The Search for Life Assignment

Name: __________________

Table of Contents

Date	Page #	Description	In-Class	Homework	Graded
9/5/18	2	Video Notes Ted Ed-What is Life?	Time permitting, will show in class, if no time—Homework.		Yes
9/6/18	3-7	Life and Purpose Article Protocol #1 Drawing Summary Protocol #2 Frayers Model	Yes	Only if you don't finish Drawing Summary in Class	Yes
9/6/18	8-11	Reading 1.2 + Drawing Summary		Yes	Yes
9/7/18	11	Video Big History—Threshhold 5	Yes; video notes	Yes; summary of video notes	Yes
9/7/18	12	Video Big History—6 Minithreshholds of Life	Yes; Video notes	Yes; summary of video notes	Yes
9/7/18 9/10/18	13-14	Video—Wonders of Life	Yes; Video notes and summary of notes. (to be completed on 9/10/18)		Yes
9/8/18-9/9/18	15-18	Virus Article—Highlighting Evidence		Yes	Yes
9/8/18-9/9/18	19	Big History Video—What is Life?		Yes	Yes
9/10/18	20-22	Article Biosignatures		Yes	Yes
9/11/18-9/12/18	23	Final Report, Frayer Models, Journal	Time has been set aside to work on in class. I have requested a computer lab—for those dates. Unconfirmed. You will need to complete work at home to make sure you hit the deadline, which is Wednesday, Sept. 12th, 9PM. Electronic Submission: Showbie		Yes

Journal Notes: Ted-Ed What is Life? Is Death Real?

Write notes while watching the video:

Based on your notes/memory of the video/how would you explain life to another person?

Journal Notes: Life and Purpose

What separates living things from nonliving things? It starts with two very basic activities: self-generation and self-maintenance.

DRAWING SUMMARY/iES

Life and Purpose: A Biologist Reflects on the Qualities that Define Life

By Ursula Goodenough

What's the difference between nonlife and life? To answer this question, we first need to define life. I'll lay out what are to me the key hallmarks of life, and then offer a response that flows from such an understanding. A key concept is that every organism is a self, a being. To be a "self" is to engage in two fundamental activities: self-generation and self-maintenance.

Self-generation

Self-generation entails the making of a self. If you're a single-celled organism like a yeast, this involves starting out small, growing large, and dividing into two small daughter-yeasts that start the process again. If you're a multicelled organism like a human, this involves starting out as a single fertilized egg, developing from an embryo to a fetus, and then taking the path from newborn to old age.

In all organisms on our planet today, the key players in self-generation are proteins. When a particular protein is made, it folds up into a particular shape, with crevices and bumps — something like a jigsaw-puzzle piece in three dimensions. These shapes allow proteins to do two major activities.

The first is to interact with other proteins, with the bumps fitting precisely into the crevices, to form the thousands of different kinds of chemical structures that make up a cell. Most parts of a cell are constructed from proteins, including the filaments that act as cellular skeletons, the channels that let ions in and out of the cells, and the receptors that let the self know what's going on in the environment.

The second activity of proteins is to serve as enzymes, which allow chemical reactions inside the cell to take place with remarkable efficiency and accuracy. Again, shape is the key. The bumps and crevices bring together the participants in a chemical reaction and ensure that they form the proper kinds of chemical bonds with one another.

Journal Notes

DRAWING SUMMARY/iES

Self-maintenance

Critical to self-generation is obtaining the molecules and the energy that the self needs to run the store. One strategy is to use photosynthesis, turning the Sun's light energy into food. The second is to ingest molecules that are made as a consequence of photosynthesis — that is, to eat — and then break them down, using the energy released to drive self-generation. Here again, the shapes of enzymes are critical, but instead of controlling the formation of chemical bonds as in self-generation, they deftly supervise the breaking of chemical bonds, coupling this activity with the formation of energy-rich molecules like ATP (adenosine triphosphate) that keep the cell going.

Self-maintenance also entails self-protection, avoiding environmental hazards, predators, and disease.

Every organism is instructed

All the proteins we've been thinking about are encoded in genes embedded in DNA molecules. Each gene specifies the amino-acid sequence of a particular protein, and that sequence then defines how the protein will fold up into its functional shape.

The full set of genes necessary to pull together a self-generating and self-maintaining self is called a "genome." A yeast genome and a human genome have many genes in common, notably those concerned with the universal project of self-maintenance, and many others that are distinctive. Daughter organisms inherit copies of genomes from parent organisms, allowing that kind of organism to continue and spread.

Embedded in the organization of genomes is the capacity to express certain genes, and hence certain proteins, on some occasions and not others. When it's time to copy DNA into daughter molecules, the genes encoding the DNA-copying enzymes are "switched on." When the copying process is completed, these genes are "switched off." When it's time for you to make red blood cells, genes encoding the hemoglobin protein are switched on in certain bone-marrow cells but remain switched off in most of the cells in your body. Thus a genome isn't just a collection of genes; it functions continuously to instruct self-generation and self-maintenance.

DRAWING SUMMARY/iES

Every organism can evolve

Although DNA is copied with remarkable accuracy, mistakes sometimes happen, giving rise to mutant genes that encode variant amino-acid sequences and hence give rise to proteins with variant shapes. Also occurring are “mutations” that change the timing or magnitude of protein production.

The mutation may have no effect, at least in the short term, in which case the mutant daughter may self-organize and self-maintain just like the parent. At the other extreme, it may have disastrous consequences on self-organization and self-maintenance, and the daughter will not survive.

The most interesting mutations are those that generate instructions for a viable daughter that is somewhat different from its parent. For example, a parent duck may have delicate foot webbing while the webbing of a mutant daughter may be extra-thick. What happens next is totally dependent on environmental context. If the ducks hang out on mudflats, the mutant feet may allow for surer footing, hence better opportunities for feeding and fleeing predators, and the thick-footed trait will likely spread into future generations; if the ducks live in grasslands, the mutant feet may slow things down and the trait will be less likely to spread.

What I’ve just described is Darwinian evolution: inherited variations, coupled with natural selection. The ability of living organisms to evolve has generated the spectacular biodiversity that surrounds us, and without it, we humans would never have shown up.

Every organism has purpose

So, with this sense of what life is, can we come up with a single characteristic that distinguishes life from nonlife? Is there one towering difference between a mountain and a whale? After all, both are made of molecules. Both engage in chemistry. Both change through time.

For me, the most interesting single generalization is that organisms are purposive whereas nonlife is not. Organisms are about something, for something: muscles are for movement; eyes are for seeing. Organisms have goals. The short-term goal is to self-generate and self-maintain in a given environmental context. The long-term goal is to pass genome copies on to offspring, a goal that succeeds only if self-generation and self-maintenance succeed. Mountains are splendid, to be sure, but in the end they aren’t goal directed. They just are.

Journal Notes

DRAWING SUMMARY/iES

Taking this perspective, one could say that when life showed up on Earth, something completely new showed up: the emergence of purpose. Whether life, and hence purpose, exists anywhere else in the Universe is unknown and may remain a mystery. Meanwhile, we can enjoy and revel in the astonishing purposiveness that surrounds us here on Earth.

The Search for Life Assignment Name: ____________________________

Frayer Model—Gallery Walk Final DRAFT

DEFINITION	CHARACTERISTICS
EXAMPLES/MODELS	NON-EXAMPLES

Life

The Search for Life Assignment

Name: ___________________________

Journal Notes: Biology Openstaxx Reading

DRAWING SUMMARY/iES

1.2 | Themes and Concepts of Biology

By the end of this section, you will be able to:

- Identify and describe the properties of life
- Describe the levels of organization among living things
- Recognize and interpret a phylogenetic tree
- List examples of different sub disciplines in biology

Biology is the science that studies life, but what exactly is life? This may sound like a silly question with an obvious response, but it is not always easy to define life. For example, a branch of biology called virology studies viruses, which exhibit some of the characteristics of living entities but lack others. It turns out that although viruses can attack living organisms, cause diseases, and even reproduce, they do not meet the criteria that biologists use to define life. Consequently, virologists are not biologists, strictly speaking. Similarly, some biologists study the early molecular evolution that gave rise to life; since the events that preceded life are not biological events, these scientists are also excluded from biology in the strict sense of the term.

From its earliest beginnings, biology has wrestled with three questions: What are the shared properties that make something "alive"? And once we know something is alive, how do we find meaningful levels of organization in its structure? And, finally, when faced with the remarkable diversity of life, how do we organize the different kinds of organisms so that we can better understand them? As new organisms are discovered every day, biologists continue to seek answers to these and other questions.

Properties of Life

All living organisms share several key characteristics or functions: order, sensitivity or response to the environment, reproduction, adaptation, growth and development, regulation, homeostasis, energy processing, and evolution. When viewed together, these nine characteristics serve to define life.

Order

Figure 1.10 A toad represents a highly organized structure consisting of cells, tissues, organs, and organ systems. (credit: "Ivengo"/Wikimedia Commons)

Organisms are highly organized, coordinated structures that consist of one or more cells. Even very simple, single-celled organisms are remarkably complex: inside each cell, atoms make up molecules; these in turn make up cell organelles and other cellular inclusions. In multicellular organisms (**Figure 1.10**), similar cells form tissues. Tissues, in turn, collaborate to create organs (body structures with a distinct function). Organs work together to form organ systems.

Sensitivity or Response to Stimuli

Figure 1.11 The leaves of this sensitive plant (*Mimosa pudica*) will instantly droop and fold when touched. After a few minutes, the plant returns to normal. (credit: Alex Lomas)

The Search for Life Assignment

Name: ____________________________

Journal Notes

DRAWING SUMMARY/iES

Organisms respond to diverse stimuli. For example, plants can bend toward a source of light, climb on fences and walls, or respond to touch (**Figure 1.11**). Even tiny bacteria can move toward or away from chemicals (a process called *chemotaxis*) or light (*phototaxis*). Movement toward a stimulus is considered a positive response, while movement away from a stimulus is considered a negative response.

LINK TO LEARNING

Watch **this video (http://openstaxcollege.org/l/movement_plants)** to see how plants respond to a stimulus—from opening to light, to wrapping a tendril around a branch, to capturing prey.

Reproduction

Single-celled organisms reproduce by first duplicating their DNA, and then dividing it equally as the cell prepares to divide to form two new cells. Multicellular organisms often produce specialized reproductive germline cells that will form new individuals. When reproduction occurs, genes containing DNA are passed along to an organism's offspring. These genes ensure that the offspring will belong to the same species and will have similar characteristics, such as size and shape.

Growth and Development

Organisms grow and develop following specific instructions coded for by their genes. These genes provide instructions that will direct cellular growth and development, ensuring that a species' young (**Figure 1.12**) will grow up to exhibit many of the same characteristics as its parents.

Figure 1.12 Although no two look alike, these kittens have inherited genes from both parents and share many of the same characteristics. (credit: Rocky Mountain Feline Rescue)

Regulation

Even the smallest organisms are complex and require multiple regulatory mechanisms to coordinate internal functions, respond to stimuli, and cope with environmental stresses. Two examples of internal functions regulated in an organism are nutrient transport and blood flow. Organs (groups of tissues working together) perform specific functions, such as carrying oxygen throughout the body, removing wastes, delivering nutrients to every cell, and cooling the body.

Homeostasis

Figure 1.13 Polar bears (*Ursus maritimus*) and other mammals living in ice-covered regions maintain their body temperature by generating heat and reducing heat loss through thick fur and a dense layer of fat under their skin. (credit: "longhorndave"/Flickr)

Journal Notes

DRAWING SUMMARY/iES

In order to function properly, cells need to have appropriate conditions such as proper temperature, pH, and appropriate concentration of diverse chemicals. These conditions may, however, change from one moment to the next. Organisms are able to maintain internal conditions within a narrow range almost constantly, despite environmental changes, through **homeostasis** (literally, "steady state")—the ability of an organism to maintain constant internal conditions. For example, an organism needs to regulate body temperature through a process known as thermoregulation. Organisms that live in cold climates, such as the polar bear (Figure 1.13), have body structures that help them withstand low temperatures and conserve body heat. Structures that aid in this type of insulation include fur, feathers, blubber, and fat. In hot climates, organisms have methods (such as perspiration in humans or panting in dogs) that help them to shed excess body heat.

Energy Processing

Figure 1.14 The California condor (*Gymnogyps californianus*) uses chemical energy derived from food to power flight. California condors are an endangered species; this bird has a wing tag that helps biologists identify the individual. (credit: Pacific Southwest Region U.S. Fish and Wildlife Service)

All organisms use a source of energy for their metabolic activities. Some organisms capture energy from the sun and convert it into chemical energy in food; others use chemical energy in molecules they take in as food (Figure 1.14).

Levels of Organization of Living Things

Living things are highly organized and structured, following a hierarchy that can be examined on a scale from small to large. The **atom** is the smallest and most fundamental unit of matter. It consists of a nucleus surrounded by electrons. Atoms form molecules. A **molecule** is a chemical structure consisting of at least two atoms held together by one or more chemical bonds. Many molecules that are biologically important are **macromolecules**, large molecules that are typically formed by polymerization (a polymer is a large molecule that is made by combining smaller units called monomers, which are simpler than macromolecules). An example of a macromolecule is deoxyribonucleic acid (DNA) (Figure 1.15), which contains the instructions for the st

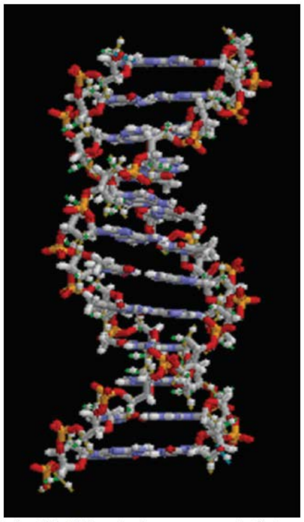


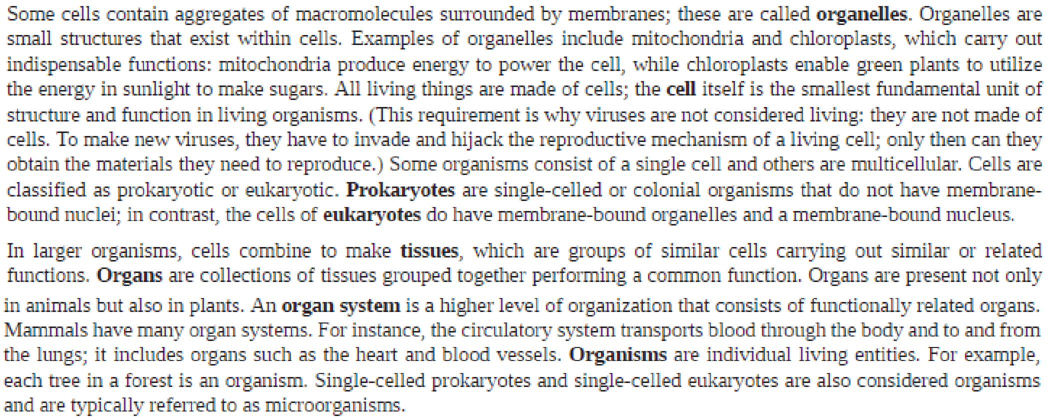
Figure 1.15 All molecules, including this DNA molecule, are composed of atoms. (credit: "brian0918"/Wikimedia Commons)

The Search for Life Assignment

Name: ___________________________

Journal Notes

DRAWING SUMMARY/iES



Some cells contain aggregates of macromolecules surrounded by membranes; these are called **organelles**. Organelles are small structures that exist within cells. Examples of organelles include mitochondria and chloroplasts, which carry out indispensable functions: mitochondria produce energy to power the cell, while chloroplasts enable green plants to utilize the energy in sunlight to make sugars. All living things are made of cells; the **cell** itself is the smallest fundamental unit of structure and function in living organisms. (This requirement is why viruses are not considered living: they are not made of cells. To make new viruses, they have to invade and hijack the reproductive mechanism of a living cell; only then can they obtain the materials they need to reproduce.) Some organisms consist of a single cell and others are multicellular. Cells are classified as prokaryotic or eukaryotic. **Prokaryotes** are single-celled or colonial organisms that do not have membrane-bound nuclei; in contrast, the cells of **eukaryotes** do have membrane-bound organelles and a membrane-bound nucleus.

In larger organisms, cells combine to make **tissues**, which are groups of similar cells carrying out similar or related functions. **Organs** are collections of tissues grouped together performing a common function. Organs are present not only in animals but also in plants. An **organ system** is a higher level of organization that consists of functionally related organs. Mammals have many organ systems. For instance, the circulatory system transports blood through the body and to and from the lungs; it includes organs such as the heart and blood vessels. **Organisms** are individual living entities. For example, each tree in a forest is an organism. Single-celled prokaryotes and single-celled eukaryotes are also considered organisms and are typically referred to as microorganisms.

Journal Notes—Video Evidence

Big History Project—Threshold 5

Video Notes	Summarized Understanding of Video

The Search for Life Assignment

Name: ________________________________

Journal Notes—Video Evidence

Big History Project—6 Mini Threshold's

Video Notes	Summarized Understanding of Video

The Search for Life Assignment

Name: ____________________________

Source: Brian Cox Wonders of Life, Episode #1: What is Life?

This resource will help you understand what life is. Here are some guiding questions to get the most out of this video. Review them before watching and make notes on this page as you are watching. Then organize the information you learned on the back page.

1. What is the purpose of a proton pump?
2. How are proton pumps used by life?
3. How are proton pumps used in environment?
4. Is a proton pump a characteristic of life?
5. What are the ingredients of life?
6. What is entropy?
7. Is entropy in the universe increasing or decreasing?
8. Can the rate of entropy be used to determine if life is present?

Video Notes:

Any drawings or additional notes from documentary.

The Search for Life Assignment **Name: ________________________**

Organize your video notes to show understanding of the topics explored in this video; Wonders of Life, "What is Life"

The Search for Life Assignment

Name: ____________________________

Are Viruses Alive? Journal Notes

Using two different colored highlighters; read the following article.

☐ Color represents evidence in-text that supports that viruses are alive.

☐ Color represents evidence in-text that supports that viruses are NOT alive.

Although viruses challenge our concept of what "living" means, they are vital members of the web of life

By Luis P. Villarreal on August 8, 2008

Editor's Note: This story was originally published in the December 2004issue of Scientific American.

In an episode of the classic 1950s television comedy *The Honeymooners*, Brooklyn bus driver Ralph Kramden loudly explains to his wife, Alice, “You know that I know how easy you get the virus.” Half a century ago even regular folks like the Kramdens had some knowledge of viruses—as microscopic bringers of disease. Yet it is almost certain that they did not know exactly what a virus was. They were, and are, not alone.

For about 100 years, the scientific community has repeatedly changed its collective mind over what viruses are. First seen as poisons, then as life-forms, then biological chemicals, viruses today are thought of as being in a gray area between living and nonliving: they cannot replicate on their own but can do so in truly living cells and can also affect the behavior of their hosts profoundly. The categorization of viruses as nonliving during much of the modern era of biological science has had an unintended consequence: it has led most researchers to ignore viruses in the study of evolution. Finally, however, scientists are beginning to appreciate viruses as fundamental players in the history of life.

It is easy to see why viruses have been difficult to pigeonhole. They seem to vary with each lens applied to examine them. The initial interest in viruses stemmed from their association with diseases—the word “virus” has its roots in the Latin term for “poison.” In the late 19th century researchers realized that certain diseases, including rabies and foot-and-mouth, were caused by particles that seemed to behave like bacteria but were much smaller. Because they were clearly biological themselves and could be spread from one victim to another with obvious biological effects, viruses were then thought to be the simplest of all living, gene-bearing life-forms.

Their demotion to inert chemicals came after 1935, when Wendell M. Stanley and his colleagues, at what is now the Rockefeller University in New York City, crystallized a virus— tobacco mosaic virus—for the first time. They saw that it consisted of a package of complex biochemicals. But it lacked essential systems necessary for metabolic functions, the biochemical activity of life. Stanley shared the 1946 Nobel Prize— in chemistry, not in physiology or medicine—for this work.

Further research by Stanley and others established that a virus consists of nucleic acids (DNA or RNA) enclosed in a protein coat that may also shelter viral proteins involved in infection. By that description, a virus seems more like a chemistry set than an organism. But when a virus enters a cell (called a host after infection), it is far from inactive. It sheds its coat, bares its genes and induces the cell’s own replication machinery to reproduce the intruder’s DNA or RNA and manufacture more viral protein based on the instructions in the viral nucleic acid. The newly created viral bits assemble and, voilà, more viruses arises, which also may infect other cells.

These behaviors are what led many to think of viruses as existing at the border between chemistry and life. More poetically, virologists Marc H. V. van Regenmortel of the University of Strasbourg in France and Brian W. J. Mahy of the Centers for Disease Control and Prevention have recently said that with their dependence on host cells, viruses lead "a kind of borrowed life." Interestingly, even though biologists long favored the view that viruses were mere boxes of chemicals, they took advantage of viral activity in host cells to determine how nucleic acids code for proteins: indeed, modern molecular biology rests on a foundation of information gained through viruses.

Molecular biologists went on to crystallize most of the essential components of cells and are today accustomed to thinking about cellular constituents—for example, ribosomes, mitochondria, membranes, DNA and proteins—as either chemical machinery or the stuff that the machinery uses or produces. This exposure to multiple complex chemical structures that carry out the processes of life is probably a reason that most molecular biologists do not spend a lot of time puzzling over whether viruses are alive. For them, that exercise might seem equivalent to pondering whether those individual sub-cellular constituents are alive on their own. This myopic view allows them to see only how viruses co-opt cells or cause disease. The more sweeping question of viral contributions to the history of life on earth, which I will address shortly, remains for the most part unanswered and even unasked.

The seemingly simple question of whether or not viruses are alive, which my students often ask, has probably defied a simple answer all these years because it 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. For example, a living entity is in a state bounded by birth and death. Living organisms also 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. This level of autonomy is essential to most definitions.

Viruses, however, parasitize essentially all biomolecular aspects of life. That is, they depend on the host cell for the raw materials and energy necessary for nucleic acid synthesis, protein synthesis, processing and transport, and all other biochemical activities that allow the virus to multiply and spread. One might then conclude that even though these processes come under viral direction, viruses are simply nonliving parasites of living metabolic systems. But a spectrum may exist between what is certainly alive and what is not.

A rock is not alive. A metabolically active sack, devoid of genetic material and the potential for propagation, is also not alive. A bacterium, though, is alive. Although it is a single cell, it can generate energy and the molecules needed to sustain itself, and it can reproduce. But what about a seed? A seed might not be considered alive. Yet it has a 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.

Another way to think about life is as an emergent property of a collection of certain nonliving things. Both life and consciousness are examples of emergent complex systems. They each require a critical level of complexity or interaction to achieve their respective states. A neuron by itself, or even in a network of nerves, is not conscious—whole brain complexity is needed. Yet even an intact human brain can be biologically alive but incapable of consciousness, or "brain-dead." Similarly, neither cellular nor viral individual genes or proteins are by themselves alive. The enucleated cell is akin to the state of being braindead, in that it lacks a full critical complexity. A virus, too, fails to reach a critical complexity. So life itself is an emergent, complex state, but it is made from the same fundamental, physical building blocks that constitute a virus. Approached from this perspective, viruses, though not fully alive, may be thought of as being more than inert matter: they verge on life.

In fact, in October, French researchers announced findings that illustrate afresh just how close some viruses might come. Didier Raoult and his colleagues at the University of the Mediterranean in Marseille announced that they had sequenced the genome of the largest known virus, Mimivirus, which was discovered in 1992. The virus, about the same size as a small bacterium, infects amoebae. Sequence analysis of the virus revealed numerous genes previously thought to exist only in cellular organisms. Some of these genes are involved in making the proteins encoded by the viral DNA and may make it easier for Mimivirus to co-opt host cell replication systems. As the research team noted in its report in the journal *Science*, the enormous complexity of the Mimivirus's genetic complement "challenges the established frontier between viruses and parasitic cellular organisms."

Impact on Evolution

Debates over whether to label viruses as living lead naturally to another question: Is pondering the status of viruses as living or nonliving more than a philosophical exercise, the basis of a lively and heated rhetorical debate but with little real consequence? I think the issue *is* important, because how scientists regard this question influences their thinking about the mechanisms of evolution.

Viruses have their own, ancient evolutionary history, dating to the very origin of cellular life. For example, some viral-repair enzymes—which excise and resynthesize damaged DNA, mend oxygen radical damage, and so on— are unique to certain viruses and have existed almost unchanged probably for billions of years.

Nevertheless, most evolutionary biologists hold that because viruses are not alive, they are unworthy of serious consideration when trying to understand evolution. They also look on viruses as coming from host genes that somehow escaped the host and acquired a protein coat. In this view, viruses are fugitive host genes that have degenerated into parasites. And with viruses thus dismissed from the web of life, important contributions they may have made to the origin of species and the maintenance of life may go unrecognized. (Indeed, only four of the 1,205 pages of the 2002 volume *The Encyclopedia of Evolution* are devoted to viruses.)

Of course, evolutionary biologists do not deny that viruses have had some role in evolution. But by viewing viruses as inanimate, these investigators place them in the same category of influences as, say, climate change. Such external influences select among individuals having varied, genetically controlled traits; those individuals most able to survive and thrive when faced with these challenges go on to reproduce most successfully and hence spread their genes to future generations.

But viruses directly exchange genetic information with living organisms—that is, within the web of life itself. A possible surprise to most physicians, and perhaps to most evolutionary biologists as well, is that most known viruses are persistent and innocuous, not pathogenic. 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.

Furthermore, a virus genome (the entire complement of DNA or RNA) can permanently colonize its host, adding viral genes to host lineages and ultimately becoming a critical part of the host species' genome. Viruses therefore surely have effects that are faster and more direct than those of external forces that simply select among more slowly generated, internal genetic variations. The huge population of viruses, combined with their rapid rates of replication and mutation, makes them the world's leading source of genetic innovation: they constantly "invent" new genes. And unique genes of viral origin may travel, finding their way into other organisms and contributing to evolutionary change.

Data published by the International Human Genome Sequencing Consortium indicate that somewhere between 113 and 223 genes present in bacteria and in the human genome are absent in well-studied organisms—such as the yeast *Saccharomyces cerevisiae*, the fruit fly *Drosophila melanogaster* and the nematode *Caenorhabditis elegans*—that lie in between those two evolutionary extremes. Some researchers thought that these organisms, which arose after bacteria but before vertebrates, simply lost the genes in question at some point in their evolutionary history. Others suggested that these genes had been transferred directly to the human lineage by invading bacteria.

My colleague Victor DeFilippis of the Vaccine and Gene Therapy Institute of the Oregon Health and Science University and I suggested a third alternative: viruses may originate genes, then colonize two different lineages—for example, bacteria and vertebrates. A gene apparently bestowed on humanity by bacteria may have been given to both by a virus. In fact, along with other researchers, Philip Bell of Macquarie University in Sydney, Australia, and I contend that the cell nucleus itself is of viral origin. The advent of the nucleus— which differentiates eukaryotes (organisms whose cells contain a true nucleus), 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. Some support for this idea comes from sequence data showing that the gene for a DNA polymerase (a DNAcopying enzyme) in the virus called T4, which infects bacteria, is closely related to other DNA polymerase genes in both eukaryotes and the viruses that infect them. Patrick Forterre of the University of Paris-Sud has also analyzed enzymes responsible for DNA replication and has concluded that the genes for such enzymes in eukaryotes probably have a viral origin.

From single-celled organisms to human populations, viruses affect all life on earth, often determining what will survive. But viruses themselves also evolve. New viruses, such as the AIDS-causing HIV-1, may be the only biological entities that researchers can actually witness come into being, providing a real-time example of evolution in action.

Viruses matter to life. They are the constantly changing boundary between the worlds of biology and biochemistry. As we continue to unravel the genomes of more and more organisms, the contributions from this dynamic and ancient gene pool should become apparent. Nobel laureate Salvador Luria mused about the viral influence on evolution in 1959. "May we not feel," he wrote, "that in the virus, in their merging with the cellular genome and reemerging from them, we observe the units and process which, in the course of evolution, have created the successful genetic patterns that underlie all living cells?" Regardless of whether or not we consider viruses to be alive, it is time to acknowledge and study them in their natural context—within the web of life.

The Search for Life Assignment **Name: ___________________________**

Big History Video—What is Life?

Video Notes	**Drawing/Sketch/Graphic Organizer Showing Your Understanding of the Videos Main Points**

The search for life on other planets could get a boost from biosignatures.

By AMINA KHAN

JAN 25, 2018 | 2:10 PM

Future telescopes, such as the James Webb Space Telescope, will be able to search for signs of life on other planets by studying the composition of their atmospheres. (J. Krissansen-Totton)

By studying the atmospheric contents of ancient and present-day Earth, scientists say they've discovered specific chemical combinations that could reveal the presence of biological activity on other planets.

These biosignatures, described in the journal Science Advances, could offer a key tool in the search for extraterrestrial life. "There's a direct path from the conclusions of our work to the possible discovery, which would be an historic one, of life elsewhere," said senior author David Catling, a planetary scientist and astrobiologist at the University of Washington in Seattle. Thousands of planets beyond our solar system, known as exoplanets, have been discovered in the last several years, a small number of which appear to be rocky, Earth-sized planets at the right distance from their star to hold liquid water. Studying the ones with detectable atmospheres could provide crucial clues as to whether they host life.
As powerful new telescopes start to come online, researchers are trying to figure out exactly which atmospheric chemicals they should be looking for. After all, just because a planet looks like it has the right ingredients for life doesn't mean there's actually anything living there.

Scientists have focused on a few potentially telltale molecules, such as methane. Methane is produced in large quantities by microbes on Earth (including those in the bellies of cattle). But methane can also be produced by nonbiological sources, such as volcanoes. Molecular oxygen (two oxygen atoms bonded together) is produced in massive amounts today by photosynthesizing algae, plants and microbes. But the photosynthetic mechanism is so complicated that scientists think it evolved only once on our own planet. That means there's no guarantee of finding oxygen-producing photosynthesis on other worlds, even if life does exist there.

Thus, relying on any individual chemical could produce false positives or false negatives, said study coauthor Stephanie Olson, an astrobiologist and graduate student at UC Riverside. But living things alter their environments in complex ways. What if there was a particular mixture of molecules that would not exist without life?

To find out, Catling's graduate student Joshua Krissansen-Totton led a study that examined the Earth's atmosphere in three stages of its existence: The Archean (4 billion to 2.5 billion years ago), the Proterozoic (2.5 billion to 541 million years ago) and the Phanerozoic (541 million years ago to the present). During each of these time periods, life (and the planet itself) looked very different. Place a snapshot of each Earthly period side-by-side, and they'd look like totally different planets. "The phrase Earth-like does not refer to a planet that necessarily resembles modern-day Earth at all," Olson said. "It's actually a very broad term that encompasses a broad variety of worlds. It includes hazy worlds like the

Archean; it includes icy worlds like the 'snowball Earth' intervals; it includes anoxic worlds with exclusively microbial ecosystems; it includes worlds with complex and intelligent life; and it includes worlds that we haven't even seen yet."

That's helpful for scientists, she added, who need several models for what life on other worlds might look like.
In spite of their differences, each of these periods in Earth's history share at least one characteristic: chemical imbalances in their atmosphere. That's because biological activity produces substances that otherwise have no business coexisting, Catling said. Take methane and oxygen: Placed together, these gases quickly react and destroy each other. But there's plenty of both on Earth, because living things keep making them. "If you find a system in equilibrium, you've found something that's dead. Or something that's not alive," Catling said. "When we see something unusual, that's out of whack, it can be a sign of life." People have talked about this idea since the 1960s, Catling said, but hadn't really quantified it up until now. For this paper, the scientists ran simulations using the known chemical contents of each atmosphere to see whether any telltale chemical disequilibriums existed.

The researchers found that during the Archean, when there was little oxygen, the coexistence of methane, nitrogen and carbon dioxide in the atmosphere (together with liquid water) would have been a sign that living things were hard at work."Large fluxes of each gas in the absence of biology is really difficult to explain," Olson said of the coexistence of carbon dioxide and methane. In the mid-Proterozoic, as oxygen-producing microbes rose, the giveaway would be a combo of oxygen, nitrogen and liquid water. Even if the levels of atmospheric oxygen are too low to be detectable, scientists could look for ozone instead, Olson said. That's because ozone (composed of three oxygen atoms) is made by reactions involving biologically produced oxygen and it produces a very strong signal that could be detectable even at low levels.

In the Phanerozoic, which includes the present day, the biosignatures would be oxygen with nitrogen and water. (Oxygen levels here would far higher and much easier to detect than in the mid-Proterozoic.) A few of the chemical cocktails, such as the combination of methane and carbon dioxide, might be detectable by future observatories like NASA's James Webb Space Telescope, set for launch in 2019. "It's really giving people a path forward on what to focus on in their observations," said Nikole Lewis, a project scientist for the James Webb who is based at the Space Telescope Science Institute in Baltimore. James Webb will survey a broad range of planets, and having a wide variety of biosignatures and a range of planetary templates is a crucial tool, she added. That's because the more planets they're able to find that fit these criteria, the more likely they are to discover the few that might really host living things.
"We'll have a large enough sample that hopefully there'll be a few that will stick out like sore thumbs," Lewis said.
Until James Webb and other telescopes capable of finding these atmospheric contents come online, the hunt for possible biosignatures continues, scientists said.

"At the moment we're not yet prepared to recognize life on the full diversity of Earth-like exoplanets, and we can only imagine what life might look like on a planet that's not Earth-like," Olson said. "That's of course a huge area of research, and I don't think we've quite figured it out yet. But disequilibrium is potentially a particularly powerful path forward."

The Search for Life Assignment

Name: ___________________________

Journal Notes—Explaining Biosignatures in the Search for Life

Using what you know about the properties of life and the above article—how can we look at an entire planet to determine if life may exist there?

The Search for Life Assignment Name: ___________________________

What needs to be in my Final Report?

Using the resources in this assignment, create a report of your findings to explain what life is, how do we know the difference between something that is alive or not alive, and what do we look for when trying to find life on a distant world.

Format of your final report:

Turn In Your Completed Journal Notes Uploaded to Showbie

Option 1: Take photos and insert into a word document (must be in order). Then upload word doc to Showbie.

Option 2: Using the library copy machine; scan and email this document to yourself. Then upload to Showbie.

Option 3: Download and use a PDFapp that allows you to take multiple photos and convert into 1 larger PDF file. Then upload to Showbie.

Turn in Your Completed 5 Paragraph Report detailing your findings (as follows) to Showbie

Paragraph I: Introduction into your objective and methods of research/investigation

Paragraph II: Description of the properties (emergent) of life that you will be using and/or defining in your Frayer Models.

Paragraph III: Analysis of why life is hard to define and examples of this issue.

Paragraph IV: Explanation of how the properties of life can leave clues on the planet itself.

Paragraph V: Short summary of how you have organized your findings.

Your report must be saved as a PDF. To achieve this, use the ***Save As*** and select PDF.

Turn in Your Completed Frayer Models to Showbie

There is a template for the Frayer Model on our website; In-Class Investigations, it is a fill-able PDF.

Using the structure of the Frayer Model, create a model for each of the properties that define life.

Use the SAVE-AS feature to reuse the same template for each of your properties of life.

Please refer to the rubric to determine how you will be evaluated.