[4] URL: https://wireless4u.ca/virus-removal/.

[5] URL: https://wireless4u.ca/virus-removal/.

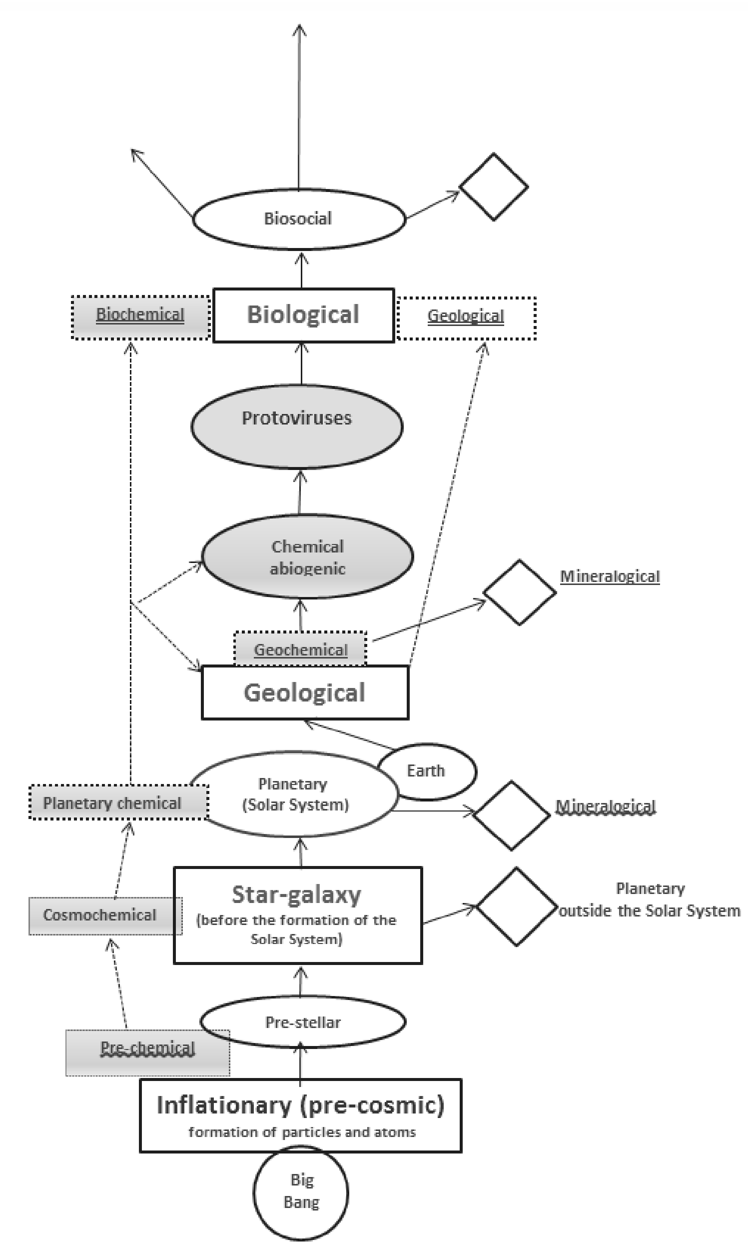

Fig. Evolutionary phases of Big History

Viruses also demonstrate involvement in the evolution of all types of organisms as well as all basic principles of evolution such as diversity, specialization, *etc*. Their role in evolution is obviously underestimated. A breakthrough in virology in the coming decades could be no less important as a breakthrough in understanding the nature of bacteria, both pathogenic and beneficial.

Viruses are an important component from the perspective of information evolution, because in some respect they can be regarded as pure information particles and as basic information agents that transmit genetic information, serve as a resource for mutations, and thus are the major molecular tool of evolution. Moreover, this tool is beginning to be used by humans for the genetic alteration of many organisms, including themselves.

Viruses are self-regulating systems similar to many other complex systems. An integrated approach to the study of self-regulating systems can become the key to exploring the interconnections and direction of Big History.

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