

It will be helpful for students to recall that the three states of matter are solid, liquid, and gas. The tricky one is gas, because it is usually invisible.

Students will intuitively know that people breathe, eat, and drink. It may be necessary to review for them that they are breathing in order to take in oxygen ( $O_2$ ) and that carbon dioxide ( $CO_2$ ) is exhaled as a waste product. Drinking water and eating food inevitably result in solid and liquid waste products, but you should not have to organize a field trip to the restroom to get the class to come up with this information. One last thing: humans perspire (from the Latin *per* “through” and *spirare* “pores”) and thus put water directly into the air when it evaporates from their skin.

You might remind the class that all animals (including fish) also take in oxygen, food, and water and put out carbon dioxide, waste solids, and waste liquids.

Plants can conveniently be thought of as the opposite of animals in terms of some of the things they consume and produce. Plants also “breathe, eat, and drink” and thus need carbon dioxide, nutrients (commonly called fertilizer), and water. Fortunately for life as we know it on Earth, plants produce oxygen and edible parts such as leaves, fruits, and seeds (i.e., food). One last thing about plants: plants transpire (*trans* “across,” *spirare* “pores”) and thus also put water directly into the air from their leaves. Transpired and perspired water is a gas (water vapor) and is exceptionally pure. This piece of information will be important later.

Probably everyone in the class has had a personal experience with mold and other spoilage of some long-forgotten leftovers in the back of the fridge. What is that yucky stuff? And how did it get into the Tupperware®? Bacteria and mold (fungus) spores are in the air just about everywhere, and they like our food at least as much as we do... more in the case of some foods that I will not name. (No Mom, of course I love your eggplant soufflé). So they start to feed immediately, and as they feed, they grow and reproduce—slower in colder temperatures, hence the importance of refrigerators. Pretty soon you’ve got lush fungus gardens and soupy bacterial broths. Yum. (Not!)

These microbes will be on the spacecraft too, and in thinking about them it will be useful to place them with the animals because of how they function: most of them require oxygen and produce carbon dioxide as a waste gas. What they are doing by their simple existence is decomposition. They break down complex organic materials such as food into simpler compounds. These simple compounds can in turn be used by plants for their growth (i.e., fertilizer, compost) and the cycle of life is completed.

It will be important for students to have a basic understanding of what a cycle is. The word *cycle* can be thought of as an alternate pronunciation of the word *circle*. (Try it with a variety of accents!) A cycle is a process or journey that ends where it began, or repeats itself. Cycles in nature are characterized by feedback among the parts of the system. Feedback may be an unfamiliar term for the students but they are wholly aware of the concept and have been since they were babies squalling for: a) attention, b) food, c) clean diaper, d) the remote, and an older human flailed around trying to figure out what was wrong. The wailing (signal) gets a response (feedback) that quiets the wailing (one hopes) and possibly produces a toothless drooly grin (best case).

Feedbacks in nature may be triggered by such signals as increasing carbon dioxide content of the air (feedback: plants grow faster). When the signal changes, the feedback changes as well. In this example,

rapidly growing plants take up carbon dioxide, and as its concentration decreases, plants grow more slowly. Needless to say, in nature there are many signals and feedbacks operating simultaneously.

Finally, the students will need to keep in mind that a spaceship on a long-duration mission is a *closed system*. This means that the crew will not be able to step out to the store if they forgot something. And if they run out of something they are likewise out of luck. The phrase *reduce, reuse, recycle* will take on new meaning on the spaceship.

**Common student misconceptions related to this topic:**

Common student misconceptions related to this topic revolve around the fallacy that humans are separate from nature and independent of it. For example, food comes from the store, water comes from the tap, and waste disappears down the toilet. Trash vanishes from the curb, the garbage disposal gets rid of the banana peels, and oxygen is just there to breathe.

Another common misconception is to think of the properties of a system as belonging to individual parts of it rather than as arising from the interaction of the parts.

**Related benchmarks:**

Ideas in this lesson are also related to concepts found in the following benchmarks:

**K-2**

6A The Human Organism: Human Identity #2

8A The Designed World: Agriculture #1

**3-5**

4B The Physical Setting: The Earth #3

5C The Living Environment: Cells #1

5D The Living Environment: Interdependence of Life #1

5E The Living Environment: Flow of Matter and Energy #1, #2, #3

6E The Human Organism: Physical Health #1

8A The Designed World: Agriculture #1

11A Common Themes: Systems #1, #2

**6-8**

4D The Physical Setting: Structure of Matter #7

5A The Living Environment: Diversity of Life #5

11A Common Themes: Systems #1, #3

**9-12**

4C The Physical Setting: Processes that Shape the Earth #1