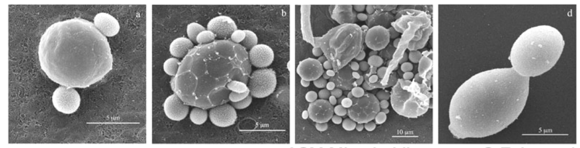
Microbes

Microbes (also called microorganisms) are truly the most underappreciated living organisms on Planet Earth. Billions of them can fit on a fingernail, and they make up more than half of the living biomass on the planet. In your body, 9 out of 10 cells are microbes (not your own human cells!). Microbes are just so **small**, from our perspective, that we rarely think about them. That is, until a few of them make us sick. But what about the fungi that decompose dead materials or make bread rise? What about the bacteria in our stomach that allows us to digest food? What about the algae that produce half of the planet's oxygen (it is not just the visible and famous plants that produce oxygen!) or the bacteria that provide nitrogen to plants?



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Microbes, whether they are good, bad, or benign, are certainly everywhere. This includes on our body, in our homes, far below the earth's surface and up to the atmosphere, in cold, cool, warm and hot and very hot places, and even in places without oxygen. Microorganisms always live in water (directly in aquatic environments, in water inside animals or plants, or in water around soil particles). They can eat all sorts of things, including oil, rocks, dead and living plants and animals. Here is just a sample of the amazing things microbes do in an ecosystem, and for humans:

Oxygen producers. Half the oxygen we breathe is produced by plants, and half is produced by algae and photosynthetic bacteria.

Nitrogen fixers. Rhizobium (a type of bacterium) fixes the abundant, but useless, nitrogen in the air to make it suitable for plants.

Decomposers. Did you ever consider what happens to all the leaves that fall in autumn? Many types of fungus and other microbes release enzymes that digest dead stuff (just the opposite of animals, they digest their food *before* eating it!). These microbes turn trash to treasures by recycling nutrients back into the soil. Microbes are also essential in breaking down animals waste, and are therefore present in the treatment of raw sewage.

Nutrient scavengers. Mycorrhizae are fungal nutrient scavengers that supply nutrients to plants and, in turn, get protection and food (in the form of glucose) from plants. 98% of terrestrial plants have mycorrhizae.

Dwellers of the human body ecosystem. There are microbes that live in and on us, as well as microbes that harm us. Those that live on us may just be going about their business of living, without harming or helping us. Others, however, may be eating our dead skin cells while guarding our skin from harmful bacteria. Still others live in our digestive system and help to break down our food. Those that harm us include some strains of bacteria and viruses that cause diseases like malaria, strep throat and Lyme disease, to name a few.

Food for larger animals. Many microbes, like algae, are critical food sources for larger animals like insects or fish.

There are 4 major types of Microbes: bacteria, fungi, protists and viruses.

Prokaryotes (bacteria) are simple celled organisms, meaning that they have no membrane-bound organelles. In other words, the small organs and DNA are free-floating within the cell. Bacteria can occur as little round balls, tiny short sticks, or spirals that look like springs. These three basic forms are often stuck together in long strings or clusters that look like little squares, cubes, or random grape-like clusters. There are three basic types of bacteria: 1) Eubacteria (the most common), 2)Archaebacteria who live in extreme environments and 3) Cyanobacteria, which are the only living things that can do photosynthesis *and* fix nitrogen. Of interesting note:

- A thousand bacteria can "sit" side by side in just 1 tiny millimeter.
- Bacteria are the most abundant organism on Earth and are found in all natural waters and sediments.
- Some bacteria can divide every 12 to 20 minutes.
- Bacteria do not have a mouth. They make proteins called enzymes inside the cell and these travel thru the cell wall into the surrounding medium. The enzymes break down the food into tiny subunits which then come into the bacteria cell by osmosis or active transport.

Eukaryotes are more complex because their cells have membrane bound organelles, meaning that the small organs are not free floating, but compartmentalized within the cell. Fungi and protists are the 2 types of microbial eukaryotes. Unlike plants, algae and some bacteria, **Fungi** are not able to make their own food. All fungi survive by eating dead or living organic materials. They have a rigid cell wall; and grow in the shape of hypha (hair-like filaments) and/or yeast (single cells that multiply by budding). Basidiomycotina, the mushrooms and toadstools, are the most widely recognized type of fungus. These fungi are made of a continuum of interconnecting hyphae that can grow to be very large and old. They randomly spread their hyphae as they age. Despite these hyphae networks, we recognize them by their short-lived fruiting bodies that produce large numbers of spores.

Protists are a group of organisms that might be best thought of as eukaryotes that are not plants, animals or fungi. This very diverse group consists of organisms that can move through the water by means of flagella, or pseudopodia ("false feet"). They also can do chemotaxis (swim or crawl towards nutrients) and/or chemotropism (directed growth). Some widely recognized protists include algae, amoebas, *Plasmodium* (which causes malaria), and water and slime molds. Algae, including diatoms, are mainly aquatic and are almost always photosynthetic. They range in size from single-celled to a multicellular giant kelp.

Lastly, **Viruses** are not actually living cells, but are often placed into the microbe category. As opposed to complete cells, they are little packages of DNA that can infect cells of other microbes, animals and plants. They can stay dormant for long periods of time, but once they enter a cell they begin to reproduce and then take over the cell. They may or may not cause disease, but when they do cause disease, it is because they destroyed host cells.

References

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Macroinvertebrates

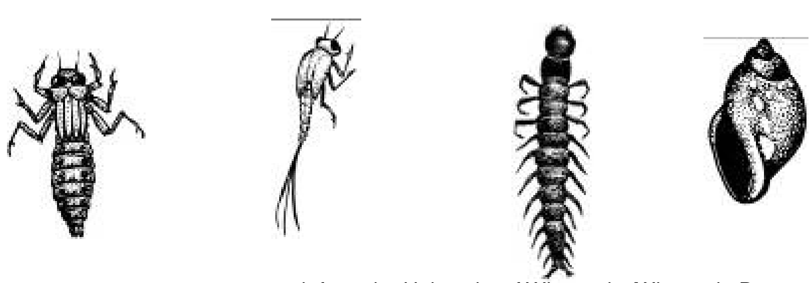
You probably already know what an invertebrate is…an animal without a backbone! On land, this includes worms, insects, and crustaceans such as pill bugs. There are a huge number of insects, worms, and crustaceans that live in water, providing food for other animals and serving as part of a very important aquatic food web. We call these invertebrates “macro” because we can see them without a microscope.

If you are studying water quality, macroinvertebrates are an important indicator of the health of an aquatic ecosystem. Immature insects such as stoneflies, mayflies, and water pennies (a type of beetle larvae) require a high amount of dissolved oxygen (DO), while aquatic worms, leeches and pond snails can survive in low DO. We call oxygen-loving species like mayflies and stoneflies “indicator species” because they provide important clues about the water they are living in. If you only find animals like leeches, snails, and aquatic worms, then you know that you don’t have clean water.

One of the most useful indicators is the diversity or numbers of kinds of organisms. If you find only one or two kinds of animals, no matter what kind they are, you should perform other water quality tests to determine what might be wrong with your aquatic ecosystem. Sometimes, low diversity can indicate a pollution problem or other habitat change that is affecting the ecosystem.

A number of factors can influence the diversity and density of macroinvertebrates present in an aquatic ecosystem. Seasons, life cycles, types of substrate, food sources, water velocity, and sampling techniques can all affect the diversity in your sample. For example, if you are testing the water in the spring, you might find fewer animals after a flood or heavy rain.

It is also important to know the animals’ life cycles. Many larvae emerge as adults in late spring and are present only as eggs during other parts of the year. The substrate on the river bottom can affect your results too. A rocky bottom provides more habitat than a silty or muddy bottom. Also, a fast moving stream can reduce the amount of habitat available to macroinvertebrates. You should also take into consideration the surrounding habitat: a forest often provides more food (in the form of plant material) than a meadow. Finally, you need to decide what kind of sampling technique you are going to use. A screen or net that is too large will cause you to miss some animals, while inappropriate equipment use means you won’t collect a good sample of all the animals living in the ecosystem.



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Dissolved oxygen

Did you ever wonder how fish breathe? Like us, they have to breathe oxygen, but they get it from the water. The oxygen they use is dissolved in the water, in much smaller quantities than what is in the air. Animals and plants do not use the oxygen from the molecular structure of water (H_2O), but rather, they use the oxygen gas that is dissolved in the water. Oxygen is important for many living things and for many of the chemical processes that happen in the water. There are two ways that dissolved oxygen enters water, either from photosynthesis from aquatic plants or through diffusion with the surrounding air. Oxygen is also consumed in the water by respiration of aquatic animals and plants, decomposition of organic matter by microorganisms, and different chemical reactions. The combined oxygen consumed by all of the biological processes is called 'Biochemical Oxygen Demand', or BOD for short-this is described in more detail at the end of this section. Most likely, you will be measuring only DO. When more oxygen is consumed than produced, dissolved oxygen levels in the water will decline.
When water has high, relatively stable levels of DO, it is usually considered a healthy ecosystem, capable of supporting lots of different kinds of aquatic organisms. Organisms have to adapt to changing levels of dissolved oxygen, and if these are extreme, it can cause them stress. Low DO levels usually indicate pollution or some type of human-caused change, of which there are several major categories:

- Addition of organic waste in the form of sewage and animal manure, organic fibers from textile and paper processing, and food wastes. These organic materials are decomposed by microorganisms that use up oxygen.

- Addition of nutrients from fertilizers and agricultural runoff as well as through sewage. This causes lots of plants and algae to grow and then decay. The bacteria that decompose the plants consume oxygen during the decay process

- Changing the flow of the water through dams and water withdrawal (for irrigation, snowmaking, water supply, or cooling systems of electric or nuclear power plants). The reservoirs created through a dam may increase the temperature and reduce the amount of dissolved oxygen.

- Raising the water temperature through the removal of vegetation from stream banks, which increases the water temperature and therefore decreases the dissolved oxygen levels. Another way that temperature can be affected is through the release of heated water that was used to cool an industrial plant.

Natural processes also affect the dissolved oxygen levels:

- Warm water holds less dissolved oxygen than cold water.

- The lowest levels of DO usually occur in the morning, because photosynthesis stops at night while respiration continues.

- Water at higher altitudes holds less oxygen.

- Fast-moving water generally has more oxygen than still water, because the movement mixes the air into the water. However, if the water is very turbulent, it may hold too much oxygen, causing stress to the aquatic organisms.

- Water with lots of aquatic plants have higher levels of dissolved oxygen, since submerged plants produce oxygen through photosynthesis. Also, as mentioned above, too many plants will ultimately reduce the DO levels, because of either night-time oxygen use by plants or the decay process that consumes oxygen.

In the Hudson, however, there are other factors that affect DO levels. Along the banks where the water moves more slowly, an invasive plant called water chestnut has dramatically reduced the DO in the water, often causing an anoxic situation. Anoxic means that the water doesn't contain any dissolved oxygen.

Some animals, like carp and catfish, can survive with less oxygen, while others, such as salmon and trout, require more. When DO becomes scarce, some animals may be able to obtain their oxygen directly from the surface, such as the diving beetle, frogs, or even catfish. Testing water samples for DO will let you know if your water is healthy and can sustain life.
Dissolved oxygen is measured in a few different ways: parts per million (ppm), milligrams per liter (mg/L), or percent saturation. When measuring DO, concentrations range from 0 to 14 ppm or mg/L (they measure the same thing, but sometimes your test kit will use only one of the measurements), and 0-125+ percent saturation. When measuring percent saturation, you also need to know the temperature of the water, because that can change the result.
For mg/L:
0-2 mg/L: not enough oxygen to support most animals
2-4 mg/L: only a few kinds of fish and insects can survive
4-7 mg/L: good for most kinds of pond animals
7-11 mg/L: very good for most stream fish
For percent saturation:
Below 60%: poor quality, bacteria may be using up the DO
60-79%: acceptable for most stream animals
80-125%: excellent for most stream animals
125% or more: too high. It is possible to get more than 100% saturation. The sample can be supersaturated in an area where there are a lot of plants or algae on a sunny day (due to photosynthetic activity).

pH

Why does a lemon taste tart? Acidity, measured as pH accounts for part of the explanation. Lemons, which have a low pH, are acidic. The scale of pH measurements goes from 0 (the most acidic) to 14 (the most basic). Pure water is right smack in the middle with a pH of 7, which is neutral. The pH scale is logarithmic, meaning that each one-unit change in pH actually represents a 10-fold change in acidity. For example, lemon juice at pH 2.0 is ten times more acidic than vinegar at pH 3.0. pH is a measurement of the amount of H+ ions in a solution. Pure water is considered neutral at a pH of 7 because the number of H+ ions is exactly the same as the number of OH- (hydroxide) ions produced when these dissociate in water. In nature, water is never pure; it has dissolved substances and gases in it. For example, the carbon dioxide in the air causes water to have an acidic pH (near 5.6).

pH, which literally stands for the 'power of hydrogen', is an important part of water quality. Many fish and invertebrates are sensitive to high (above 9) and low (below 5) pH levels. At low pH levels the bones of fish can become soft and they may be unable to lay eggs successfully. In acidic conditions fish gills become clogged with mucus, making it difficult for the animals to get oxygen into their bloodstream. Sometimes, air pollution can cause precipitation to have a lower than normal pH. The pH of unpolluted rain is about 5, while rain that has become acidic because of pollutants has a range from 3.5 to 4.5. This is called "acid rain". Other substances, like concrete or drain cleaner can cause the pH of water to be very high.

Natural variation in soil and bedrock can greatly alter the pH of streams and ponds as well as buffer their susceptibility to acidification. Areas of limestone, therefore, have naturally high pH and greater resistance to acid rain. Much of the lower Hudson (below the Troy dam) is well-buffered and therefore fairly insensitive to acid deposition, while parts of the Adirondacks are poorly buffered and therefore very sensitive to acid deposition. Aquatic invertebrates can be more sensitive to pH changes than fish. Some insects that are especially sensitive to drops in pH are mayflies, sowbugs, damselflies, and dragonflies, crayfish, and snails. Carbonate, which is a component of the shells of clams and snails, begins to dissolve if pH goes below about 6.0.

What does this mean?

Water with a pH range from 6.5 to 8.6 is best for fish and most invertebrates, and most natural waters fall within this range. Exceptions are bog-dominated lakes which often have a very low pH and some naturally eutrophic systems and inland saline lakes which can have very high pH values. Water with a pH less than 5.0 or greater than 9.0 is harmful for aquatic life, and is usually due to some kind of human input.