Journal of Research High School

Volume 2021 (2) 7 - 13
ISSN 2688-3651 [online]

Living or Nonliving? Reconsider Biology through the Concept of Viruses

Thomas Lee[1*]

[1]Chino Hills High School, CA, USA

Received February 26, 2021; Revised July 7, 2021; Accepted, July 14, 2021

Abstract

The concept of viruses has been a century-old debate among scientists due to their peculiar traits. Some viewed the virus as nonliving, initially seen as a poison and later as a simple protein molecule. Some challenged this nonliving nature of the virus due to its infectivity and filterability. The reason that scientists arrive to contrasted perspectives and theories in viruses derives from the fundamental perception of what constitutes life. While some scientists may overlook such a quest as a task in the philosophical scope, it is through philosophical lens that empirical scientific data have been processed, resulting in various theories. Upon examining the concept of the virus of André Lwoff, Patrick Forterre, and Luis Villarreal based upon their views of life, it is concluded that their respective understanding of viruses is not a direct reflection of the scientific data of the living traits (system, matter, chemical metabolism, complexity, reproduction, and evolution), but also reflects their employment of the philosophical lens and the perceptual principles. Thus, the approach to the study of biology requires philosophical process in perceptualizing life.

Keywords: viruses, living, nonliving, life, biology, philosophy

1. Introduction

"A virus is an infectious particle consisting of little more than genes packaged in a protein coat," as stated in the high school AP Biology textbook in the chapter on viruses (Reece et al., 2011). The definition is followed by a question: "Are viruses living or nonliving?" To answer this seemingly simple question, the authors describe briefly the changing definition of the virus over time and quickly conclude viruses are nonliving, except with an ambiguous tone: "Most biologists studying viruses today would probably agree that they are not alive" (Reece et al., 2011). The author's indefinite word choices such as "most biologists" and "probably" connote a controversial nature of the virus, and yet the authors' conclusion as "nonliving" seems confusing, if not, oversimplified. The rest of the chapter primarily focuses on the structure and the replication of viruses without further mentioning any details about its fundamental nature. This ambiguity and dissatisfaction in explaining the nature of the virus prompted this research. Especially, due to COVID-19, viruses have been the most concerning topic presently, it is important to revisit its concept to better inform young biology students since, after all, the heart of biology lies in the matter of life. If we investigate a more comprehensive understanding of

* Corresponding Author
liferesetinternational@gmail.com

Advisor: Samuel Leung
Samuel_leung@chino.k12.ca.us

the living or nonliving nature of viruses, biology itself inevitably expands to philosophical conceptualization of life because the concept of life itself is comprehensive, beyond scientific facts and data. Therefore, the objective of this research is, through examining the debate of the virus as living or nonliving, to demonstrate the importance of a philosophical understanding of the biological concept in processing factual data. With only this broader approach, the complexities of life can be better understood and appreciated. In so doing, the uniqueness of viruses can be adequately perceived beyond the binary polarity between living and nonliving.

2. The History of the Concept of the Virus

The virus has a long history of its enigmatic position. Its first recognition traces back to the ancient Greek period. The ancient Greeks had identified the virus as a "transmittable poison." The famous philosopher Aristotle contributed to this notion based on the observation of the transmission of rabies from rabid dogs: "Dogs suffer from the madness. This causes them to become irritable and all animals they bite to become diseased" (Steele, 1991). This view of the virus was not challenged until the contribution Louis Pasteur made to the concept of the virus. Throughout his lifetime, Pasteur dedicated his life to finding vaccinations after inoculating cowpox to prevent smallpox. In the development of a smallpox vaccination, he discovered that disease was not caused by "poisons," but rather by another entity. Pasteur proposed the germ theory to explain the role of this entity as the causal agent in all infectious diseases. According to the germ theory, diseases arise due to the activities of microorganisms. He defined microorganisms as any entity too small to be viewed by the unaided eye, as bacteria, protozoa, and some fungi and algae. He concluded that viruses were living microorganisms, to be more specific, a virulent bacterium (Berche, 2012). Pasteur had advanced the concept of the virus from a "poison" to a microorganism largely due to the fact that viruses exhibited the same traits as bacteria in terms of their infectivity and microscopic size. Although Pasteur mistakenly included viruses in the same category with bacteria, he advanced the ancient metaphysical notion as poison to a more modern scientific notion based on empirical observation. Concurrently, with his theory, Pasteur had opened Pandora's Box that has led to a 100-year-old debate on the nature of the virus: living or nonliving. Pasteur's new point on viruses as microorganisms was based on the premise of their nature as living, like bacteria.

It was not until the end of the 19th century that the nature of the virus was rechallenged. Dmitri Ivanovski attempted to prevent the tobacco plants from a disease known as Tobacco Mosaic Virus (TMV). In the process Ivanovski discovered that TMV was able to pass through the porous membrane of unglazed ceramic. He reported his observation as follows: "[It] filtered the sap of diseased plants through a porcelain filter and stated the sap sterilized in this fashion, [but] retained its infectivity" (Lechevalier, 1972). Since bacteria were never able to pass through the membrane of unglazed ceramic due to their size, Ivanovski concluded TMV was a toxin produced by the bacteria. This brings the concept of the virus back to its original position: a poison. Although his claim demoted the concept of virus, his model of experiment was later repeated by another microbiologist to advance its concept further.

Martinus Beijerinck created a similar experiment and took a different perspective of the causal infectious agent and also concluded the infectious agent must be another being separate from a bacterium. Beijerinck observed that the infectious agent was more fluid than a cell, since he observed a drop of infected sap was able to diffuse slowly through an agar gel, an impossible task for a cell. In addition, he knew that the infectious agents from the TMV had the same characteristics, and toxins would not have the complexity to infect more plants with the disease. Upon discovering its unique nature, Beijerinck coined the term "virus," a Latin derived term referring to venom or poison, to describe as he put "contagium vivum fluidum," that is, living fluid contamination (Méthot, 2016). In his discovery, Beijerinck defined the virus as a living entity which had the capabilities of being soluble and still have the infectious abilities similar to a bacterium. Despite the shared infectious nature, Beijerinck noted that this new being must be differentiated from a bacterium due to its significant size difference compared to bacteria. For this reason, he created a new term and was the first one to be credited to introduce the word “virus” to the world in a modern context (Machemer, 2020). This reintroduction of the concept of the virus became controversial from the beginning of the announcement. Having the toxic fluid in non-bacterial nature received heavy criticisms in the scientific circle because Beijerinck's new idea that pathogens can multiply inside the cell was “revolutionary and new” (Kammen, 1999). This idea was radical because the pathogen was a category used to define a living organism which causes disease, but Beijerinck presented an addition to the category of pathogen, which is non-organized, non-cellular but has a living nature (Bos, 1999).

Beijerinck’s concept of virus as living invites the host of debates whether virus is living or nonliving. Wendell Meredith Stanley refuted Beijerinck’s view of the virus as living with his discovery of the constituency of the virus. The crystallization of the TMV showed the inside of the virus: a combination of protein and nucleic acid, RNA. Based on this finding, he concluded that viruses are “inorganic, carbohydrate, hydrocarbon, lipid, protein, or organismal in nature” (Stanley, 1935). For Stanley, these inorganic chemicals are not complex enough to be considered life, such as lacking ribosomes, which is the necessary component to decode RNA for the replication process of all living organisms. Undoubtedly, his research contributed to a better understanding of the anatomy of the virus, and yet, his conclusion on the nature of the virus as an inanimate chemical added more controversy. How can this chemical-constituted agent without adequate qualities of life infect and replicate? Seeing the lack of essential anatomical parts, Stanley sided with the virus as the nonliving while his opponents argued that the presence of genetic material such as DNA or RNA and protein coat are the evidence that supports that viruses are the living (Hegde et al., 2009). It is noted that the same scientific materials were employed for Stanley to view as “the results demonstrating unequivocally that viruses are non-living” (Stanley, 1939), while others view they are the components to prove viruses are the living. In this sense, it is similar for one to ask, “Is the glass half full or half empty?” Based on the same empirical scientific data, how scientists perceptualize them can be drastically different. Raising this question suggests that there is a gap between what the scientific reality is and how it can be perceptualized and articulated by humans, and it varies depending on the elusive definition of life one holds.

3. The Conceptual Principles of A. Lwoff, P. Forterre, and L. Villarreal in Defining the Virus

At this point, it is important to further review in detail how other biologists after Beijerinck employed their conceptual principles in an effort to process the researched data on viruses. Three virologists’ views will be considered: André Lwoff, Patrick Forterre, and Luis Villarreal. The table 1 shows their respective understanding of the virus based on living traits. It is interesting that each virologist projected different view, and I will analyze how each virologist arrived at different understanding.

André Lwoff (1957), in his famous article “The Concept of Viruses,” stated “viruses are viruses” (pg. 240). For this seemingly simple statement, he critically analyzed the behavior and properties of the bacteriophage at different stages of its life cycle: proviral, vegetative and infective phase. Placing infectivity as the distinctive trait of the virus, he viewed proviral and vegetative phage lack infectivity. Regardless of the absence, he stated that one cannot deny classifying proviral or vegetative phage as a virus because Lwoff emphasized the holistic or “the sum of the various phases of its life cycle” in defining viruses (Lwoff, 1957, pg 242). For him, the collection and integration of the properties from various phases of life cycle collectively contributes to a particular class identity. For this reason, Lwoff wanted to endow the virus with a separate class apart from other infectious agents and claimed that “viruses are viruses.” Then, he explained his conceptual principle in defining the virus as follows: “Our definition of viruses is valid only because. . . it includes a homogeneous class of entities, viruses, and excludes another homogeneous class of entities, micro-organisms” (Lwoff, 1957, pg 246). Recognizing the virus as its own kind, he compared the virus to the micro-organism to further buttress his point that viruses have their own class contrasted to the existence of different objects, categories, or concepts.

Table 1. Comparison of viruses based upon the six most common characteristics of life collected by Edward Trifonov (2011).

Living traits	Lwoff	Forterre	Villarreal
System (organized)	+	+ in virocell, - in virion	0 Only through the host cell (borrowed)
matter	+	+	+
Chemical (metabolism)	+Through Lipmann system (i.e. a system of enzymes for the production of energy) during vegetative state	+ in the vegetative state of autonomous replication	0 only possible through the host cell
Complexity (information)	-Not acknowledge	+ in virocell, - in virion	-Lacks full critical complexity
reproduction	-Lack ability to binary fission	+	0 only possible through host cell (living or dead)
Evolution(change)	Not stated	+ viruses are evolved by virocells	+ viruses are fugitive host genes that have degenerated into parasites

+ found in virus, - not found in virus, 0 circumstantial

As shown in Table 2, Lwoff focused on individual traits in comparison to microorganisms. Upon comparing between microorganisms and viruses, Lwoff employed the similar conceptual principle that separated the virus from other infectious agents. This principle is sharply contrasted to Beijerinck's or Stanley's. Both Beijerinck and Stanley focused on particular traits in an effort to characterize the virus. For Beijerinck, filterability was the focal trait while Stanley focused on simple molecule constituency of the virus anatomy. For Lwoff, although he emphasized infectibility, the *integration* of various traits of the virus in defining it was more highlighted. In this train of thought, he viewed viruses lack dynamics in the process of integration of its various traits to become functionally independent. He claimed that life happens at this complex level of integration, and yet viruses lack this "transcendence" despite the evidence of shared organism qualities between viruses and microorganisms. This view is clearly evident when he stated:

> "Worms and vertebrates possess a digestive tract, but this does not prove that worms are vertebrates because insects also possess a digestive tract. Viruses and organisms have a few in common. These characters being also present in cellular organelles, they cannot be considered as supporting the conclusion that viruses are organisms" (Lwoff, 1957, pg. 247).

This view is contrasted to his contemporary virologist, Salvador Luria who defined living as one that presents individuality along with evolutionary independence rather than functional independence (Luria, 1959). Going back to the analogical question, "Is the glass half full or half empty?" can be redirected this way: Do biologists focus on the similarities or differences of the virus' traits vis-à-vis other living beings? Or do they focus on individual, independent traits or the sum or integration of the dependent and interdependent traits? Depending on the emphasis placed by biologists, living and nonliving is defined, and so is the nature of the virus.

A more recent virologist, Patrick Forterre emphasized the evolving dynamics or process of life in defining a virus. He stated, "Life and living processes are simply names for complex evolving forms of matter that are now present on our planet" (Forterre, 2017).

Table 2. Lwoff's comparison between micro-organisms and viruses

Micro-organisms	viruses
Cellular size	Filterable size
Contain nucleic acids, DNA, RNA	Contain One type of nucleic acid
Reproduce	Replicate in the form of their genetic material
Have infectivity	Have infectivity
Able to grow	Unable to grow and to undergo binary fission
Replicate its nucleic acid	Multiply and reproduce (only in host cell)
presence of a "Lipmann system"	Devoid of a "Lipmann system"
Independent unit of integrated and interdependent structures and functions	Dependent on host-cell metabolism
Control its dependent and interdependent parts	Completely rely upon the cell
Forms a regular gradient of size	Forms a regular gradient of size

Forterre challenged the former perception of the virus often equated to a virion, which refers to the static structural aspect of the virus. Instead of virions, he suggested to focus on a biological process that includes a viral reproduction cycle to go beyond the static biological nature of the virus. In this sense, he clearly distinguished virions from virocells or "ribovirocell" as he coined the term to refer to the active state of the virus. Instead of virions, Forterre proposed to focus attention on the virocell, which is the intracellular phase in the virus reproduction cycle since virocells are cellular organisms that are living (Forterre, 2013). Forterre's view somewhat resonates with F.C. Bawden's proposal earlier. He argued classifying the virus as living or nonliving should depend on what medium one focuses on. Depending on the medium of the observation - the virus in a test tube or the virus in the infected plant or animal cell - it can be viewed as either living or nonliving. The virus in a test tube is a mere protein molecule while the virus in the infected plant or animal cell is clearly living as it can multiply and mutate (Bawden, 1945). Similar to Bawden, Forterre treated the virocell as a living organism, but he remained uneasy defining the virus as a "living organism." Just like a virion, which refers to one phase of the whole viral cycle, the virocell is simply another phase, not the whole process of the biological process of the virus. For Forterre, living means "a collection of integrated organs (molecular machines/structures) producing individuals evolving through natural selection" (Forterre, 2010, pg 158). Similar to Lwoff, he used integrative approaches by emphasizing the holistic aspect of the virus in its transition, except he furthered his view by emphasizing the virus as a major actor of variation and selection in the web of life (Forterre, 2012). In fact, this collective view of the virus by encompassing all phases of the virus life cycle has been embraced by many biologists recently (Nasir, Romero-Severson, & Claverie, 2020).

Another evolutionary virologist Luis Villarreal recognized a "spectrum" between living and nonliving in defining a virus's position (Villarreal, 2004). He used a phrase, "a verge life" to refer to the nature of the virus because it can have "living" conditions such as metabolism, nucleic acid synthesis, protein synthesis, processing and transport, and all other biochemical activities viruses to multiply, but only through the host cell. For this perplexing nature of the virus, Villarreal suggested a "spectrum" of life. To better explain, he compared a virus to a seed, arguing that a seed itself may not be viewed as living but has a potential for life, which is also capable of being destroyed. Viruses having living qualities without autonomy resemble seeds in nature. Another comparison he proposed was the human brain as defining life as "an emergent property of a collection of certain nonliving things" (Villarreal, 2004, pg 103). He explained that a neuron by itself cannot be conscious but requires the whole brain complexity to be biologically alive and conscious. Although viruses lack this complexity, life itself as an emergent state is made from the same fundamental, physical building blocks that constitute a virus. He added that the discovery of Mimivirus in 1992, which is the largest and the most complex virus discovered, as an example to support the spectrum of life in the emergent nature in life since it carries genes that cellular organisms possess. In this view, he categorized viruses as neither living nor nonliving. Especially, considering the capacity to grow and multiply in dead cells to revive the dead cells, a virus deserves its own space between living and nonliving. Villarreal concluded that it is in this middle position that viruses' innovative actions and constant invention of new genes enable them to contribute to evolutionary change. In short, Villarreal focused on the spectrum of emergent life to seek the role of viruses and attempted to seek a practical bearing from the debate on whether viruses are living or nonliving. He believed such a debate was often treated rhetorical among many scientists, but it has a practical bearing: "I think the issue is important, because how scientists regard this question influences their thinking about the mechanisms of evolution" (Villarreal, 2004, pg 104).

4. Conclusion

A virus with its peculiar characteristics and traits has been inviting various theories over a century, and this quest always prerequisites the philosophical quest of the definition of life. Due to the nature of this quest, scientists have defined the virus not solely based on empirical, scientific facts and data, but through the perceptual lens to process those collected data. Therefore, in approaching the essence of the study of life, namely biology, one cannot deny the importance of the philosophical investigation of what life is, as being demonstrated in the century long debate on the nature of viruses. While some scientists ignore the quest of life as a rhetorical debate that has no practical bearing, the absence of it will significantly curtail the proliferation of scientific theories. In this sense, "disagreement" in the debate on the nature of viruses showcased that dissent should not be seen as negative, but a necessary factor to proliferate various perspectives in the research of biology. In the case of Villareal's research, his "middle position" provided him a tangible way to enhance further his theory on viruses in the web of life and its contributions to the origin of species. Agreeing with Forterre, "the goal of biology should be to explore and understand exhaustively the mode of existence of living organisms" (Forterre, 2010, pg. 158). It is expected that the definitions of life must constantly evolve as biology progresses. Therefore, biology as the study of life inevitably requires conceptual and philosophical quests in order to invite broader new scientific views.

References

Bawden, F. C. (1945). The nature of viruses. *The Scientific Monthly,* 60, 1, 48-50.

Berche, P. (2012). Louis Pasteur, from crystals of life to vaccination. *Clinical Microbiology and Infection, 18*, 1-6. doi:10.1111/j.1469-0691.2012.03945.x

Bos, L. (1999). Beijerinck's work on tobacco mosaic virus: Historical Context and Legacy. *Philosophical Transactions: Biological Sciences*, 354(1383), 675-685.

Forterre, P. (2010, 03). Defining Life: The Virus Viewpoint. Origins of Life and Evolution of Biospheres, 40(2), 151-160. doi:10.1007/s11084-010-9194-1

Forterre, P. (2012). Darwin's goldmine Is still open: Variation and selection run the world. *Frontiers in Cellular and Infection Microbiology, 2*. doi:10.3389/fcimb.2012.00106

Forterre, P. (2012, 10). The virocell concept and environmental microbiology. The ISME Journal, 7(2), 233-236. doi:10.1038/ismej/2012.110

Forterre, P. (2017). Viruses in the 21st Century: From the curiosity-driven discovery of giant viruses to new concepts and definition of life. *Clinical Infectious Diseases, 65*(Suppl_1), doi:10.1093/cid/cix349

Hegde, N. R., Maddur, M. S., Kaveri, S. V., & Bayry, J. (2009, 08). Reasons to include viruses in the tree of life. *Nature Reviews Microbiology, 7*(8), 615-615. doi:10.1038/nrmicro2108-c1

Kammen, A. (1999). Beijerinck's contribution to the virus concept - An Introduction. *100 Years of Virology,* 1-8. doi:10.1007/978-3-7091-6425-9_1

Lechevalier, H. (1972). Dmitri Losifovich Ivanovski, (1864-1920). *Bacteriological Reviews, 36*(2), 135-145. doi:10.1128/mmbr.36.2.135-145.1972

Luria, S. E. (1959). Viruses as infective genetic materials. In V.Najjar (Ed.). *Immunity and Virus Infection.* (pp.188-195). New York, USA: Wiley.

Machemer, T. (2020). How a few sick tobacco plants led scientists to unravel the truth about viruses Retrieved January 31, 2021, from https://www.smithsonianmag.com/science-nature/what-are-viruses-history-tobacco-mosaic-disease-180974480/

Méthot, P. (2016). Writing the history of virology in the twentieth century: discovery, disciplines, and conceptual change Retrieved February 1, 2021, from https://www.sciencedirect.com/science/article/pii/S1369848616300061

Nasir, A., Romero-Severson, E., & Claverie, J. (2020). Investigating the concept and origin of viruses. *Trends in Microbiology, 28*(12), 959-967. doi:10.1016/j.tim.2020.08.003

Prud'Homme-Généreux, A. (2013, 01). What Is Life? An Activity to Convey the Complexities of This Simple Question. The American Biology Teacher, 75(1), 53-57. doi:10.1525/abt.2013.75.1.11

Reece, J. B., Urry, L. A., Wasserman, M. L., Minorsky, S. A., & Jackson, R. B. (2011). *Campbell biology, AP edition* (Ninth ed.). San Francisco, CA: Pearson Benjamin Cummings.

Stanley, W. M. (1935). Isolation Of a crystalline protein possessing the properties of Tobacco-Mosaic Virus. *Science, 81*(2113), 644-645. doi:10.1126/science.81.2113.644

Stanley, W. M. (1939). The architecture Of viruses. *Physiological Reviews, 19*(4), 524-556. doi:10.1152/physrev.1939.19.4.524

Steele, J.H., (1991). History of rabies and global aspects. In G.M. Baer (Ed.) The natural history of rabies. New York, USA: CRC Press.

Trifonov, E. N. (2011, 10). Vocabulary of Definitions of Life Suggests a Definition. Journal of Biomolecular Structure and Dynamics, 29(2), 259-266. doi:10.1080/073911011010524992

Villarreal, L. P. (2004, 12). Are Viruses Alive? *Scientific American,* 291(6), 100-105. doi:10.1038/scientificamerican1204-100