Photosynthesis is the turning of the Sun's light energy into food. Then molecules that are made as a consequence of photosynthesis can be ingested — that is, eaten — and then broken down, using the energy released to drive self-generation. Photo: Photo: Big History Project

What is the difference between nonlife and life? To answer this question, we first need to define life. Below are the key features of life. Our answer will flow from understanding these features.

A key concept is that every organism is a self, a being. It takes two fundamental activities to be a self: self-generation and self-maintenance.

**Self-generation**

Self-generation means 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-yeast 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.
For all organisms on our planet today, proteins are very important for self-generation. When a protein is made, it folds up into a particular shape, with crevices and bumps — something like a 3-D jigsaw-puzzle piece. These shapes allow proteins to do two major activities.

The first is to interact with other proteins. Bumps from one protein fit into the crevices of others. They combine to form the thousands of different kinds of chemical structures that make up a cell.

Most parts of a cell are made from proteins. This includes the filaments that act as cell skeletons, the channels that let ions in and out of cells, and the receptors that let the cell know what's going on in the environment.

The second activity of proteins is to serve as enzymes. Enzymes allow chemical reactions inside the cell to happen with remarkable efficiency and accuracy. Here, the shape of proteins is important. The bumps and crevices bring together the proteins in a chemical reaction and ensure that they form the right kind of chemical bonds with each other.

**Self-maintenance**

The self must get the molecules and energy that it needs for self-generation. One strategy is to use photosynthesis, turning the Sun's light energy into food. The second is to ingest molecules that are made using photosynthesis — to eat — and then break them down, using the energy released for self-generation.

Here again, the shapes of enzymes are critical. Instead of controlling the formation of chemical bonds as in self-generation, they supervise the breaking of chemical bonds and form energy-rich molecules to keep the cell going.

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

**Every organism is instructed**

All the proteins we've been thinking about are encoded in genes. The genes are embedded in DNA molecules. Each gene specifies the amino-acid sequence of a particular protein. That sequence 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 self-maintenance. They also have many others that are distinctive. Daughter organisms inherit copies of genomes from parent organisms, allowing that kind of organism to continue and spread. A genome has the ability to express certain genes, and certain proteins, on some occasions and not others.
When it’s time to copy DNA into daughter molecules, the genes controlling the DNA-copying enzymes are “switched on.” When the copying process is finished, these genes are “switched off.”

When it’s time for you to make red blood cells, genes controlling the hemoglobin protein are switched on in certain bone-marrow cells, but they 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.

**Every organism can evolve**

DNA is copied with remarkable accuracy, but mistakes sometimes happen. These mistakes produce mutant genes that make proteins with different shapes.

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 daughter that is somewhat different from its parent.

For example, a parent duck might have delicate foot webbing while the webbing of a mutant daughter might be extra-thick. What happens next depends on environmental setting. If the ducks hang out on mudflats, the mutant feet might allow for surer footing and better opportunities for feeding and fleeing predators. The thick-footed trait will likely spread into future generations. If the ducks live in grasslands, the mutant feet might 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, now we have a 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 over time.

For me, the most interesting single generalization is that organisms have purpose where nonlife does 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 environment. The long-term goal is to pass genome copies on to offspring. This goal only succeeds 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.
If we take this view, we can say that when life showed up on Earth, something completely new showed up: the emergence of purpose. Whether life, and purpose, exist anywhere else in the Universe is unknown and may remain a mystery. Meanwhile, we can enjoy and appreciate the astonishing purpose that surrounds us here on Earth.
Quiz

1. Which sentence from the section “Every organism is instructed” BEST summarizes the role of the genome?
   (A) The full set of genes necessary to pull together a self-generating and self-maintaining self is called a “genome.”
   (B) A genome has the ability to express certain genes, and certain proteins, on some occasions and not others.
   (C) When it’s time to copy DNA into daughter molecules, the genes controlling the DNA-copying enzymes are “switched on.”
   (D) It functions continuously to instruct self-generation and self-maintenance.

2. Which sentence from the article BEST explains why a protein is made with crevices and bumps?
   (A) These shapes allow proteins to do two major activities.
   (B) They combine to form the thousands of different kinds of chemical structures that make up a cell.
   (C) That sequence defines how the protein will fold up into its functional shape.
   (D) These mistakes produce mutant genes that make proteins with different shapes.

3. Which selection from the section “Every organism can evolve” BEST shows the role of mutation in how organisms evolve?
   (A) DNA is copied with remarkable accuracy, but mistakes sometimes happen. These mistakes produce mutant genes that make proteins with different shapes.
   (B) At the other extreme, it may have disastrous consequences on self-organization and self-maintenance, and the daughter will not survive.
   (C) The most interesting mutations are those that generate instructions for a daughter that is somewhat different from its parent.
   (D) If the ducks live in grasslands, the mutant feet might slow things down and the trait will be less likely to spread.
4 Which of the following is a MAIN idea of the article?

(A) Proteins are very important to the self-generation of organisms.

(B) The purpose of every organism is to self-generate and self-maintain.

(C) Passing mutations from one generation to the next is vital to the evolution of an organism.

(D) In an organism, the genome contains instructions for self-generation and self-maintenance.
Answer Key

1. Which sentence from the section “Every organism is instructed” BEST summarizes the role of the genome?
   (A) The full set of genes necessary to pull together a self-generating and self-maintaining self is called a “genome.”
   (B) A genome has the ability to express certain genes, and certain proteins, on some occasions and not others.
   (C) When it’s time to copy DNA into daughter molecules, the genes controlling the DNA-copying enzymes are “switched on.”
   (D) It functions continuously to instruct self-generation and self-maintenance.

2. Which sentence from the article BEST explains why a protein is made with crevices and bumps?
   (A) These shapes allow proteins to do two major activities.
   (B) They combine to form the thousands of different kinds of chemical structures that make up a cell.
   (C) That sequence defines how the protein will fold up into its functional shape.
   (D) These mistakes produce mutant genes that make proteins with different shapes.

3. Which selection from the section “Every organism can evolve” BEST shows the role of mutation in how organisms evolve?
   (A) DNA is copied with remarkable accuracy, but mistakes sometimes happen. These mistakes produce mutant genes that make proteins with different shapes.
   (B) At the other extreme, it may have disastrous consequences on self-organization and self-maintenance, and the daughter will not survive.
   (C) The most interesting mutations are those that generate instructions for a daughter that is somewhat different from its parent.
   (D) If the ducks live in grasslands, the mutant feet might slow things down and the trait will be less likely to spread.
Which of the following is a MAIN idea of the article?

(A) Proteins are very important to the self-generation of organisms.

(B) The purpose of every organism is to self-generate and self-maintain.

(C) Passing mutations from one generation to the next is vital to the evolution of an organism.

(D) In an organism, the genome contains instructions for self-generation and self-maintenance.