# Chapter 2
## Understanding the Natural World

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Introduction

John Muir’s quote prepares us for a never-ending quest of understanding the natural world: he hints at the depths of its complexity. To begin to appreciate the intricacies of nature requires delving into various scientific disciplines as well as philosophy and related subjects. With each new gain in knowledge, our satisfaction and appreciation grows and spurs us onward for more insight. An understanding of basic ecological concepts is a starting point of this journey.

Muir’s words affirm that we are part of nature. Indeed, we are connected to everything else. Our actions can send ripples as well as shock waves throughout the web of life. What we do affects how and where the rest of life must live and whether some species will exist at all! And certainly, what happens to the rest of nature affects us.

Finally, this quote heightens our anticipation for seeing the beauty of the natural world. Muir’s words not only allow us to sense the surface aesthetic of nature, but also to discover a deeper beauty in the patterns and processes that intricately link together this web of life. When we begin to see how nature works, we are awestruck by the literal beauty of its complexity—a beauty that is more than skin deep.

As you study this chapter, remember Muir’s words and the complexity and beauty of the universe. Reflect and consider how we should respond to the rest of nature. How can our understanding of ecology—the relationships of living organisms with each other and their physical environment—help us become better stewards?

Chapter Objectives: This chapter should expand your understanding of the following ecological concepts.

- Components of Nature—abiotic and biotic components
- Nature’s Cycles—hydrologic, energy, and nutrient cycles
- Levels of Relationships—trophic, individual, species, population, community, ecosystem, and biosphere relationships
- Biodiversity—natural selection and evolution
- Patterns and Processes of Nature—dynamic stability, succession, photosynthesis, Land Community

“When we try to pick out anything by itself, we find it hitched to everything else in the universe.”  

John Muir (1911)

To learn more about John Muir, read "John Muir’s University of the Wilderness," The Illinois Steward, Winter 1994.
Components of Nature

A good way to learn and think about how nature works is to use the Land Pyramid Model. This model explains how non-living entities—the air, water, soil, rocks, etc.—relate to living organisms and how living organisms relate to one another. This is what the science of ecology is all about—studying and explaining these many relationships. This model can help you understand how energy and nutrients drive living systems, from the smallest ecosystem to the sum total of all life in our biosphere.

At first glance nature may seem chaotic, but it is bound by structure, processes, complex relationships, and hierarchies. Part of the fun of being a naturalist is discovering how the pieces of an ecosystem fit together. You will find that as you spend time studying nature, you will slowly become familiar with an order and rhythm of the natural world. To begin your journey of exploration, let’s see how ecosystems are structured.

We will start with a simple, basic model of the Land Pyramid and add to it as we develop our understanding of the natural world. We will add complexity to the model as we increase our levels of understanding of how nature works. To begin, let’s represent a pyramid of life that is supported by the abiotic (non-living) entities upon which all life depends.

Abiotic and Biotic Parts

Every ecosystem, whether natural or man-made, is composed of abiotic and biotic parts. The abiotic components are the non-living entities of nature, i.e. the land (rock, sediment, soil), water, and atmosphere. There are two types of abiotic components: 1) physical (e.g., sunlight, precipitation, climate, temperature) and 2) chemical (e.g., mineral). Both the physical and chemical components influence the biotic community of life. The biotic components of nature are the living organisms in an environment—eubacteria, archaeabacteria, fungi, protists, plants, and animals. While biotic communities do not have much control over the physical factors that govern their fate, they do influence the chemical factors by cycling nutrients between the biotic community and the abiotic environment.

To learn more about The Land Pyramid, read “The Land Pyramid,” by Aldo Leopold, A Sand County Almanac.
For example, a common milkweed seed that lands in a roadside ditch must make do with the local soil conditions. The quality of the soil, along with the amount of sunlight and precipitation the plant receives, will determine how well the milkweed grows in that particular location. If the plant survives, it will draw up nutrients from the soil and will pass them through the food chain as it is fed upon by hungry monarch larvae, milkweed bugs, milkweed beetles, and other insects. However, herbivory of milkweed is tempered by the plant’s ability to produce cardiac glycosides, chemicals that are toxic to vertebrate animals if consumed in sufficient quantities. Thus, the nutrients available in the milkweed plant are not available to all in the biotic community.

In a classic example of how complex the relationships between members of the biotic community can be, the same glycosides that would make a rabbit or deer sick if they ate the milkweed, actually help protect monarch larvae and butterflies. Monarch butterflies only lay their eggs on milkweed plants—the only plant that monarch larvae feed upon. After the larva emerges from the egg, it consumes the cardiac glycosides as it eats the milkweed. The chemicals do not harm the larva, but they do make it distasteful to predators. The glycosides continue to protect the monarch from predators even after it has turned into a butterfly. The relationship between the milkweed and the monarch serves to illustrate that it is too simplistic to assume that only the abiotic components drive community structure. The living organisms of a place also direct the conditions under which they live.

Range of Tolerance

Every living organism on Earth has resource requirements that it must meet in order to survive. While organisms are able to survive within a range of abiotic conditions, they cannot survive outside the minimum and maximum of that range. For example, salamanders require humid environments in which to live. Salamanders respire through their skin and will desiccate and die if trapped in a dry environment. Some species of salamanders have a greater range of tolerance than others. Aquatic species, such as the mudpuppy, spend their entire lives in aquatic habitats. Others, such as the tiger salamander, are terrestrial species and can tolerate living in moist leaf litter, under logs and rocks, or in underground burrows.

Organisms are dependent on multiple abiotic components for their survival; however, often an abiotic component is critical to survival and it is referred to as a limiting factor. Some of the basic limiting factors are soil moisture, precipitation, light, nutrients, and space. In Volo Bog, in Lake County, the limiting factors are moisture and nutrients. While there is plenty of water available in the bog, the acidity of the water makes it difficult for plant roots to take up water or nutrients. Thus, not just any plant can grow in the bog. Only specialized plants—such as the pitcher plant, leatherleaf, and tamarack which have developed unique strategies for overcoming the limiting factors in the bog—can survive. For example, pitcher plants have developed a very interesting way of increasing the amount of nitrogen available to them. These carnivorous plants have liquid-filled cavities in which they capture and digest insects, arthropods, and the occasional small frog. These prey provide nitrogen.

To learn more about Volo Bog, read “No Place Like Volo Bog,” The Illinois Steward, Spring 1996.
Nature’s Cycles

People tend to move and think in a linear fashion. Nature, on the other hand, moves in interconnected circles—the cycle of life, the cycle of seasons, the cycle of water, the cycle of nutrients. Perhaps this constant process of renewal is one of the reasons that we are drawn to nature. Additionally, we may be attracted to nature because it models the importance of recycling. Nature has to recycle. While mass and energy are interchangeable at some level, their sum total is constant. Unlike our current throw-away culture, nature judiciously reuses materials. There is no such thing as “waste” in nature. Every atom is a useable resource and has its place, time, and function in various phases of natural cycles.

Let the Sun Shine In
Being hitched to everything else in the universe really starts with being hitched to the sun. Life as we know it could not exist without the sun. It is the sun that produces solar energy that heats the Earth, drives atmospheric circulation, weather patterns, and the hydrologic cycle, and provides energy for living organisms.

Energy is defined as the capacity to do work. While energy can neither be created nor destroyed, it does change form. Light energy from the sun can be converted into chemical energy, kinetic energy, or heat.

As chemical energy is used by plant and animal tissue, it is eventually converted to heat. The energy is not wasted, but is used to maintain body-temperature in warm-blooded animals. In this way, energy can be said to flow through a system.

Organisms that are capable of harvesting energy from inorganic sources and converting it to organic molecules are called autotrophs or self-feeders. Plants are the most well-known type of autotrophs and are capable of converting light energy (sunlight) into chemical energy (sugar) through the process of photosynthesis.

Unlike autotrophs, heterotrophs or other feeders cannot make their own food. Consumers obtain energy by feeding on other living organisms while decomposers feed on dead organisms or organic compounds in the environment. In this way, energy is cycled through the biotic community.

Where in the World is Water?—Understanding the Hydrologic Cycle

Water is a key component of life. But where is water found? Lake Michigan, the Mississippi River, the vast network of other rivers, streams, drainage ditches, lakes and backyard ponds that span the length and breadth of Illinois, all are obvious sources of surface water. But where else is water

to be found? Anyone who lives in Illinois knows about precipitation: the sudden, summer rain showers and the joy of shoveling 6 inches of snow out of the driveway in the winter. Less obvious reservoirs of water include groundwater, the water stored inside plant and animal cells, and water vapor. All are important sources of water in the hydrologic cycle.

The hydrologic cycle is nature’s way of circulating water between the oceans, Earth, and atmosphere. Of the water available to circulate through the hydrologic cycle, approximately 97% of the Earth’s water is stored in the oceans. The rest is stored in polar ice caps and glaciers, or takes the form of water vapor, surface water, water stored in living organisms or the soil, or groundwater.

The sun drives the hydrologic cycle by causing water to evaporate from the surface of the oceans and other bodies of water. Evaporation happens directly, as sunlight heats the upper surface of water bodies, and indirectly, by winds that are generated by solar heating of the atmosphere. Water vapor is also released by plant transpiration and through evaporation from soil. As the moist air rises, it cools, and the water vapor condenses to form clouds. Eventually the water is released as precipitation—rain, snow, or hail. Once the water reaches the Earth’s surface, the water may be stored as snow or ice, penetrate the soil and be taken up by plants, percolate into the soil and become groundwater, recharge aquifers, or it may run off into bodies of surface water.

The Earth’s total water supply remains constant as it cycles. However, water is not distributed equally everywhere. Some areas naturally receive more precipitation than others. Additionally, people can alter the hydrologic cycle. By over-drawing on aquifers, increasing the amount of hardscape, and reducing vegetative cover on the land, we can negatively alter the cycle. For example, while we do not experience the severe water shortages common in western states, it is not uncommon in Illinois communities for water restrictions to be placed on watering lawns or washing cars during dry summer months.

Sometimes, it is not a matter of too little water, but of too much. Water that lands on roofs, driveways, sidewalks, parking lots, and roadways is directed in short order to our rivers and streams courtesy of storm drains. This distributes unnaturally high amounts of water—along with debris and chemicals—into the riverine systems which can cause severe flooding. Installing rain barrels and rain gardens, restoring natural vegetation in floodplains, and conserving water are all ways that we can help the hydrologic cycle function more effectively.

To learn more about Illinois’ climate, read “Climate Change and Variability,” The Illinois Steward, Fall 1999.
“In the flash of a century the rock decayed, and X was pulled out and up into the world of living things. He helped build a flower, which became an acorn, which fattened a deer, which fed an Indian, all in a single year.”

Aldo Leopold

The Essentials, Nutrients that is—Introduction to the Biogeochemical Cycles

Chemical elements are essential to the survival of all living organisms. Some, such as carbon, oxygen, and nitrogen, are known as macronutrients and serve as the fundamental building blocks of organic tissues. Other elements, such as iron and zinc, are needed in smaller quantities and are called micronutrients. All species have an optimal quantity and range of tolerance for the different elements. However, ecosystems often do not provide the optimum level of resources. That is why farmers apply nitrogen to their cornfields, and why ponds sometimes experience algal blooms when runoff containing phosphorus and nitrogen enters the waterway. These are both instances of humans adding nutrients to the environment. But how does nature move nutrients through ecosystems?

In layman’s terms, the biogeochemical cycles are simply the processes that nature uses to move elements back and forth between living beings and the environment. The process of nutrient cycling is most commonly taught using the carbon, nitrogen, sulfur, and phosphorus cycles. Instead of providing exhaustive details about any one of those cycles here, this section will serve as an introduction to the basic concepts that apply to each of the cycles.

All biologically important elements are stored (in varying quantities) in four sources: the atmosphere, water, rocks and soil, and living organisms, i.e. in all components of the Land Community. Each cycle has an organic and an inorganic phase, but as with any circle, there is no starting point. This is because, unlike energy, elements are constantly recycled. A basic pathway into the biological community is through plants. Plants take in elements from the air, soil, and water and convert them into carbohydrates, fats, and proteins. Plants are then consumed by animals. When organisms breath, defecate, or die and decompose they release the elements back into back into the soil, water, and air. Thus, food webs help illustrate the movement of nutrients through the biological community.

The conversion of elements into biologically usable forms can be rather complex. For those who would like to learn more, an ecology textbook can provide detailed explanations and diagrams illustrating how the different cycles work. Or for those with the inclination towards prose, one of the best literary expressions of how nutrient cycling takes place was captured by Aldo Leopold in his essay titled “Odyssey”.

Relating to Nature

Exploring and learning about nature as a Master Naturalist may raise more questions than provide answers at times. Although we sometimes refer to things in nature as pure and simple, in reality they can be very complex and even competitive. Daily survival for some organisms depends on a relationship with another organism, or perhaps the specific conditions created by the environment in which they live. One way to learn about these relationships is to take a closer look at a woodland in the eastern deciduous forest.

Natural Organization

Let’s begin our woodland exploration by looking at nature from a global perspective. From this global view, we notice distinct regions of plant and animal communities around the world. Looking at one of these regions, you’ll notice that the plants and animals in the community are different, but all have some basic similarities which have been influenced by the climate of the region. These regions are called biomes. Both, terrestrial or land based and aquatic or water based biomes can be found throughout the world. Within North America, the naturalist could explore the tundra, boreal forest, temperate deciduous forest, temperate grasslands and desert biomes. In the eastern United States, we can explore the temperate deciduous forest, so let’s take a closer look at relationships here that can also be found in other biomes.

Upon entering your local forest, a few immediate observations might be made, the most obvious being that the plant cover is dominated by trees. As you look around though, other plants are also present including shrubs, vines, wildflowers, and grasses. Also present in the forest are animals including birds, mammals, reptiles, and amphibians. Through observation you can see that a forest is a community of various populations of plants and animals, but trees predominate. Across the forest community, we might notice that the populations of species change.

In communities that have a closed community structure, species density and geographic range is separated by sharp, discrete boundaries, for example where a beach separates water and land. However, on your forest exploration you might not notice these dramatic divisions; such is the case with an open community structure. We may still notice a change in the populations within the community, but it is more subtle. That’s because in this type of open community structure, the soil moisture gradient or moisture availability affects the habitat and therefore the type of plants growing in the forest. On a low hill top, we might see trees species such as white oak, black oak, and shagbark hickory. As we travel down the hill towards a creek, we might encounter northern red oak and bitternut hickory. Down in the creek bottom, we see still another change in the population of tree species, discovering silver maple, cottonwood, and sycamore. The populations of plants growing on the forest floor also change across this soil moisture gradient.

Relationships in Nature

The populations within communities interact with each other in beneficial and sometimes negative ways. A relationship in which there are benefits for both of the interacting organisms is called mutualism. In the forest, there is a hidden example of mutualism beneath the forest floor. Mycorrhizae fungi are associated with the roots of trees, and both organisms benefit. The fungi benefit from getting energy from the tree roots. The fungi increase the surface area of the trees’ roots which provide the benefit of increased absorption of minerals in the soil for the tree. In a similar relationship referred to as commensalism, only one population of organisms receives benefits, while the other organism receives none, but is not harmed either. In an aquatic community the relationship between fish and sea anemones is one of commensalism.

Oftentimes, two populations interact in a community while attempting to obtain the same resources, such as sunlight or nutrients, and competition occurs. In competition, ultimately one population will be harmed, while the other benefits, often in the form of survival. In a forest, examples of competition for sunlight can be found by looking at the tree population in the canopy or overstory. An example of competition can be seen in mature oak–hickory forests where sugar maples growing in the understory become the dominant trees in the community. This occurs over time because the sugar maple is tolerant of shade, but the oak is not. Thus the maple wins the competition in the understory. Then as the oak trees die and create openings for additional sunlight and space, the forest community becomes dominated by maples.

Activity 3: Assessing Forest Health

The health of forest ecosystems has gained popular attention in recent years because of concerns about air pollution, acid rain, global climate change, and long-term resource management. The purpose of this activity is to help you become familiar with methods that can be used to determine forest ecosystem health. In this activity, you will use a mathematical model and observational skills to critique the health of a local forest.

Levels of Living
A closer look at the energy flow begins with the source of the energy, the sun. Green plants convert the sun’s energy into chemical energy in the form of sugar through photosynthesis. In this first energy or trophic level, green plants are referred to as producers, because they are producing their own food.

In the forest, we might see squirrels, white-footed mice, cottontail rabbits, and deer consuming plant materials. These herbivores are in the second energy level and are referred to as primary consumers. These consumers are dependent upon the producers for their energy.

On a hike through the forest, you may have witnessed a rabbit or mouse being caught and eaten by a coyote or snake. The coyote and snake are examples of animals in the next trophic level and are called secondary consumers. They are also carnivores, the meat eaters in the ecosystem.

In addition, there are organisms that can be observed eating both plant and animal matter. Examples of these omnivores that you might observe in a forest ecosystem include raccoons and skunks. These animals would also be considered to be secondary consumers.

The flow of energy continues through the ecosystem with the help of decomposers. Organisms, such as fungi and bacteria, use the organic material that is found in a dead animal or plant as their energy source. This use of organic matter for energy involves a breakdown process which releases the nutrients into the soil for further cycling, part of which will go to producers for growth.

Although energy flows through the ecosystem, not all of the energy from one trophic level is available to the next trophic level. This is because some of the energy in each trophic level is used for respiration by organisms within that level. In addition, some of the plant or animal matter in each level is not consumed, and some is not completely used or digested. Therefore, if we graphically present the amount of available energy at each trophic level, a Land Pyramid would be seen with the producers represented at the base and secondary consumers at the top.

Energy flows through ecosystems via food chains and food webs. A simple food chain in a forest might be a white oak tree using the sun’s energy to produce an acorn, which is eaten by a mouse, which is then eaten by a coyote. The coyote dies of old age and bacteria release the nutrients back into the soil. In reality, these food chains are interwoven into a food web, because of the variety of herbivores, carnivores, and omnivores in the environment. Looking closer, we see that the mouse actually consumes parts of many different plants (producers), and perhaps mushrooms and fungi (decomposers). The mouse might be eaten by a weasel, which is consumed by a snake. The snake dies and is eaten by a skunk, which in turn is eaten by a great-horned owl. The owl dies and provides a source of food for bacteria, fly larvae, and fungi. The interconnections in this food web are endless.

Place in Nature
As a naturalist, you might ponder about your place in the world or the environment. Someone may ask you, “What good is a mosquito, tick, or poison ivy?” As we have discussed in this section, everything in nature has a place or role. There are interconnections that we don’t even know or understand. If we look at trophic levels for a simplified understanding of place, it is easy to see that if we eliminate or reduce the availability of energy at one level, subsequent levels will be reduced.

As you explore various ecosystems, take a closer look at relationships in nature. Some will be obvious, but many will require you to dig deeper into the natural world.
What sets the Earth apart from the other planets in our solar system, perhaps from all other planets in our galaxy? The answer is simple—life—an amazing and bewildering variety of life that we call biodiversity. From the ocean depths to the highest mountain peaks, the Earth is enveloped in a mantle of living organisms that has developed across evolutionary history. Organisms vary in size from bacteria to blue whales and have colonized virtually every available habitat on Earth. Even the extreme conditions surrounding the poles have their contingent of life. Natural selection, the driving force behind this species diversity, revolves around differential survival and adaptation by organisms. This process leads to differential reproduction, and, ultimately, change. Simply put, given the vast expanses of time and seemingly infinite genetic diversity, the Earth’s biodiversity is an inevitable, yet remarkable result.

From a strictly human perspective, this biological diversity is the most important, yet least understood, of all natural resources. The diverse species provide most of the life-support materials upon which we ultimately rely. Each species is unique, “a magic well of eons-old genetic information”—information that we humans cannot afford to be without. Every species that is lost reduces the options for nature—and for us—to respond to a continually changing environment. While the evolution of new species and the extinction of other species is a natural process, the current rate of extinction is progressing at an unnaturally high rate. Scientists have found that the normal species extinction rate on a geological or evolutionary time scale is one species every 1,000 years. By 1950, however, the rate had increased to one species every 10 years. Today, the rate is estimated to be at least one species per day! In this context, perhaps the least useful statement that a human can make regarding an organism is “What good is it?” Ignorance of the potential use of a species to humans is a poor excuse for the finality of extinction. Add to this the issue of global climate change and we paint a somewhat grim picture of the future of the Earth’s organisms.

Despite its importance, biodiversity remains an enigma for most citizens. During April 1994, a nationwide phone survey of over 1,200 randomly selected adults revealed that 73% were totally unfamiliar with the concept of “loss of biodiversity.”

How Much Diversity?

In the last 30 to 40 years, the sciences of taxonomy and systematics (the naming of organisms and the study of their natural relationships) have expanded rapidly, and a huge body of information about the diversity of organisms found on the Earth is accumulating. Currently, about 1.6 million species of plants and animals have been described by scientists and given a name. Approximately 900,000 are insects, 41,000 are vertebrates (mammals, birds, etc.), and 250,000 are plants. The remaining species include various kinds of invertebrates,

To learn more about biodiversity, read “The Importance of Biodiversity,” The Illinois Steward, Summer 1995.
Activity 5: Illinois’ Amazing Diversity

Illinois is a relatively large state, with a wealth of terrestrial and freshwater habitats that support many species. However, the populations of some species can be quite small. Given the limited portion of Illinois that contains suitable habitats, each of these biological “islands" becomes very important in preserving biodiversity. In this activity, you will compare Illinois' biodiversity with the variety of organisms that inhabit the Earth.

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Mississippi River: Lake Michigan forms the border in the northeastern part of the state: and the southern and southeastern borders are the Ohio and Wabash rivers. There is not much altitudinal range in Illinois, the highest point being Charles Mound in the northwestern part of the state at 376 meters (1,235 feet), while the lowest point is 85 meters (279 feet) at the southern boundary of the state at the confluence of the Mississippi and Ohio rivers.

Because of this unique geographic location, Illinois has within its borders an unusually large variety of plants, animals, and habitats. Illinois has nearly 100 habitat types, and conservative estimates put the number of species at over 54,000. This is an especially large number of species for a geographic area the size of Illinois in a temperate climate. Situated at the intersection of the eastern deciduous forest, the western Great Plains, the southern coastal plain, the Ozark uplift, and the boreal (northern) forests, Illinois provides a meeting ground for organisms from very different geographic regions. These wondrous, rich, self-sustaining natural ecosystems that contain everything from lady's slipper orchids to badgers are our natural heritage. Surprisingly, most of the organisms that occurred in Illinois before settlement by Europeans are still present.

Illinois Habitat Diversity—Then and Now

In general, the greater the number of habitats that exist, the greater the potential for species diversity. Habitat types originally found in Illinois included forests, prairies, savannas, marshes, fens, lakes and ponds, fungi, algae, and microorganisms. Despite all this information, we are still woefully ignorant of the organisms with whom we share the Earth. Only a small percentage of species (less than 15%) have been named, estimates of the actual number of species on Earth range from 5 to 30 million! In addition, our knowledge of the life histories of most species and their ecological interactions is limited to a relatively low number of organisms, confined mostly to those that are directly beneficial or harmful to us.

Local Biodiversity

What about the biodiversity of Illinois? Most citizens would say that Illinois is a nice place to live but that it is far from a biological wonderland. A trip across the state yields a vast panorama of corn and soybean fields, interspersed with the occasional urban or industrial complex. In 1961, Illinois Natural History Survey scientist Philip Smith described the state as "... a great corn desert..." To view Illinois from an interstate highway, though, does the state a great disservice.

The state of Illinois is situated rather centrally in the North American continent. Illinois is a long state from north to south, a distance of about 612 km (380 miles). The northern border is about 42° 30' N, nearly the same latitude as Boston, Massachusetts, while the southern border is about 37° 00' N, almost the same as Norfolk, Virginia. The state lies between about 87° 30' W and 91° 30' W longitude, a distance of about 346 km (215 miles). Much of the boundary of Illinois is determined by bodies of water. It is essentially a peninsula. The entire western border of Illinois is formed by the
Ironically, in early Illinois, human developments existed as tiny islands in a “sea of grass”. Today, the plants and animals that made up the Illinois prairie now exist only as equally tiny sanctuaries in a vast “sea of development.”

Activity 6: Measuring Biodiversity

Biodiversity is determined not only by the number of species within a habitat, but also by the relative abundance of individuals. A habitat that supports several individuals of many species is more diverse than a habitat that supports many individuals of one species but very few other species. In this activity, you will apply a diversity-index model to generate a numerical rating of plant biodiversity.

streams, and caves. Although each of these habitats continues to exist, most are exceedingly small and often rare because of the extensive urban and agricultural developments that have occurred in Illinois during the past 150 years. The Harvard entomologist E.O. Wilson has noted, “… humanity spread across the worlds… godstruck, firm in the belief that virgin land went on forever…”. Inevitably, as land use changed, the number of species and the population sizes of most declined. The decline in biodiversity is not usually the direct result of human exploitation (although numerous examples of this exist), but because of the habitat destruction associated with development and expansion of human activities.

Even though Illinois has nearly 100 habitat types, these fit nicely into three broad categories: prairies, forests, and wetlands. In 1820, approximately 13.8 million acres of Illinois were forested. Today, nearly 4.3 million acres of trees can be found in Illinois. Most of the forest acreage of today is second- or third-growth timber or pine plantations, only 13,500 acres of relatively undisturbed forests remain. Why is this important? Illinois forests provide habitat for over half of Illinois’ native plants. In addition, 47% of Illinois’ threatened and endangered species are forest inhabitants, and 75% of wildlife habitat in the state is found in forests.

Early Illinois settlers were concerned with survival and making a new life on the prairies and forests. They navigated and explored, logged, farmed, and constructed. Resources appeared inexhaustible. Many of the first Europeans to see the Illinois country had crossed a vast ocean, snaked their way through a nearly impenetrable mountain range, and forged a path through a thousand miles of dense, primeval forest. They did it with indomitable spirit and by sheer force of will. Yet when they reached the edge of the eastern deciduous forest, today approximated by the Indiana–Illinois border, they stopped in wonder and marveled at the splendor and incredible magnitude. Here was a landscape so different and so unique—a grassland that stretched for a thousand miles—their language had no word for it. In time this landscape came to be known as “prairie,” a word derived from the French word for meadow. At first, early settlers avoided living on the prairie. But soon they realized the prairie made excellent cropland, especially after John Deere invented the moldboard plow that allowed virgin prairie soil to be more easily plowed. The wild prairies became cropland at an astonishing rate—approximately 3.3% per year. Over 300,000 people settled on the prairie in the period from 1830 to 1840, and by 1860, much of the prairies had disappeared. Ironically, in early Illinois, human developments existed as tiny islands in a “sea of grass”. Today, the plants and animals that made up the Illinois prairie now exist only as equally tiny sanctuaries in a vast “sea of development”.

A poll of current Illinois residents would find that most do not consider their state to be particularly wet. The early settlers, however, would have had a very different impression. Illinois originally had an estimated 8 million acres of wetlands. Since Illinois became a state in 1818, more than 95% of these have been drained. The tile factory was one of the first businesses to open its doors in areas of new settlement. A concomitant loss in the natural biodiversity that wetlands contain was inevitable. Today, high quality wetlands that reflect presettlement conditions are rare. Only about 6,000 acres remain.

In 1890, Dr. A.W. Herre commented on the demise of Illinois’ landscape. “What a pity that some of it could not have been preserved, so that those born later might enjoy its beauty also.” Fortunately, his lament was heard as remnants of nearly all the habitats that originally occurred in our state can be found in nature preserves, state parks, conservation areas, and other protected sites that are refugia for much of the state’s biological diversity. What does this mean to us as humans, and more importantly, as naturalists?

To learn more about wetlands, read “Wetlands Yesterday and Today,” The Illinois Steward, Spring 1997.
Nature Never Stops

Processes of nature are always on the move: nature is inherently dynamic. Oftentimes, we hear of the "balance of nature"—a phrase that can be misleading, especially if we take the phrase as meaning a static, status quo. Think more of the processes of nature as continually working toward establishing and maintaining a biodiversity that fosters an enduring, dynamic stability. Individual plant species may ebb and flow. Some may even be relegated to the seedbank for a time. But the land will be populated with plants, and the fauna living there will reflect the composition of that present plant community. And, all the while, this enhanced biodiversity ensures that life will go on, and that ecosystems will provide vital services for human and nonhuman species alike, that is, if these basic processes are not disrupted, overly simplified, or so altered to the extent they are no longer functional.

Sometimes, nature’s processes move at such a slow pace that change is almost imperceptible—such as weathering of stone. Limestone may weather faster than granite. Still, these processes are seemingly slow. Nonetheless, nature depends on these weathering processes to form soil. At other times, nature’s goings-on move incredibly fast as do weather phenomena; the windstorm that knocks down a forest canopy, lets in light, and sets changes in motion—both fast and slow—that alter the forest ecosystem. Nature never stops.

The mosaic of fall colors—the pigmented carotenoids, anthocyanins, and tannins splashed across a wooded hillside—is the outward result of metabolic processes such as photosynthesis, senescence, and resorption that occur within and between plant cells.

Understanding and appreciating the patterns and processes of nature is critically important for a budding naturalist. Being given insight into the natural rhythms helps interpret what is going on around you. Becoming attuned to the relaxed natural aesthetic of nature helps you bond to the rest of the living world and become part of it.

The natural patterns we observe are often the highly visible, outward manifestations of the sometimes invisible processes of nature. For example, the mosaic of fall colors—the pigmented carotenoids, anthocyanins, and tannins splashed across a wooded hillside—is the outward result of metabolic processes such as photosynthesis, senescence, and resorption that occur within and between plant cells.

In this brief introduction, we will give an example of processes that occur at a macro-scale and play out across a landscape as well as those that happen on an infinitely smaller scale at the cellular level.

To learn more about fall color processes, read “Fall Leaf Color—Essential for Life,” The Illinois Steward, Fall 2006.
Succession in a Nutshell

Nature abhors nothingness. Bare ground doesn’t stay bare for long, whether it’s a freshly plowed field or silt deposited by a springtime flood. Nature covers and protects bare soil by plant succession—a continuous, usually predictable progression of both the plant species and plant communities that occurs over time. Succession is usually initiated by some major disturbance—a natural occurrence such as a storm or fire, or human induced happenings such as farming or logging.

Consider a simplified example of succession occurring on a recently tilled ag field almost anywhere throughout Illinois. What will grow, and when will it begin, if nature is left to its own devices? Specifically, which plant species grow will depend on local seed sources and conditions of the site such as drainage and soil type. However, a discernable pattern usually emerges over time.

Herbaceous annuals such as ragweed, cocklebur, velvet leaf, and foxtail will be the first to germinate and grow. In just a few years, herbaceous perennials—milkweed, goldenrod, bluegrass, and the like—will become well established and begin outcompeting the annuals. After the wave of herbaceous perennials have become dominant, woody perennials—shrubs such as elderberry and sumac; and trees such as choke cherry, red haw, and eastern red cedar—will seed in, become thicker and taller, progressively shade the ground, and finally outcompete the herbaceous perennials.

Then comes the competition between the woody perennials that takes decades to finally sort things out. Depending on the local seed sources and site particulars, eventually a tree canopy develops with the most favored tree species winning out.

If our site was on well drained upland, any number of hardwoods could be favored—oaks, walnut, sugar maple, hackberry, or hickories—depending on seed sources and on the abiotic factors of the site. If the site was farmed bottomland instead, the eventual canopy could be composed of any number of species including cottonwood, silver maple, sycamore, and hackberry—even green ash.

Understanding the basics of plant succession helps you read the landscape, take a look back in time, and make logical deductions about what has happened on the Land—whether the Land was farmed, logged, or some other disturbance occurred. Appreciating succession also allows you to predict what the future might hold—with or without major disturbances such as fire, storm, cultivation, and the like. You can make inferences about both the future fauna and flora of a site because faunal composition usually reflects the plant community.

See for Yourself

Generally, this is the way plant succession proceeds—herbaceous annuals, followed by herbaceous perennials, and finally by woody shrubs and trees. And this is the way it is usually explained in textbooks and by professionals. But, it doesn’t always happen this way! Go out and make your own observations. See for yourself! There may be a surprise or two. Nature doesn’t always follow human-established dogma.

For example, if our tilled ground adjoined an oak–hickory woodlot, and that first year we had a good crop of white-oak acorns, squirrels would be busily burying acorns with reckless abandon in a pattern of planting only they could mimic. That first fall, many of these white-oak acorns...
would germinate, sending up a miniature attempt at a tree and sinking down roots. The upward thrust will be thwarted by the first hard freeze, but the roots will remain on the ready for next spring.

Already that second year, white-oak seedlings would become established. Granted, they would not be exerting a noticeable effect in that succession scenario until some years later. But, they would be bona fide members of that developing plant community long before you would suspect if you just got your information from a textbook.

The lesson is a simple one. Go outside and see for yourself. By careful observation you may discover something the experts have overlooked. And it may be very important. Let nature come alive before your very own eyes. That is the joy of becoming a naturalist!

Going Green—a Process of a Different Color

The process of photosynthesis is very basic to life. All animals, including humans, need a fairly constant supply of carbon in the form of carbohydrates, fats, and proteins that we eat. Green plants take this carbon from the atmosphere—one carbon atom at a time—as carbon dioxide (CO₂). By combining CO₂ with water from the soil, green plants make simple sugars and eventually more complex compounds—carbohydrates, oils, and proteins. The sun’s energy is the initial driver of the food web because it powers this photosynthetic process.

The green-colored chlorophyll in plant cells help capture and use the radiant energy from sunlight. Some of the sun’s energy is harnessed in the carbon–carbon bonds of these complex, carbon–containing compounds. When we eat plant–source foods and digest and metabolize these carbohydrates, oils, and proteins to build and repair tissues, this harnessed energy is released and is used to power our bodies and maintain body temperature.

Thus, green plants are actually natural solar collectors and the first food source for us and other animals. And, of course, photosynthesis is just another example of many of the cellular processes that are essential for life.

Understanding and appreciating these very basic cellular processes of nature helps us grasp what is going on around us. Gaining insight into these processes helps us realize how all of nature is truly tied together. Indeed, “Everything is hooked to everything else in the Universe.”

Activity 8: Mapping Energy Flow

Through the process of photosynthesis, green plants—called producers—harness energy from the sun into chemical energy in simple sugars. Plants are then eaten by primary consumers—herbivores such as deer or rabbits. They in turn are eaten by other animals—secondary consumers. Eventually all organisms die, and decomposers make the nutrients available to a new generation. In this activity, you will learn about food webs and what happens to the flow of energy when the community of producers, consumers, and decomposers becomes less diverse.

To learn more about photosynthesis, ruminants, and grasslands, read “Growing the New Grasslands,” The Illinois Steward, Summer 2000.
Self-Renewal—A Measure of Health

If the basic processes and cycles are not disrupted, nature works to renew itself, not necessarily in its present form, but toward a state that is more advantageous in the ever-changing conditions of its surroundings. This ability of the Land Community to renew itself is a measure of health.

A healthy Land Community maintains the integrity of its patterns, cycles, and processes, possesses an inner dynamic stability, and exhibits beauty beyond measure. Perhaps Aldo Leopold said it best when he coined his famous Land Ethic: “A thing is right when it tends to preserve the integrity, stability, and beauty of the biotic community. It is wrong when it tends otherwise.” Understanding and appreciating the patterns and processes of nature will help you make decisions and take actions that are needed to promote this health.

Biodiversity of species and genetic diversity within a species is critical in promoting the health of the Land Community. Consider the model of the Land Pyramid once more. Compare a very biodiverse model with one that has a paucity of life forms as well as compromised abiotic support, for example eroded soils and polluted waters.

Biodiverse ecosystems afford many more options for energy and nutrients to flow through the system. The diverse system—both in terms of number of species and genetic diversity within a species—is more resilient to stressors. In a diverse system, a single species may be lost, but another species may be available to continue the flow of energy and nutrients. Also, it becomes apparent why compromised abiotic support can have dire consequences. Indeed, soil erosion becomes a nutritional problem for our own species with more far-reaching implications than we might first think.

Additionally, biodiverse systems hold more potential to engender a biophilic response from us. According to E.O. Wilson, biophilia is an innate affinity that we have for all other life that helps us feel, as Leopold said, that we are a “plain member and citizen” of the Land Community. We perceive biodiverse systems as possessing more beauty—there is more to love. And we save what we love. Thus, we can see the intuitive logic in Leopold’s Land Ethic that places importance in preserving natural beauty. In these ways and others, biodiversity contains inherent safeguards for survival. Unfortunately, the safeguards of biodiversity are often overridden by our short-term political and economic thinking.

A naturalist is able to relate to and establish relationships with nature as part of his or her daily experiences. Such relationships bestow full-fledged membership in the Land Community. The ability to communicate and work with nature on a very down-to-earth, practical level brings much meaning and fulfillment to our lives as we promote the health of the Land.

Activity 9: Food Webs and Land Health

The health of people is dependent upon the health of the land and other organisms that share the planet with us. A land community that supports a wide diversity of organisms is better able to cope with stressors, and nutrients and energy flow easily through the system. In this activity, you will learn how a food web portrays relationships in an ecosystem.

Suggested Readings


Selected articles from *The Illinois Steward*:

- “Fall Leaf Colors—Essential for Life.” Vol. 15, No. 3, Fall 2006.
- “Models that Migrate.” Vol. 8, No. 3, Fall 1999.

Glossary

**abiotic**: The non-living, physical and chemical components of the environment.

**anthocyanins**: Antioxidant flavonoid compounds that are responsible for the red, purple, and blue pigments of many plants.

**autotrophs**: “self-feeders”. Organisms that can convert energy from inorganic sources into organic molecules. For example, plants converting sunlight into sugars.

**balance of nature**: An ecological concept that suggests that organisms within an ecosystem are adapted to each other and interact in ways that produce an inherent equilibrium that produces a stable system of life.

**biodiversity**: The variety of a biotic community within a given place. Biodiversity includes not only species diversity but also genetic diversity of the biotic community.

**biogeochemical cycles**: All biologically important elements are cycled between living organisms and the land, water, and air. The carbon cycle and nitrogen cycle are two examples.

**biome**: A group of communities that are characterized by the climatic and soil conditions of the area.

**biophilia**: E. O. Wilson describes biophilia as the innate affinity for other living organisms that leads human beings to subconsciously seek connections with the rest of life.

**biotic**: The living components of the environment.

**carnivore**: An organism whose diet consists of meat, dead or alive.

**carotenoids**: Antioxidant compounds in plants that absorb light energy for use in photosynthesis and protect chlorophyll from photodamage. Carotenoids are responsible for the yellow, orange, and red pigments of many plants and some animals.

**chlorophyll**: A green pigment found in most plants, algae, and cyanobacteria that absorbs sunlight and uses the energy to synthesize carbohydrates from CO2 and water (H2O) in a process known as photosynthesis.

“climax” community**: Community composition changes over time in reaction to environmental factors in a process known as succession. The community of organisms that ends the sequence of succession (i.e. dynamic stability has been reached) is known as the climax community.

**closed community structure**: A community of organisms which reside in an area bounded by distinct divisions which restrict the geographic distribution of the organisms.

**community**: A group of different species which interact in a shared environment.

**commensalism**: A relationship between two organisms where one organism receives benefits from the relationship and the other does not benefit but is also not harmed.

**competition**: Organisms naturally compete for the same resources, for example food, water and shelter.

**consumers**: Heterotrophs that obtain their energy by consuming living organisms.

**decomposers**: Heterotrophs that obtain their energy by consuming dead organisms or organic compounds found in the environment.

**disturbance**: A process that alters the normal functioning of a place. Examples include natural disturbances such as fire, flooding, or drought, and human-caused disturbances such as cultivation or logging.

**dynamic stability**: While all ecosystems are constantly changing, a more biodiverse ecosystem is more stable than a less biodiverse ecosystem and is better equipped to recover more quickly after a disturbance.

**ecology**: The study of the distribution and abundance of organisms and their interactions with their environment.

**ecosystem**: A self-sustaining, natural system composed of abiotic and biotic parts.

**evaporation**: The process by which water changes from a liquid to a gas.

**evolution**: The process by which species adapt to their environment over time. Organisms pass along genetic material to their offspring and mutations in genetic combinations may produce characteristics that provide the offspring with reproductive and survival advantages in their local environment. Over time, these beneficial traits will dominate in the population.

**extinction**: The loss of all members of a species and their genetic diversity.

**food chain**: A representation of the feeding relationships between organisms in an ecosystem. Food chains illustrate the transfer of biomass from one level to another.

**food web**: A representation of the complex interactions among populations that serve to transfer energy through a community.

**groundwater**: Precipitation that seeps down through the soil until it reaches water-saturated rock or soil.

**habitat**: The physical environment that provides organisms with their basic needs for survival. Food, water, shelter, and space. A habitat is oftentimes described as an organism’s “address”, while a niche is described as an organism’s “job”.

**herbaceous annuals**: Plants with no persistent woody parts that complete their lifecycle in one year.

**herbaceous perennials**: Plants with no persistent woody parts that live for more than one year.

To learn more information that relates to this chapter, read selections from our “Suggested Readings” section.
are able to fix atmospheric nitrogen (N2) into biologically useable ammonia (NH₃) through a symbiotic relationship with bacteria that live in nodules on the legume roots. Legumes include clover, soybeans, honeylocust, and leadplant.

**limiting factor**: A resource that controls the growth of an organism or the abundance or distribution of a population within an ecosystem. Examples of limiting factors include, but are not limited to, the availability of water, nutrients, and space.

**mutualism**: A relationship between individuals of two species in which both organisms receive benefits, particularly in survival.

**natural selection**: A mechanism of evolution by which organisms with traits that make them best adapted to their environment reproduce and leave more young than others in the population. Over time, this trait becomes common to the population.

**omnivores**: Animals whose diet consists of both meat and plant material.

**open community structure**: A community of organisms which reside in an area that does not have geographic divisions that might restrict the movement of organisms into or out of the community.

**photosynthesis**: The conversion of light energy into chemical energy in the form of carbohydrates by living organisms.

**population**: A collection of interbreeding organisms of a particular species within a geographic area.

**producer**: An organism which can make its own food, for example plants.

**range of tolerance**: The range of environmental conditions in which organisms can live and reproduce.

**respiration**: A metabolic process in cells which uses oxygen and carbohydrates to produce water, carbon dioxide, and energy.

**resorption**: A process of nutrient conservation in which plants decrease the nutrients in leaves before they are dropped.

**rumen**: The first and largest stomach compartment of a ruminant animal.

**rumen microbes**: Microscopic life, such as yeast and bacteria, living in the rumen of ruminant animals that can digest and metabolize rumen contents. These microbes can break down crude fiber (roughage) and use poor quality proteins that simple stomached animals (monogastrics) cannot take advantage of.

**ruminant**: An animal that has a stomach system with either three or four specialized chambers. Ruminants with three chambers include camels and llamas. Those with four include cattle, sheep, bison, deer, and many more.

**runoff**: Water that moves across the land rather than infiltrating the ground, evaporating into the air, or being stored in a body of water.

**seedbank**: The community of viable seeds present in the soil.

**senescence**: The growth phase of plants from maturity to death.

**soil moisture gradient**: The percent of water within the soil varies depending on environmental conditions such as depth of the soil, slope steepness, exposure to the sun.

**species**: A group of organisms with similar characteristics and capable of interbreeding and producing offspring.

**succession**: A process of continuous competition among plant species in an area which leads to a predictable change in plant community composition over time.

**tannins**: Astringent compounds in plants that help protect plants from herbivory.

**transpiration**: The process by which water is carried through plants from the roots to the small pores on the underside of leaves, where it changes to vapor and is released into the atmosphere. The process is basically the evaporation of water from plant leaves.

**trophic level**: The position that an organism occupies within a food chain. Examples are: producers, consumers, and decomposers.

**woody perennials**: Plants with persistent woody parts that live for more than one year.