Teacher Notes for "Characteristics of Life"[1]

Biology is the scientific study of living things. The Student Handout, together with two videos, help students to understand the characteristics of living things and the challenges of distinguishing between living and non-living things. This analysis and discussion activity also introduces several themes that will be revisited in a general biology course.

Learning Goals

Living things share a variety of characteristics, including that they:

- acquire and use energy
- grow and develop
- reproduce
- respond to stimuli
- maintain homeostasis
- are made up of one or more cells with DNA as the genetic material
- has evolved adaptations.

Some non-living things have one or two of these characteristics, but a non-living thing does not have the majority of the characteristics of living things. Some living things lack one or two of these characteristics.

Instructional Suggestions and Biology Background

If your students are learning online, we recommend that they use the Google Doc version of the Student Handout, which is available at https://serendipstudio.org/exchange/bioactivities/lifecharacteristics.

If you use the Word version of the Student Handout, please check the PDF version to make sure that all figures and formatting are displayed properly in the Word version on your computer.

A key is available upon request to Ingrid Waldron (iwaldron@upenn.edu). The following paragraphs provide additional instructional suggestions and background information – some for inclusion in your class discussions and some to provide you with relevant background that may be useful for your understanding and/or for responding to student questions.

During the class discussion of student answers to question 1, you may want to clarify that this activity is concerned with distinguishing between living things and non-living things and is not concerned with how you tell whether something is dead or alive. Also, this activity is concerned with identifying shared characteristics of the whole range of biological organisms, including bacteria, other microorganisms, fungi, plants, and animals.

The two "Characteristics of Life" videos recommended on page 1 of the Student Handout are:

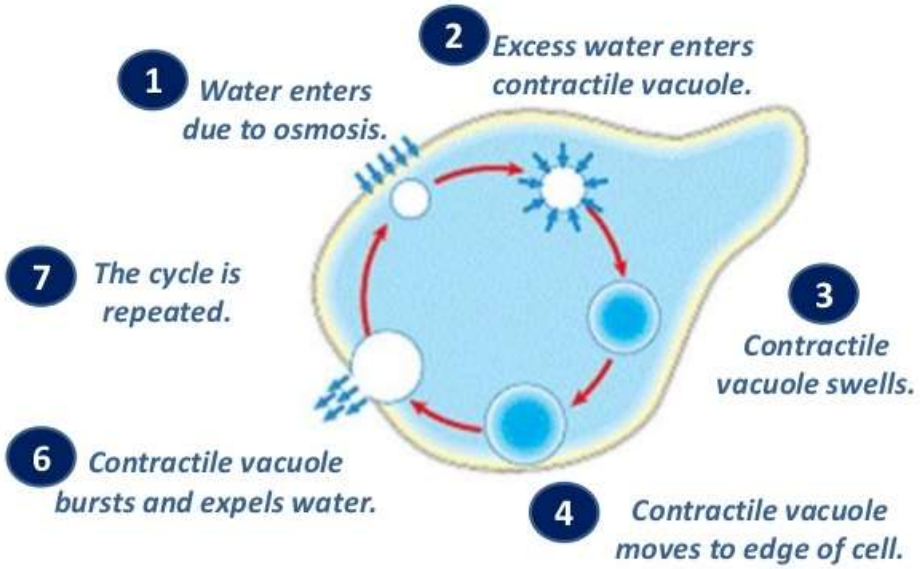
- ~2 minutes by Ricochet Science at https://www.youtube.com/watch?v=0NnFhY_STFQ
- ~8 minutes by Amoeba Sisters at https://www.youtube.com/watch?v=cQPVXrV0GNA

We recommend that, after a class discussion of the first video, you have students answer question 2 before you show the second video. The second video introduces students to the challenges of distinguishing between living things and non-living things; these challenges are revisited at the end of this activity.

---

[1] By Dr. Ingrid Waldron, Department of Biology, University of Pennsylvania These Teacher Notes and the related Student Handout are available at https://serendipstudio.org/exchange/bioactivities/lifecharacteristics.

You will probably want to supplement the discussion of natural selection in the Amoeba Sisters video by mentioning camouflage as an example of an evolutionary adaptation. In the section on homeostasis, this video mentions contractile vacuoles. The figure below can be used to help your students understand what contractile vacuoles are and how they function to pump out excess water that enters the cell by osmosis.[2]



(https://image.slidesharecdn.com/osmosisdiffusionactivetransport-120831003333-phpapp01/95/osmosis-diffusion-active-transport-44-728.jpg?cb=1346373344)

If your textbook gives a different list of characteristics of life than these videos provide, I recommend that you have your students compare the two lists and analyze similarities and differences. Your students should recognize that there is no one "correct" list of the characteristics of living things. A characteristic of life that is mentioned in these videos as part of the cellular organization or reproduction of living things is the universal genetic code in DNA.[3]

The following paragraphs provide information about the specific examples in the figures in question 4, as well as some related general themes.

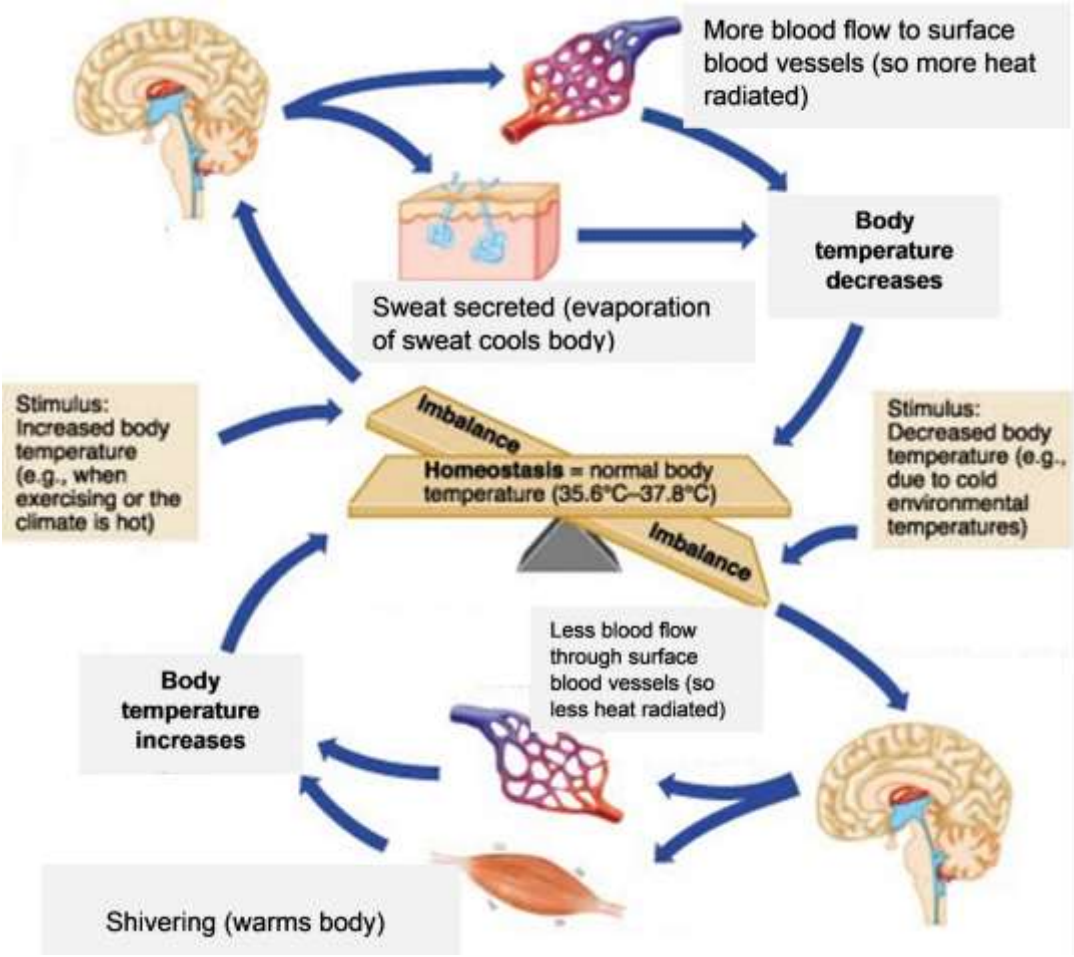
The first figure in question 4 illustrates an example of homeostasis. Temperature regulation involves behavioral responses (e.g. fanning yourself vs. warmer clothes) and physiological negative feedback (see figure below).[4] Negative feedback involves responding to stimuli (e.g. internal temperature). Although many examples of homeostasis involve negative feedback, some

[2] Many Protista that live in freshwater, as well as some other organisms, have contractile vacuoles (https://en.wikipedia.org/wiki/Contractile_vacuole).

[3] DNA is made up of four types of nucleotides. A sequence of three specific nucleotides codes for each of ~20 different types of amino acids commonly found in proteins. This DNA code plays a crucial role in allowing each type of organism to produce many different types of protein. The DNA code is the same in all organisms, with rare, minor exceptions (https://www.khanacademy.org/science/high-school-biology/hs-molecular-genetics/hs-rna-and-protein-synthesis/a/the-genetic-code). The universality of this genetic code provides evidence that all organisms are evolutionarily descended from an ancestral organism which already had this genetic code. The astonishing variety of organisms, from tiny bacteria to gigantic whales, have all been produced by evolutionary "descent with modification". For learning activities about DNA and proteins, see https://serendipstudio.org/exchange/bioactivities/proteins and https://serendipstudio.org/exchange/bioactivities#molecbio.

[4] For a learning activity about homeostasis and negative feedback, see https://serendipstudio.org/exchange/bioactivities/homeostasis.

do not. For example, human skin contributes to homeostasis by serving as a barrier that minimizes both water loss and entry of microbes (see figure on page 3 of the Student Handout).

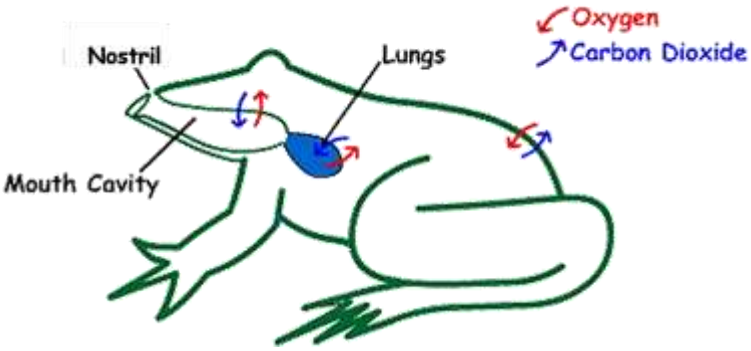


(Adapted from https://d2jmvrsizmvf4x.cloudfront.net/42IFA2i2ShiS1MpwS2yL_thermoregulation-campbell.jpg)

Frogs provide a familiar example of sexual reproduction and growth and development.[5] Students may ask questions about additional aspects of frog biology. General information is available at https://www.burkemuseum.org/collections-and-research/biology/herpetology/all-about-amphibians/all-about-frogs, https://www.livescience.com/50692-frog-facts.html, and https://animals.howstuffworks.com/amphibians/frog.htm. Frogs have evolved a developmental program that allows different adaptations at different stages in development; for example, tadpoles have a tail to swim in the water vs. frogs have legs to move on land. Another example

[5] Key concepts and learning activities to introduce students to aspects of reproduction, including mitosis, meiosis, fertilization and genetics, are summarized in https://serendipstudio.org/exchange/bioactivities/MitosisMeiosis and https://serendipstudio.org/exchange/bioactivities/GeneticsConcepts.

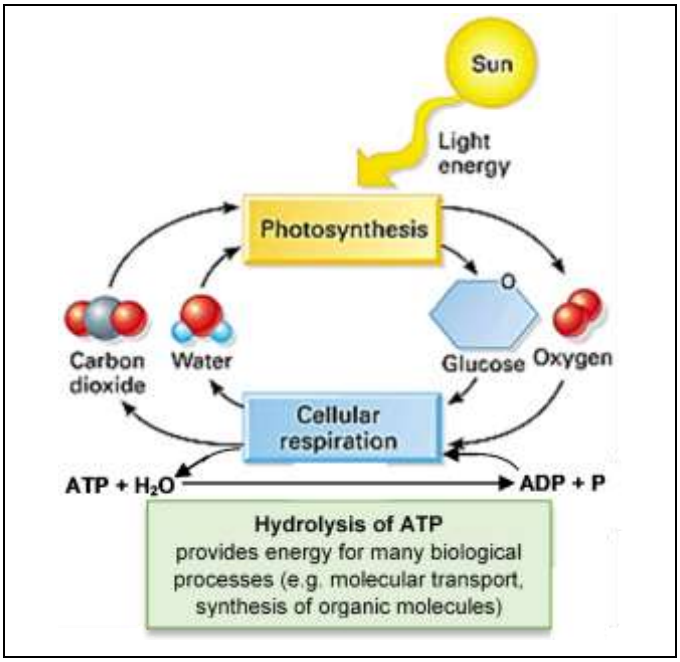
of an evolutionary adaptation is the position of frog's eyes, wide-set on the top of their heads. This gives frogs a wide field of view, which helps to compensate for their inability to turn their heads to scan different parts of their environment.



(https://www.brown.edu/Departments/Engineering/Courses/En123/MuscleExp/Frog%20Respiration.htm)

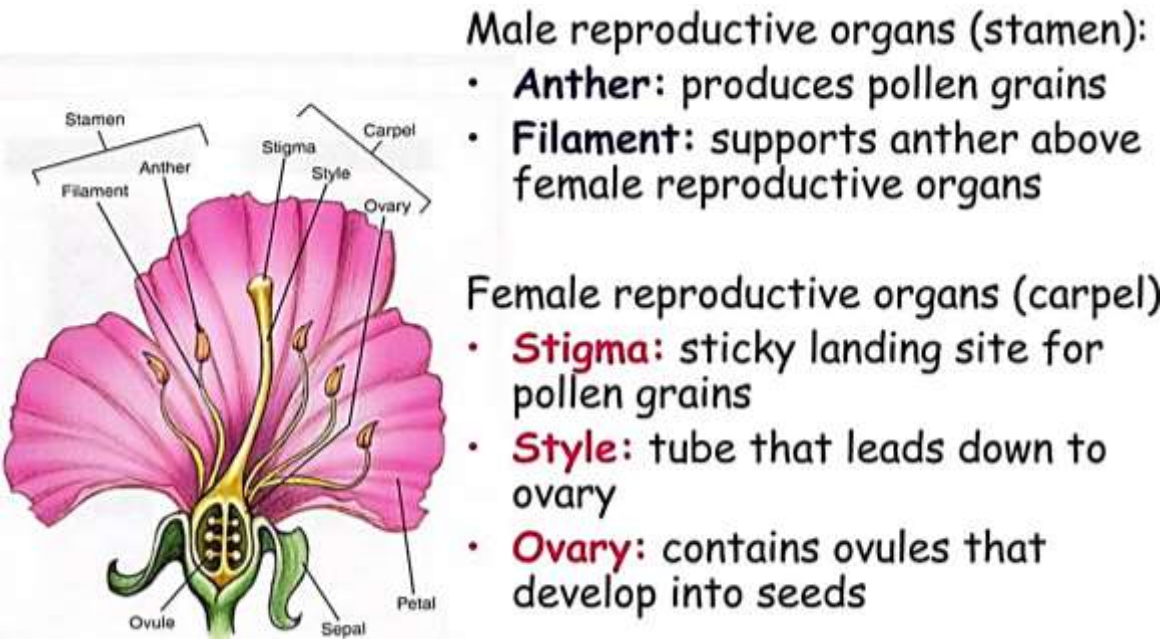
When people think about plants acquiring and using energy, they often think only about photosynthesis. However, plants also need cellular respiration to produce ATP and hydrolysis of ATP to provide the energy for plants' biological processes (see figure).

Photosynthesis makes glucose molecules which are used for cellular respiration or as raw materials for the production of the organic molecules needed for plant growth. During the day time, some of the glucose is stored in starch molecules. When night comes, some of the starch is broken down to glucose which is used for cellular respiration to produce the ATP which provides energy for the multiple biological processes that continue day and night.[6]



The plants shown in the bottom two figures on the second page of the Student Handout have flowers. Flowers are parts of plants' sexual reproduction (see figure below). Once fertilized, ovules develop into seeds which can sprout into seedlings which can grow into the next generation of plants.

[6] Learning activities to help students understand photosynthesis and cellular respiration are available at https://serendipstudio.org/exchange/bioactivities#energy.



(https://image1.slideserve.com/2978507/reproductive-parts-l.jpg)

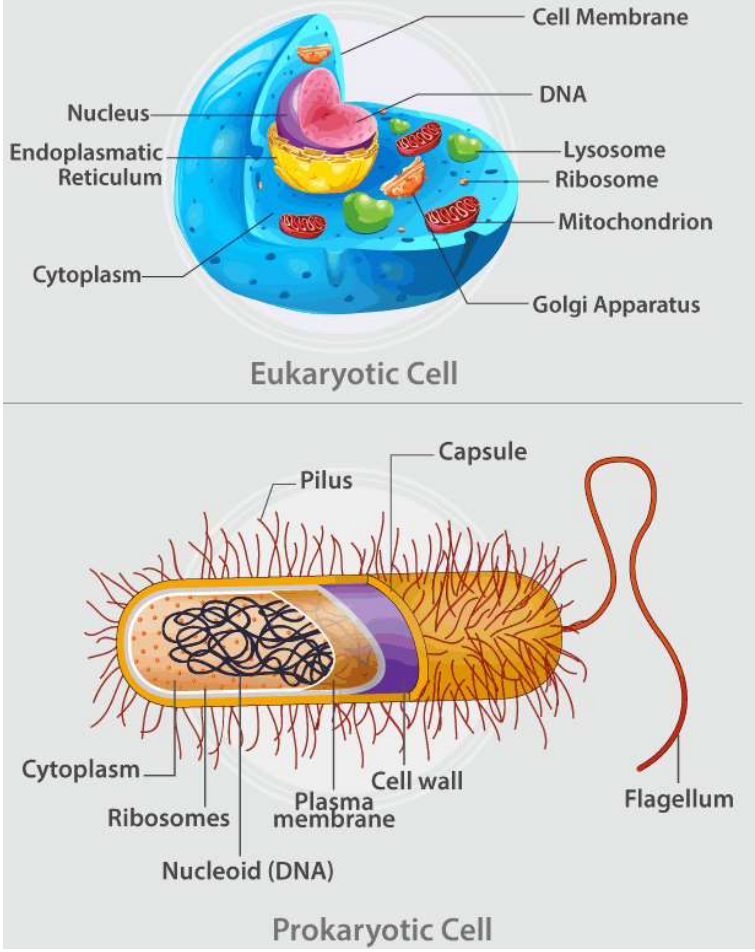
The hummingbird in the picture on the bottom of page 2 the Student Handout is using energy as it responds to the red color of the flower. The long narrow shape of the hummingbird's beak and tongue are evolutionary adaptations for feeding on the nectar in tubular flowers. Evolutionary adaptations of the flower include the red color (which attracts hummingbirds), the tubular shape (which holds lots of nectar), and reproductive organs that extend far enough to contact the hummingbird's head (so flowers get cross pollinated) (https://news.ku.edu/2016/06/09/study-flowers-co-evolution-bees-and-hummingbirds-earns-hileman-major-grants). An interesting 1-minute video shows how the hummingbird's tongue takes up nectar from an artificial tubular flower (https://www.youtube.com/watch?v=QYoYQAbPXbU).[7]

[7] For learning activities that introduce students to natural selection and other aspects of evolution, see https://serendipstudio.org/exchange/category/serendip-topic-tags/evolution.

The figure on page 3 of the Student Handout shows the cells in human skin. Your students should understand that all living things are made up of one or more cells.

This figure shows some of the similarities and differences between eukaryotic and prokaryotic cells. The defining difference is that eukaryotic cells have a membrane-enclosed nucleus, and prokaryotic cells do not. Eukaryotic cells have other membrane-enclosed organelles. Eukaryotic cells are generally larger than prokaryotic cells (roughly 10-100 µm vs. 1 µm).

As you know, there are many different types of eukaryotic cells. For example, plant cells have chloroplasts, a cell wall, and a large vacuole, in addition to the components shown in the generic animal cell in this figure. [8]



(https://cdn1.byjus.com/wp-content/uploads/2017/08/Prokaryotic-Cell-And-Eukaryotic-Cell.png)

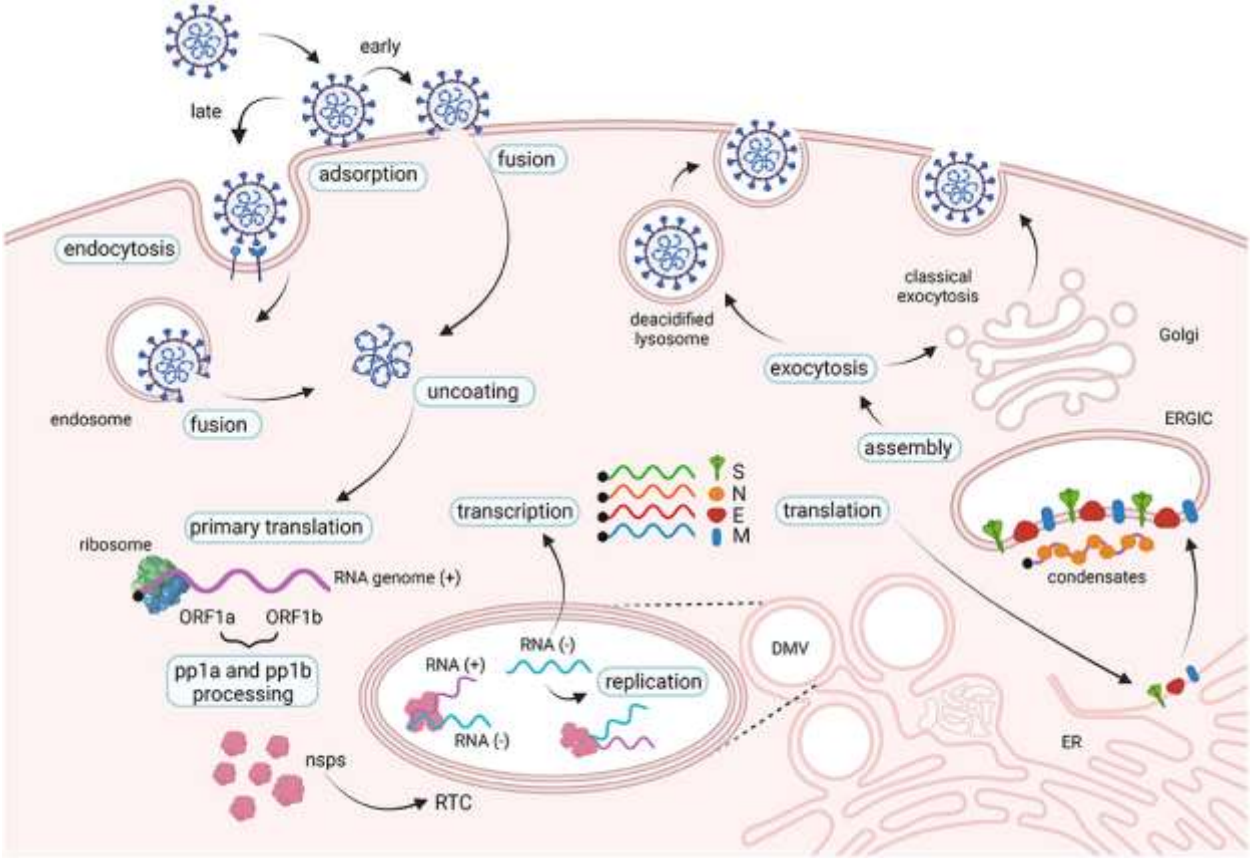
Questions 5-6 reinforce student understanding that some non-living things have one or two of the characteristics of living things, but living things have all or most of the characteristics of life.

A mule is the offspring of a female horse and a male donkey. A horse has 64 chromosomes per somatic cell and a donkey has 62 chromosomes, so a mule has 32 horse chromosomes and 31 donkey chromosomes per somatic cell. Meiosis is needed to form eggs and sperm, and homologous chromosomes need to pair at the beginning of meiosis. The horse and donkey chromosomes are sufficiently different that they don't reliably pair during meiosis in a mule. Furthermore, since mule's cells have an odd number of chromosomes, it is impossible for each chromosome to pair with a homologous chromosome during meiosis. Failed meiosis is the reason why mules cannot reproduce (with very rare exceptions).

Viruses have a few of the characteristics of life. Viruses reproduce, but only by commandeering the molecular machinery of cells in living organisms. The figure below shows how infected cells replicate the coronavirus that causes COVID. All viruses have genetic information. Some have DNA; others, including the coronaviruses, have RNA as their genetic material. Evolutionary change in viruses can result in the emergence of new threats to human health (see the video at https://www.youtube.com/watch?v=NJLXdsO1GBI). However, viruses lack other characteristics of life. For example, viruses do not have cellular organization, do not acquire and

[8] For learning activities about cell structure and function, see https://serendipstudio.org/exchange/bioactivities#cells.

use energy, and do not maintain homeostasis. This combination of characteristics has led to a lively debate about whether viruses are alive; the answer appears to depend on the definition of life.[9] Thus, viruses illustrate the complexity of the distinction between living and non-living things. Regardless of the outcome of this debate, viruses are studied by biologists.



Notice how the virus uses cellular ribosomes, endoplasmic reticulum (ER) and Golgi to replicate.
(https://www.frontiersin.org/journals/virology/articles/10.3389/fviro.2021.815388/full)

Sources for Figures in Student Handout

- Sweating and shivering – https://image.freepik.com/free-vector/kids-heat_6460-433.jpg and https://lenaweegreatstart.org/blog/wp-content/uploads/2014/01/clipart_snow_cold.jpg
- Frogs – https://media.istockphoto.com/vectors/coloring-page-with-life-cycle-of-frog-sequence-of-stages-of-of-frog-vector-id1028224944
- Skin cells – adapted from https://images.topperlearning.com/topper/question_uploads/CBSE_Bio11_AnimalTissue_SAQ_CLA_files/20140722151604_image002.jpg
- Hummingbird – https://primaryevolution.files.wordpress.com/2015/02/purple-throated_carib_hummingbird_feeding.jpg
- Plant in sunlight – https://infinitylearn.com/surge/wp-content/uploads/2023/07/Photosynthesis.jpg

[9] If living things are defined as having most of the characteristics of life or having cellular organization, then viruses are not living things. In contrast, if the defining characteristics of living things are genes and evolution, then viruses are living things. Also, the recent discovery of giant viruses that become sick when they are infected by a mini-virus suggests that viruses may be alive or may occupy an intermediate position between living and non-living things. (See https://microbiologysociety.org/publication/past-issues/what-is-life/article/are-viruses-alive-what-is-life.html and https://www.nature.com/articles/454677a.)