Teacher Tune-up

Quick Content Refresher for Busy Professionals

What does it mean for something to be alive?

Traditional views of what is and isn't alive range all over the place. In some times and places, people with animistic views have attributed life to just about everything, from plants and animals to rocks and streams. Others have seen life as a much more rare and exclusive property, and have tried to figure out what the line is between life and nonlife.

While some notions about life resort to supernatural explanations, many scientists now believe in philosophical naturalism, the idea that supernatural forces don't exist. But even scientists who differ on that philosophical question are generally united in their adherence to *methodological* naturalism, a working assumption that supernatural phenomena that cannot be measured and tested are, by definition, out of bounds for empirical science. Natural science as such limits itself to naturalistic explanations.

In a naturalistic frame of reference, then, what does it mean for something to be alive? Different authorities list different characteristics of life, and often give an impression of finality by including the article "the": *the* five characteristics of life, *the* seven characteristics of life, *the* ten characteristics of life…

There are indeed some useful and widely agreed upon ideas about what life is, biologically speaking, and we'll get to some of those in a moment. But many scientists and educators also warn against fetishizing these lists, or agonizing too much over a black and white distinction between what is and isn't alive. Scientists sometimes describe life as an *emergent* phenomenon, something that is not inherent in the smallest parts of living things, but that comes into view as you back up and see those parts interacting with increasing complexity. The perspective of *systems thinking* helps here: simple parts come together to make systems (subatomic particles form atoms), which in turn are parts of larger systems (atoms form molecules), and so on, each system being characterized by properties that are unlike the properties of its parts—until at some point, we arrive at a system that has what we think of as the properties of life.

Scientists commonly say that the simplest system that is alive is the cell. The parts of a cell—nucleus, DNA, RNA, cytoplasm, lipid membrane, etc.—are bits of organic machinery that aren't alive. But together, they enable cells to do things we recognize as characteristic of life.

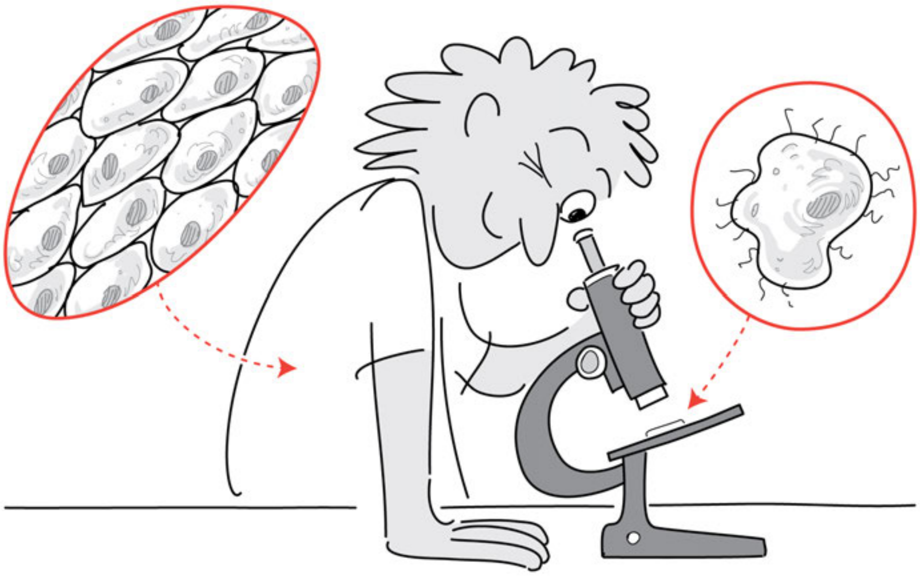
For the SciGen middle school lessons about cells, we focus on four essential things that all living entities must be able to do: (1) acquire materials for growth and maintenance of structures, (2) obtain and use energy, (3) get rid of waste products, and (4) store and use information. Only in light of these *functions* of life can the *structures* of life become meaningful to students. Cells are self-reproducing entities that can do these four basic things, and they can adopt cooperative strategies to enable multicellular organisms to do these four things on a much larger scale. A middle school student who really understands this simplified picture should be in a good position to go on to greater complexity in high school.

From Vitalism to Methodological Naturalism.

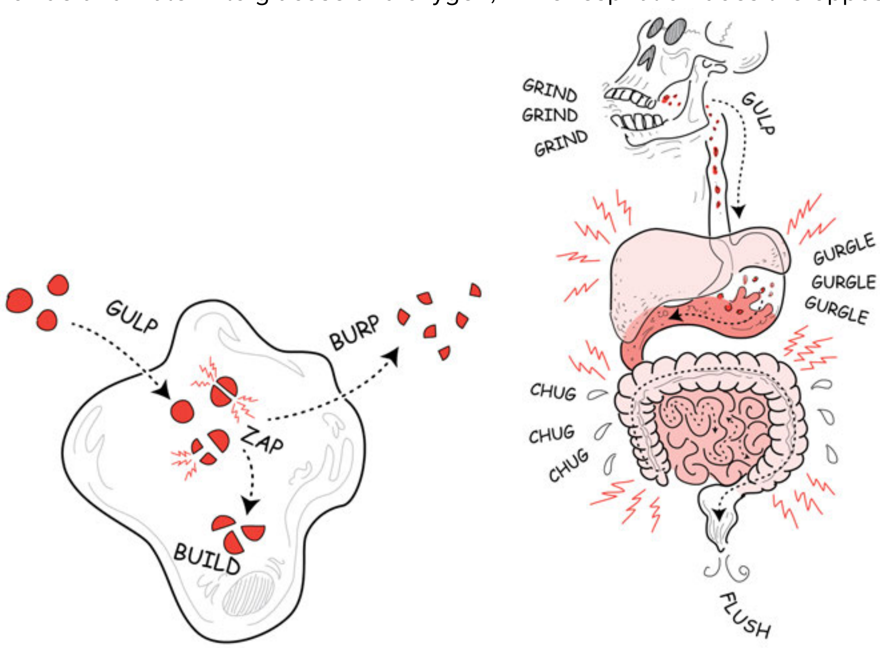
Since long before the advent of modern science, many people have resorted to supernatural vitalism to explain what makes something alive. In various ancient and modern forms, vitalism holds that life involves some vital principle or force that's fundamentally different from, and somehow impressed upon, the chemical and physical phenomena of living bodies. At one time, many scientists assumed that some such vital force was involved in "organic" chemistry, making it deeply different from physical chemistry. In 1828, the German scientist Friedrich Wöhler synthesized urea from inorganic materials, instead of getting it the old fashioned way: "I can no longer," he quipped in a letter to a colleague, "hold back my chemical urine." Wöhler's synthetic urea didn't blow vitalism out of the water at the time, but looking back, many people think of it as an early milestone in a gradual shift away from vitalistic thinking in biological science.

For teachers who would like to review a slightly more detailed list, however, here are seven (we won't say *the* seven) characteristics of life, with cartoons emphasizing that they apply at both the single-celled and the multicellular level.

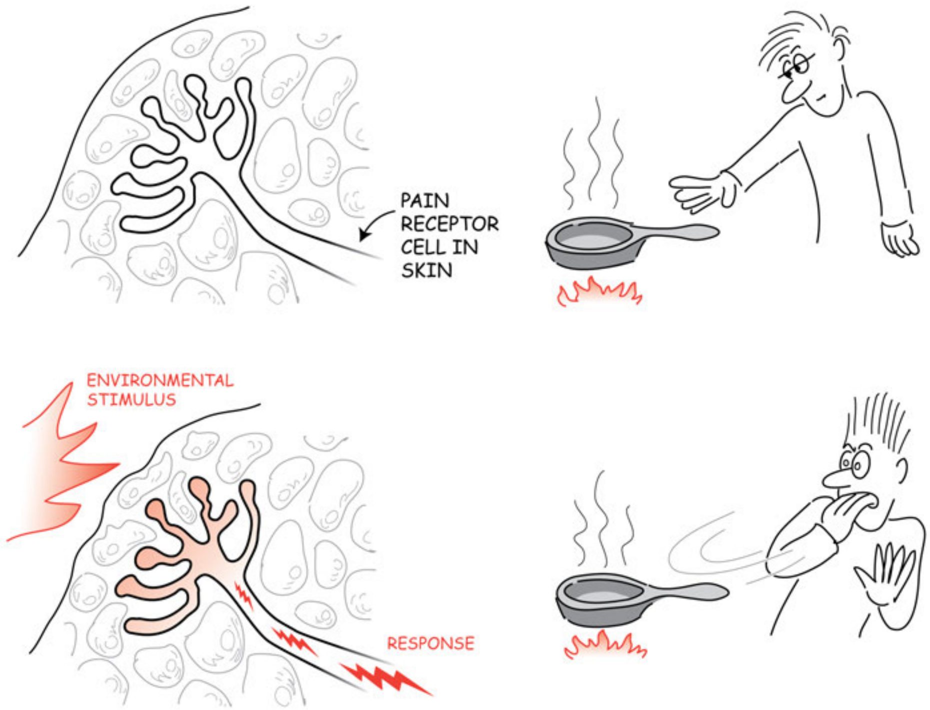
Cellularity. Living things are made of cells, which are sometimes dubbed the basic unit of life.



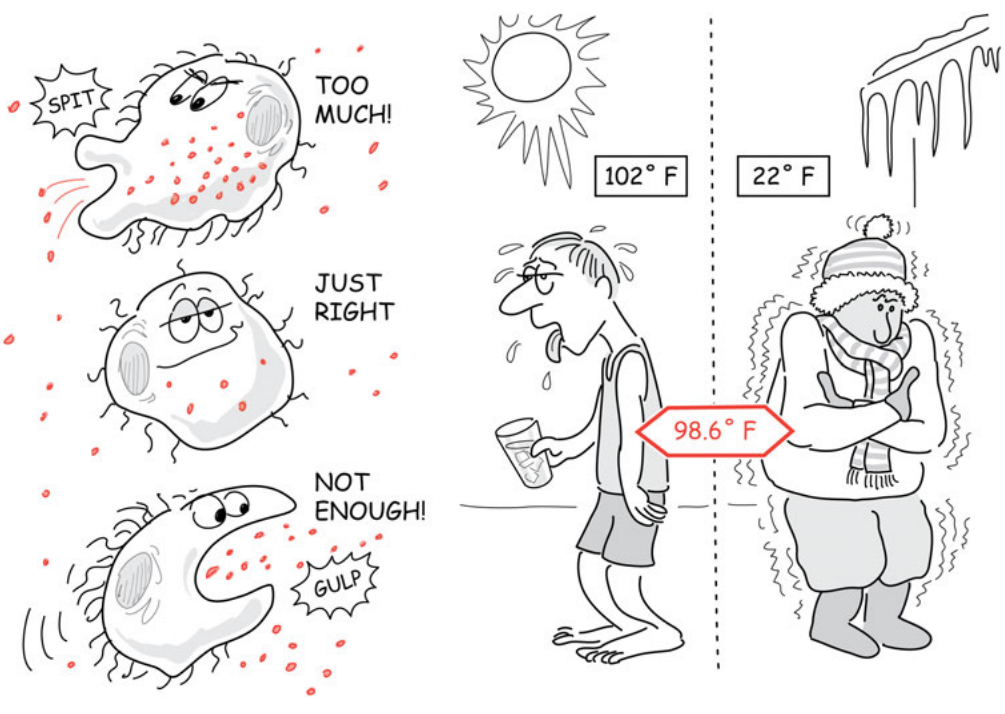
Metabolism. Living things have chemical processes that allow them to get and use energy and materials. **Photosynthesis** is one important metabolic process, by which plants and some other organisms capture energy from sunlight and store it as chemical energy in sugars. In addition to serving as fuel, sugars are building blocks for growth and maintenance. Plants and the herbivores that eat them (and the predators that eat the herbivores) then metabolize those sugars to obtain energy through a process called **respiration**. Photosynthesis and respiration are complementary processes, cycling chemicals back and forth among living things: photosynthesis converts carbon dioxide and water into glucose and oxygen, while respiration does the opposite.



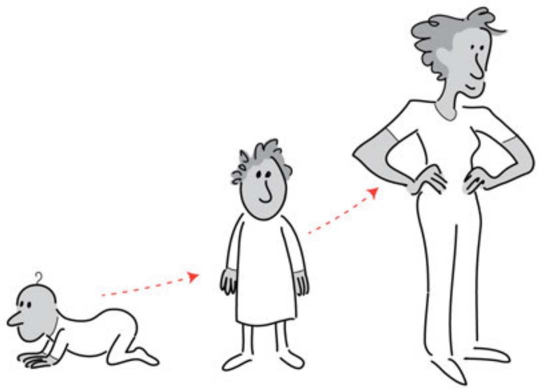
Responsiveness. Living things respond to their environment. This interactivity makes them more adaptable than they would be if they depended for survival on perfectly unchanging circumstances.

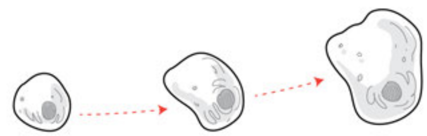


Homeostasis. This is just a fancy term for equilibrium, and *that* is just a fancy term for a nice, healthy balance. Living things must keep their internal state fairly stable. For instance, cells import or export chemicals to maintain optimal concentrations, and humans maintain safe body temperatures by either sweating to cool themselves down or shivering to warm themselves up.

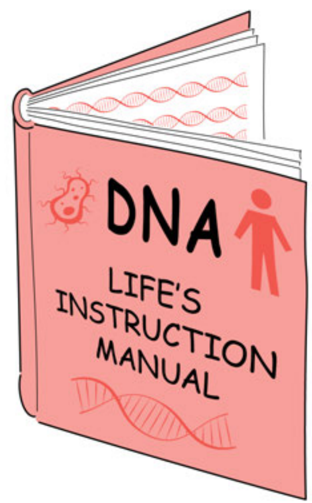


Growth. Living things grow. This is an easy one for children to understand as they look at seedlings and baby animals over time, and perhaps pencil their own vertical progress on the kitchen wall. (Crystals also grow, but it's the combination of all these different characteristics that persuades us something is alive.)





DNA (deoxyribonucleic acid). All living organisms we know of use DNA as a storehouse of genetic information: instructions that organisms execute, and also copy and pass on to their offspring. Viruses use RNA, but viruses are not generally considered to be alive (because, for instance, they lack metabolism). Some scientists think there could be (or could once have been) primitive cells that lack DNA and rely exclusively on RNA instead—but so far, that's speculation, as are guesses about the hypothetical biochemistry of extraterrestrial life. There are "denucleated" cells, like mature human red blood cells, that have lost their DNA; but such cells use DNA earlier in their life, and cannot reproduce once they've lost it.



Reproduction. Living things reproduce themselves, and pass copies of their DNA on to the next generation so the whole amazing business can keep on rolling!