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- Considering the impact of ecology
- Interacting with others and the environment
- Using ecological knowledge to restore balance

Chapter 1

Making Connections with Ecology

Ecology is the science of studying the relationships between all living things and our home, planet Earth (*oikos* = house and family). The scope of ecology is as big as the planet itself, seeking to answer questions that focus on small details, like the role of a single species in an ecosystem, to those that look at the big picture, like how climate affects the distribution of living things across the planet's surface.

The science of ecology is making important contributions to the human worldview, helping people see that we are both embedded in and dependent upon a web of life. Figure 1-1 illustrates this ecological understanding and contrasts it with an older view that sees humans as superior to other species. At its extreme, the older worldview leads people to use the natural world to serve human needs without regard to possible impacts on other species. In contrast, an ecological understanding promotes awareness of the importance of maintaining ecosystem health for humans and other species. The human population is more than 8 billion and still growing, stretching resources thin and straining ecosystems all around the world. Ecology looks at how the pieces of an ecosystem fit together to make a functioning whole and how ecosystems can recover after disturbance. Ecology is needed now more than ever as people look for solutions to modern environmental problems.

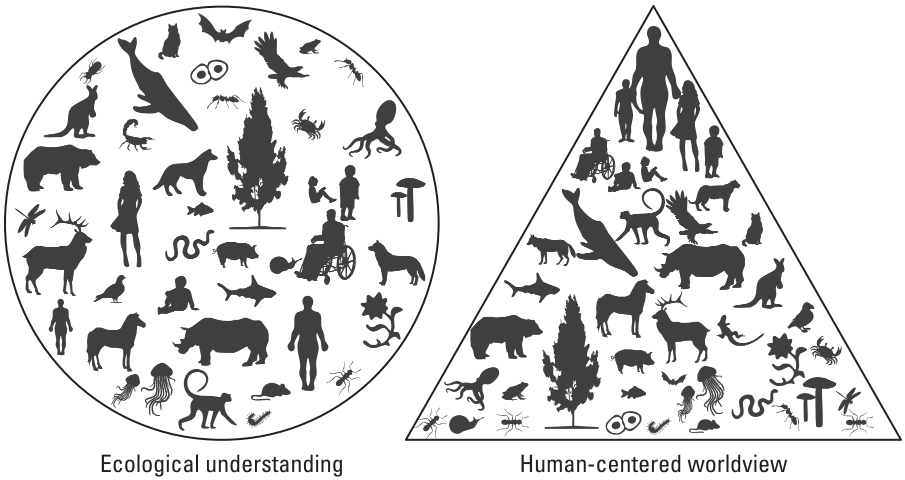

FIGURE 1-1: Ecological understanding.

Evolving to Fit the Physical World

The Earth is unique among all the known planets because it is covered with life.

REMEMBER

The *biosphere* is the interacting web of life that covers the planet's surface, extending into the Earth's crust, through the oceans, and up into the lower atmosphere.

Scientists think life is possible on Earth because of our position in the solar system and the physical properties of our planet. Earth orbits the sun at just the right distance to put it in the Goldilocks zone, neither too hot nor too cold. It has an atmosphere that protects the surface of the planet from harmful radiation and creates the pressure that makes liquid water possible. The Earth's core generates a massive magnetic field that helps protect the atmosphere from solar winds. These examples illustrate the deep connection between physical conditions and the biosphere.

Climate shapes our world

The physical conditions on planet Earth shape the environment and thus determine where organisms can live and grow.

REMEMBER

An *ecosystem* is a group of organisms interacting with each other and their environment.

The amount of solar radiation, combined with the movement of heat by wind and water currents, creates distinct climate zones on the planet (Chapter 2). Within each climate zone, differences in geology and topography further define unique environments that support distinct plant communities. These distinct large-scale communities are called *biomes*.

REMEMBER

Biomes are ecosystem types with similar climate, animals, and plants.

Ecologists generally agree that six major biomes exist on the planet: aquatic, forest, desert, tundra, grassland, and thick subarctic forests called taiga, or boreal forests. These biomes can be further divided into subcategories. Ecosystems from two completely different locations on the planet can be recognized as belonging to the same biome type. Although the species in each ecosystem may be unique, they often have similar structures and functions that enable them to live in that environment.

Living things are adaptable

Living things are found in almost all environments on the Earth, including the driest deserts, Antarctic ice, lightless caves, and deep ocean vents. In each of these environments, organisms have developed the necessary structures and strategies for success. In ecology and other biological sciences, an organism's success is ultimately defined as its *biological fitness*.

REMEMBER

Biological fitness is the ability of an organism to survive and reproduce, passing its genes to the next generation.

In any given environment, the individuals with the most advantageous traits are more likely to survive and reproduce. Scientists call this *natural selection* or *survival of the fittest* (Chapter 3). Over time, the most advantageous traits become more common in the population.

REMEMBER

Evolution by natural selection occurs when populations change over time to become more adapted to their environment.

The characteristics that help organisms succeed in a particular environment are called *adaptations* (Chapter 4). If someone asked you what traits organisms that live in the water needed to be successful, you might think about the streamlined bodies and fins of fish or the ability of whales to hold their breath for long periods of time. These are examples of adaptations to aquatic life. Likewise, organisms on land developed adaptations like the roots of plants for getting water or the wings of bats and birds for flying to escape predators. When ecologists look at unrelated species that evolved in similar biomes, they often find similar adaptations.

REMEMBER

Convergent evolution (Chapter 3) occurs when organisms that aren't closely related evolve similar characteristics, often as solutions to the same environmental problems (Chapter 4).

Reproducing into Populations

At the same time that the human population has grown to its largest size yet (more than eight billion people), thousands of other species have declined to the brink of extinction. Ecologists study the factors that affect populations, including how they grow, change, move, and decline, in order to predict how populations may change in the future. Ecologists can use these insights to develop effective strategies for the protection of threatened species and to manage populations of economic or ecological importance.

Living your life history

Natural selection favors traits that maximize reproductive success, but the road to success isn't the same for all species. Some species mature quickly and reproduce rapidly, producing vast numbers of offspring in the hopes that some will survive. Other species develop more slowly, growing and storing resources before they reproduce. Then, they produce just a few offspring at a time, which they tend carefully to increase the chance of survival. These two species could be equally successful, ultimately producing the same number of surviving offspring. The difference between the two is in the strategy they use to allocate their available resources.

REMEMBER

Life history strategies (Chapter 5) are the overall patterns and timing of events in the life history of a species, such as age of maturity, number of reproductive events, number of offspring produced, and lifespan.

As individuals reproduce, they produce groups of related organisms called populations.

REMEMBER

A *population* (Chapter 6) is a group of organisms that live in the same area at the same time and have the potential to interbreed.

Ecologists study populations to gain insight into the factors that shape their growth, distribution, and interactions. Population growth is affected by birth and death rates, as well as immigration and emigration. The balance of birth and death rates can affect the age structure of a population. For example, if the birth rate is very high, a population might have more young individuals than older ones. Populations may be distributed evenly over an area, or they may show a clumped distribution with many individuals in certain areas and fewer in others.

Interacting with others

Individuals in populations interact with each other and with members of populations of other species. Every possibility that you can imagine, from helpful to harmful, is a potential outcome of these interactions (Chapter 7). One of the most obvious interactions is a predator-prey relationship where one species eats another. A more subtle negative impact can occur when two individuals compete for a limited resource or if a parasite slowly drains resources from its host. Some of the most fascinating interactions are those that result from mutualism, where two species form a lifelong symbiotic partnership that benefits both parties. Each of the types of interactions impacts the success of the individuals involved and can also affect ecosystem function.

Forming Communities and Ecosystems

In nature, populations of different species interact with each other and their environment to form ecosystems.

Establishing a community

Populations of different species combine to form *communities* (Chapter 8). The function of the individuals within a community and their interactions with each other give communities distinct characteristics.

REMEMBER

Two important factors that influence *community structure* are the number of different species it contains and the identities of those organisms.

Some organisms have especially powerful effects on community structure:

- ***Dominant species* are the most common or largest species in a community.** They may affect community structure by outcompeting other species for resources or by altering environmental conditions such as nutrient and water availability. Humans are the dominant species in most parts of the world.
- ***Foundation species* create or maintain the physical or chemical environment that other organisms depend on.** Mangrove trees are a foundation species because their roots stabilize coastlines and provide breeding grounds for many species of fish. Coastal mangrove forests are home to insects and provide nesting grounds for shorebirds and migratory birds.

» ***Keystone species* keep a community in balance by controlling populations of other species.** Ochre seastars are keystone species in the rocky intertidal of the Pacific Northwest Coast. They prey on mussels, preventing the mussels from taking over rock surfaces. This allows other species to grow on the rocks, increasing the diversity of these intertidal communities.

Communities change over time in response to the activities of species within the community. For example, as seedlings grow into taller plants, they create shade that may favor the growth of some species but inhibit the growth of others.

REMEMBER

Ecological *succession* refers to the process by which communities and their environment change over time.

Over time, communities can change slowly by succession until they reach a stable *climax community* that is distinctive to a particular area. Examples of these late successional communities include the coastal redwood forests of Northern California or the Northern hardwood forests of the Eastern United States.

Most of the time, however, communities cycle between different phases of the succession process as they respond to disturbances (Chapter 9). Disturbances come in many forms, from biological sources such as grazing animals to destructive environmental hazards such as severe storms or forest fires. After a disturbance, *pioneer species* that have adaptations to survive in harsh environments move in. As they grow, they may change the environment in ways that facilitate the growth of other species. As these species grow, they may facilitate or inhibit others, and the community structure continues to change over time.

Getting what you need to survive

Living things all have a fundamental need for energy and matter. Energy allows organisms to move and grow, and matter is the building material that forms cells and bodies. Every ecosystem relies upon producers that capture energy from the environment and use it to build food, handy little packages of carbohydrates, proteins, or fats that contain both matter and energy.

For example, plants use *photosynthesis* (see Chapter 10) to capture energy from the sun, using it to build carbohydrates out of carbon dioxide and water. The atoms in carbon dioxide (CO_2) and water (H_2O) are the physical matter necessary to build carbohydrates like the simple sugar glucose ($C_6H_{12}O_6$). Once producers like plants make food, then other organisms in the ecosystem can eat them to get the food (so rude!), using it as their source of both matter and energy.

As living things transfer energy from food to do work in their cells, some of the energy transforms into heat that moves into the atmosphere. Heat isn't useful to producers as a source of energy for food, so ecosystems require a steady input of new energy, like the light plants receive from the sun.

REMEMBER

Energy constantly flows through ecosystems, moving from its initial capture by producers to other organisms, and then back out to the environment as heat (see Chapter 10).

Organisms break down food molecules to access the stored energy. When they use *cellular respiration* (see Chapter 10) to extract energy, atoms in the food get released back to the environment in the form of carbon dioxide and water. These molecules can get picked up again by plants and reused for photosynthesis, forming a loop which is part of the *carbon cycle* (Chapter 11). The carbon cycle describes how carbon atoms move through ecosystems, passed along from one organism to the next, and sometimes spend time in the environment.

The carbon cycle is just one example of the many ways that organisms interact to share and recycle matter. All the elements that organisms need to build their cells and function come from the environment, picked up by an organism that has the right skills, then passed around as organisms eat, breathe, and die.

REMEMBER

Scientists trace the movement of different types of atoms through their changing forms, drawing pathways called *biogeochemical cycles* (see Chapter 11), which show how matter cycles through ecosystems.

The Big Picture

The ecosystems on Earth have been changing for at least 3.5 billion years since the first cells evolved. Photosynthetic organisms created a dramatic change when they added oxygen to our atmosphere about 2.4 billion years ago. Around the same time, the first major ice age occurred, spreading ice sheets across the Earth all the way to the equator.

Since then, the ice has ebbed and flowed through seven more ice ages. In between the periods of glacial expansion, the Earth warmed, biomes shifted, and groups of species expanded and shrank. The age of reptiles brought the dinosaurs to prominence between 245 and 66 million years ago, after which the age of mammals began. Many scientists say that we're now living in a new age called the Anthropocene, which marks the dominance of humans.

Living in changing times

Although the Earth has a long record of change, it may never have changed as fast as it is today. For example, global temperatures are rising faster than they have in 10,000 years.

REMEMBER

Ninety-seven percent of scientists agree that the rapid changes in our climate happening today result from human actions.

During the Industrial Revolution, humans began to greatly increase the amount of fossil fuels they burned. The burning of fossil fuels releases greenhouse gases like carbon dioxide into our atmosphere.

REMEMBER

Greenhouse gases (Chapter 12) have a chemical structure that makes them excellent at absorbing heat.

The increase in greenhouse gases traps more heat in our atmosphere, which is causing the Earth's temperature to rise. The rising temperatures are having large-scale impacts on our climate because they're altering the flow of wind and water currents. Severe storms and wildfires are more common, resulting in increased disturbance to ecosystems. Great carbon dioxide concentrations in the ocean result in acidification, which kills the corals that are foundation species in coral reefs. Ice sheets are melting, raising water levels and affecting coastal areas.

Increased disturbance and global temperatures add to the pressures that put species at risk for extinction. Loss of species decreases diversity in ecosystems, reducing their resilience.

REMEMBER

Biodiversity (Chapter 13) is the variability in living organisms in an ecosystem.

In addition to climate change, five major factors are accelerating extinction rates. Ecologists use the acronym HIPPO to summarize these factors, which are discussed in Chapter 13:

- **H**abitat loss,
- **I**nvasive species,
- **P**ollution,
- **P**opulation growth (human),
- **O**verharvesting.

From an ecological perspective, all living things are connected to each other and to our environment. When we have diversity, we have strength and balance. When one organism makes waste, another organism might be able to use it, changing it into something else. We have enough food and clean water. As we lose diversity, we begin to lose these things.

Saving what matters

As we live through this time of rapid change, we can use the lessons from ecology to try to make things better for other species and our own.

REMEMBER

Conservation ecology (Chapter 14) is the branch of ecology that seeks to preserve and maintain biodiversity and natural ecosystems.

Conservation ecologists seek to understand human impacts on ecosystems and develop ways to counteract those impacts. For example, habitat fragmentation is pushing species toward extinction. Fragmentation happens when patches of habitat are disturbed, converting a large habitat into a bunch of smaller patches. Fragmentation can have many negative impacts on wildlife, including:

- **Increased edge effects:** The edge of a habitat is different than the interior. It may receive more light and have less moisture, leading to the growth of different plant species. It may also be riskier because of exposure to predators.
- **Inability to access potential mates:** Species that can't seek mates in a wider area may start to inbreed, which can reduce genetic diversity and contribute to the risk of extinction.
- **Loss of habitat area:** Some species can only live in one particular habitat. As patches of this habitat are lost, the number of individuals in this species is reduced.

One strategy to combat these negative outcomes is to create wildlife corridors between habitat fragments. These corridors allow individuals to move safely among the fragments, increasing foraging and breeding areas.

Another solution to human disturbance is to allow ecosystems to recover by succession. Unfortunately, the rate of recovery of ecosystems after a disturbance is often slower than the rate of disturbance due to human activity. By studying natural succession, however, ecologists can identify ways to support and facilitate recovery.

REMEMBER

Restoration ecology (Chapter 14) uses ecological principles to restore degraded ecosystems to conditions as similar as possible to their natural state.

Some examples of ways that restoration ecologists facilitate recovery include removing the source of the disturbance, planting native species, and enhancing habitats for desired species.

In addition to restoring degraded ecosystems, restoration ecologists can help plan for the changing times ahead. Species are already moving in response to climate change as former habitats become unsuitable. To save some species, we may need to create habitats for species that are displaced.