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Ecology

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Chapter 2

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Learning Objectives

At the end of this unit, you will be able to articulate and explain:

- How local climate and geology influence where different plant and animal communities occur;
- How land-use changes and gardening practices can affect the health of watersheds;
- How plants and animals interact with each other and with their environment;
- How and why plant and animal communities change over time; and
- How energy and nutrients flow through the landscape and are influenced by human activities.

Introduction

Whether you garden to grow prize-winning tomatoes, to beautify your landscape, or to attract butterflies, learning the principles of ecology can help you create a healthy, sustainable landscape. Ecology is the study of how organisms interact with each other and their environment. As gardeners we think about the colors and textures plants give to a garden and whether they contribute food or fragrance. We choose where to plant a particular plant thinking about its needs for sun, water, and soil types. We learn to protect plants from pests and diseases and to watch for pollinators and seed dispersers. The principles of ecology can tie together all of these practices by taking into account the climate and soils of the region, the adaptations plants have to grow well under particular conditions, the helpful and destructive animals or fungi attracted by certain plants, and the cycles of water, energy, and nutrients in our landscape.

If you think of your garden and landscape as an ecological system, you begin to see the connections between plants, soils, animals, fungi, water, and sunlight.

Maryland's Place on Earth

To place the state of Maryland in a biological and geological context, we will first look briefly at how global processes affect the state, which other continents share a similar biome, and the climate and geology of the region.

The Biosphere

Some processes that affect life here in Maryland happen at a global scale, like changes in climate and sea level. In the biosphere—the portions of the Earth that support life—major natural and human-caused changes can have global impacts. For example:

- Rises in sea-surface temperatures in the eastern Pacific and low barometric pressure lead to a global weather system called El Niño. Maryland tends to experience wetter than normal winters in El Niño years. Periods with low sea-surface temperatures and high barometric pressure create La Niña, tending to lead to drier winters in Maryland.
- The use of chemicals including chlorofluorocarbons (CFCs) used in refrigeration and air conditioning were found to be depleting the ozone layer in the 1970s. A global accord to reduce emissions of ozone-depleting chemicals was reached, but levels in the atmosphere still remain high enough that an "ozone hole" (actually a thinning of the ozone layer) happens over the Antarctic and southern South America every year.
- Globally, average temperatures have been rising faster than normal due to human activities such as the burning of fossil fuels and deforestation that release greenhouse gases (carbon dioxide, nitrous oxide, methane, and fluorinated gases). Greenhouse gases trap heat in the Earth's atmosphere. Increasing temperatures are reflected in the Arbor Day Foundation's revised hardiness zone map. (See references at end of this chapter and the USDA hardiness zone map (in the Appendix.)
- Sea level continues to rise as global temperatures increase resulting in more frequent coastal flooding, loss of coastal wetlands, and increased rates of erosion. According

to the Maryland Department of Natural Resources (MD DNR), in Maryland sea level has risen by 1 foot in the last 100 years. This is slightly higher than the global average because the land in our region is slowly sinking due to natural geologic processes. Scientists estimate that sea level will rise another 2-3 feet in the next 100 years in Maryland.

- Besides increasing temperatures, climate change may also result in more severe storms, more intense heat waves, and an increase in precipitation in this region, but it is difficult for climate models to predict exactly what will occur at the regional level.

Biome

The biosphere can be divided into biomes, large areas with relatively uniform vegetation. The type of vegetation in a biome is mainly determined by mean annual temperature and precipitation. The major terrestrial biomes of the world include tundra, desert, grassland, tropical forest, temperate forest, and boreal forests. Maryland is located in the temperate forest biome. Most temperate forests grow where there are distinct seasons and where there is a moderate amount of precipitation. Temperate forests are not as diverse as tropical forests, but they harbor some of the tallest living organisms, including giant sequoias in North America. Other major temperate forests grow in western Europe, southern South America, and eastern Asia.

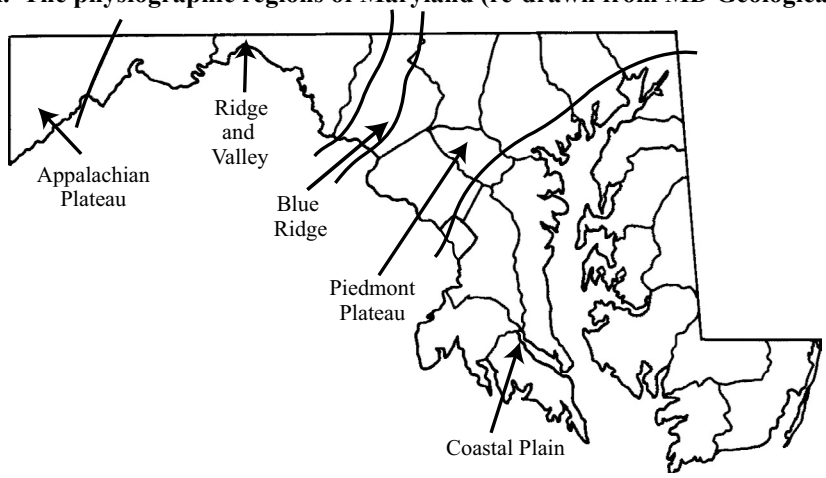
Not surprisingly, many popular ornamental non-native woody perennials come from these other temperate forest biomes (e.g., forsythia from eastern Asia and English ivy from western Europe). Houseplants are more likely to come from tropical forest biomes (e.g., philodendron and peace lily) or desert biomes (e.g., crown of thorns and cactus).

Region

Not all of Maryland is forested and vegetation types differ considerably within the state. At the regional scale, vegetation changes because of climactic differences, geology, and topography. In the mountains of western Maryland, higher elevations have colder winters, more snowfall, and slightly cooler summer temperatures. The ancient sandstones and shales of the Appalachian Mountains make up the base of the soils, and forests of hemlock, white pine, and northern hardwoods grow well. On the coastal plain the topography is much flatter, temperatures are slightly warmer, and the soils are formed from deep deposits of sand and gravel or silt from rivers. Mixed loblolly pine and oak forests are common on the coastal plain. Chapter 4 (Soils and Fertilizers) contains more information on Maryland's soil types.

Using geological features of Maryland's landscape, the state can be divided into six physiographic regions (Fig. 2-A). Garrett County and western Alleghany County are part of the Appalachian Plateau. The eastern part of Allegany County and all of Washington County are part of the Ridge and Valley province where rivers have carved deep valleys through the rock layers. The area of Frederick County between Catoctin Mountain and South Mountain lies within the Blue Ridge province, characterized by ridges of quartzite rock. The fall line between the Piedmont and Coastal Plain runs through the eastern borders of Montgomery and Howard Counties following roughly along Interstate 95. You can see the change in elevation at the fall line at Great Falls National Park on the Potomac River.

Fig. 2-A. The physiographic regions of Maryland (re-drawn from MD Geological Survey)



Geography influences differences in climate within Maryland. Maryland is located between 75° to 79° West longitude and 38° to 40° North latitude. At this latitude and longitude the prevailing winds are from the west. We have well-defined seasons with most plants going dormant in winter, from about November to April depending on location. Maryland covers an area of 12,303 square miles and is 80% land and 20% water. The land gradually rises as you move west from the Coastal Plain to the Piedmont (Fig. 2-B). This change in elevation corresponds with changes in average yearly air temperatures and rainfall (Figs. 2-C, 2-D). Near large urban areas such as Baltimore, there are higher average temperatures as heat radiates from paved surfaces and less vegetation is present to cool the air. Mountains disrupt air flow causing rain shadows, which are areas on the eastern side of the mountains which receive less rainfall.

These regional geographic, geologic, and climatic differences determine the types of soils in your landscape and the native plant communities. Hardiness zone maps reflect minimum winter temperatures and roughly follow Maryland's changing elevation. Understanding your soils and the climate of your region will help you to select the right plants for your landscape.

Fig. 2-B. Elevation change across Maryland from west to east along I-68 to I-70, then to Route 50 (Friendsville to Ocean City)

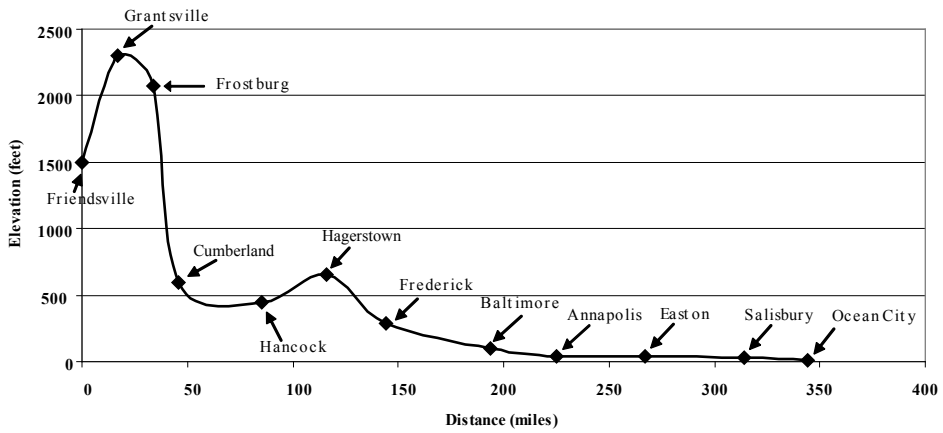


Fig. 2-C. Average yearly air temperature across Maryland (data from Anon1 2006)

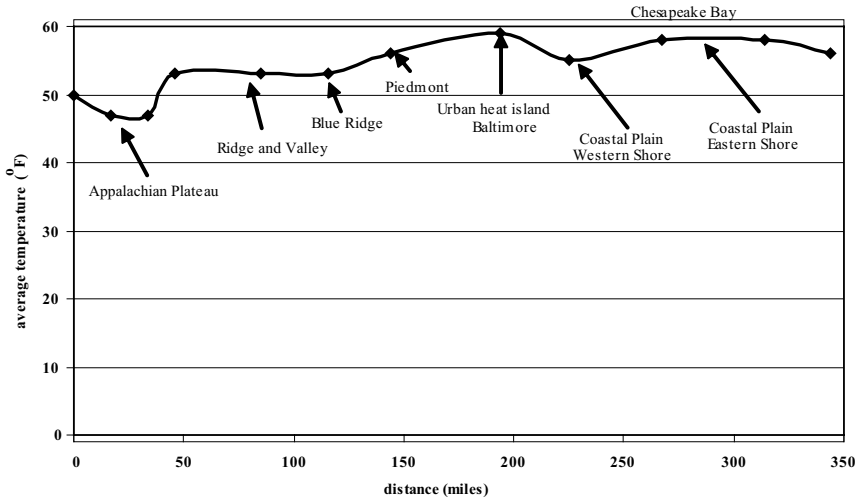
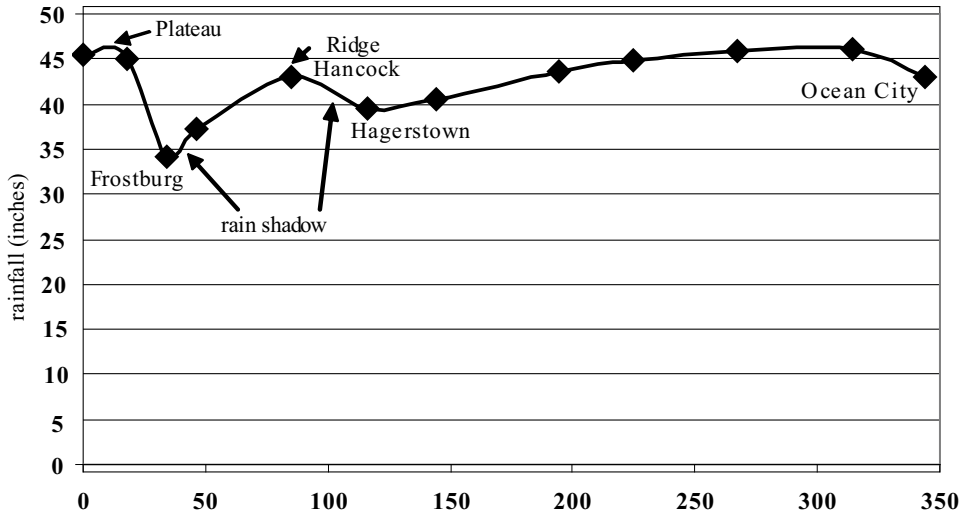


Fig. 2-D. Average rainfall across Maryland (data MD Geological Survey)



Landscape

To an ecologist, a landscape is an area containing various plant and animal communities or different uses of the land. For example, a residential development with lawns and trees might be surrounded by a ribbon of wooded stream, an office complex, and highways.

Watersheds

One way of using natural boundaries to subdivide the landscape is to think about watersheds. Geologist John Wesley Powell described a watershed as "that area of land, a bounded hydrologic system, within which all living things are inextricably linked by their common water course and where, as humans settled, simple logic demanded that they become part of a community." Within a watershed all the water on or under the land drains to one common place. In Maryland, most water drains into the Chesapeake Bay and Atlantic Ocean. In far western Maryland, water from the Youghiogheny watershed drains into the Ohio River and from there to the Mississippi River and Gulf of Mexico. Increasingly, government agencies, such as EPA and MD DNR, collect data based on watershed boundaries. Many communities also have watershed organizations. (See references at end of this chapter for web addresses of these organizations.) Landscaping practices are often connected to water use and cleanliness. Examples of landscaping practices that conserve water include:

- Choosing drought-tolerant plants;
- Mulching;
- Drip irrigation; and
- Rainwater collection.

Stormwater runoff collects sediments, excess fertilizers, herbicides, pesticides, and other pollutants and carries them into streams and wetlands. Keep water cleaner by:

- Reducing the use of chemicals;
- Preventing erosion;
- Cleaning up other pollutants; and
- Slowing the flow of stormwater.

You will learn more about these practices in Chapter 25 (Water Quality and Conservation). At the larger scale, Maryland encourages the restoration of stream channels, wetlands (Chapter 27), and forest buffers along streams.

Forests to Farms

Most of Maryland's watersheds have gone from being forested to a mix of land uses, including residential, industrial, and agricultural. It is important to learn a little about the history of

Maryland's landscape to understand how ecological processes have changed over time and how land use affects the ecology of an area.

In the early 1700s, 90% of Maryland was forested with a mix of hardwood and pine forests. The Native American Indians cleared small plots of land for agriculture and burned some forests to keep the understory clear of vegetation. In the 1700s, extensive deforestation began as settlers cleared fields and iron furnaces consumed wood for smelting iron ore. The invention of the steam engine and the circular saw in the 1800s expanded forest cutting into the mountains and valleys. By the mid 1800s, Maryland had lost half its forests.

As a result of this massive deforestation, many areas had terrible erosion problems and streams were choked with sediments. Some stream valleys and floodplains are still covered by several feet of sediment. The composition of the forests changed too. Many of our current forests have regrown since that time, and the trees are relatively uniformly aged.

Introduced diseases such as chestnut blight and Dutch elm disease killed off millions of trees in the 1900s. Gypsy moth infestations killed thousands of oak trees. Decreases in fire frequency have favored fire-intolerant species such as red maple and American beech over fire-tolerant species such as loblolly pine and oak.

Agricultural land use began to decline after the Civil War and into the 20th century. Forest conservation initiatives included massive replanting of cutover forests and abandoned farm land. Some land was converted to pine plantations to provide an alternative income source. The soils of abandoned agricultural lands were often depleted of topsoil and compacted by farm machinery, making forest regrowth a slow process.

By the 1950s, forest cover had reached about 46% of Maryland through natural regeneration and tree planting. Since the 1960s however, forest cover has declined to about 41% as second-growth forests are cut to make way for housing developments, roads, and office parks (Widmann 1999). The remaining forests continue to mature and fewer new stands of trees grow. As you will learn in the section on succession, having mixed ages of vegetation can add to the overall biodiversity and stability of an ecosystem. Programs such as Program Open Space, the Forest Conservation Act, Rural Legacy program, and Treemendous Maryland work toward preserving and restoring Maryland's forests.

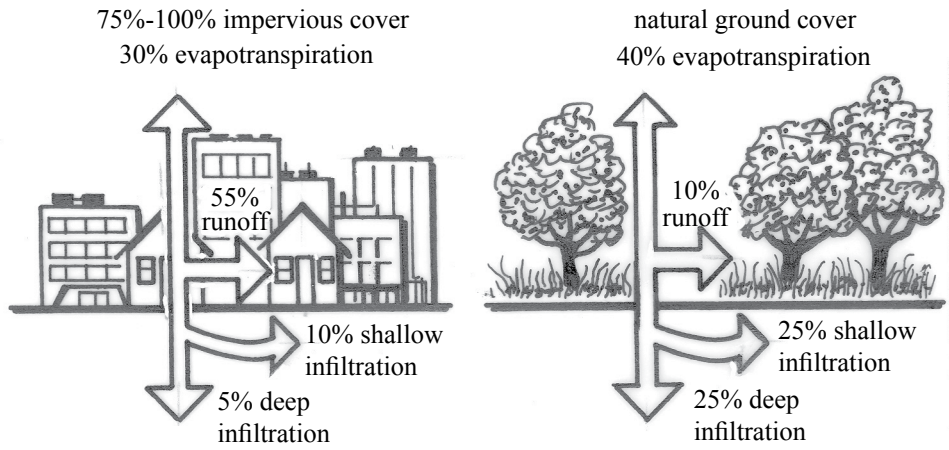
Urbanization

More than 80% of Marylanders live in urban areas, according the U.S. Census Bureau, which defines an urban area as one with more than 1000 people per square mile. Urbanization has a tremendous impact on ecological processes, and it is important to understand how your landscape might be affected:

- Increase in area of impervious surfaces—Since impervious surfaces like roads, roofs, and sidewalks do not let water drain through, runoff increases dramatically. In a forest, only about 10% of the water that falls during a rain storm runs off into streams and wetlands. In a watershed with 10-20% impervious cover, runoff increases to 20%, enough to increase flooding and erosion in stream channels (Fig. 2-E). If you live in an urban or suburban area, think about the amount of impervious cover just around your home, such as your driveway, sidewalk, patio, and the roof of your house.
- Stream channelization—Channelization removes natural curves that slow the flow of water. Urban stream banks are often armored with stone or cement to reduce erosion caused by the faster flowing water. The stormwater runoff, besides being greater in volume, also picks up pollutants that may harm aquatic life. The water in urban streams is often warmer because of the lack of tree cover, and the warmer water causes a change in the species that can live in the stream.
- Soil alteration—Soils are often significantly altered in urban environments through compaction, pollution, and topsoil removal. It may be difficult to get plants to grow without amending or even replacing soils. Compacted soils lack air and water spaces and channels for roots to grow through. Often street trees are planted in special artificial soils that hold moisture and air since their roots cannot spread as much as they could in a forest or even a yard.
- Changes to plant and animal communities—Habitat becomes divided into smaller and smaller pieces as roads and buildings are constructed. Animals that migrate or

have large territories are killed crossing highways or find barriers to movement. Plant populations become fragmented and may have difficulty dispersing their seeds or being pollinated. Some plants and animals adapted to urban environments begin to thrive, displacing more sensitive species.

Fig. 2-E. Stormwater infiltration and runoff in landscapes with pervious versus impervious surfaces

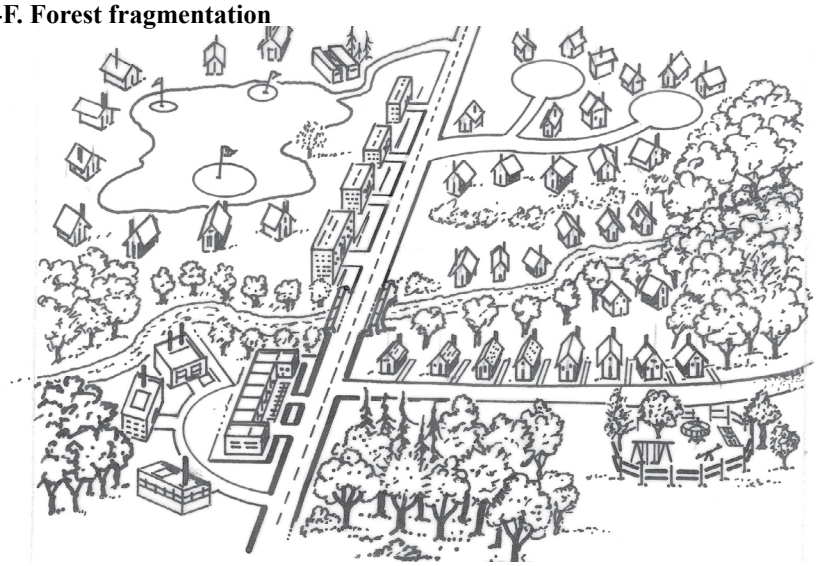


Source: U.S. Environmental Protection Agency, Washington, D.C. "Protecting Water Quality from Urban Runoff." Document No. EPA 841-F-03-003.

Making Connections in the Landscape

Think of the urban landscape as a quilt. It consists of patches of forest, backyards, parking areas, abandoned lots, and buildings sewn together by roads, streams, and railway lines (Fig. 2-F). Large patches will support more species than small patches, and species must have a way to move from one patch to another. If you transform your backyard into a habitat suitable for native plants and wildlife, it provides a tiny refuge. If you convince your neighbors to do the same, you create a larger habitat that might attract migratory birds and a greater diversity of butterflies. In a community, focusing on preserving high quality forests and wetlands and connecting them through corridors of green space to other parks and preserves will do more to enhance the environment than preserving scattered small spaces. Tree cover is particularly important in our temperate forest biome because so many plants and animals rely on trees for food and shelter. Forested buffers along streams can act as corridors. Corridors that cross roads should have safe passageways under or above the road for animals.

Fig. 2-F. Forest fragmentation



Roads and development often isolate patches of natural habitat. Corridors between isolated patches can be formed from rivers or by linking undeveloped areas and parks.

Plant and Animal Communities

This section explores what organisms, such as plants and animals, physically need to survive in a particular place.

What Organisms Need to Survive

Habitat is the physical space that provides the environment and resources needed by a population to survive and reproduce. The habitat for a holly tree would have enough space, nutrients, light, and water to support the growth of the tree. Insects would be essential for pollination because hollies have separate male and female trees. The climate would have to be cold enough in winter to freeze the fruits and make them palatable to birds. Birds ensure that the fruits, with their seeds, are dispersed. So the holly shares its habitat with pollinators, birds, and other plants. The assemblage of all the species in a given area is considered a *community*.

A garden provides habitat for the plant community you choose as well as for species that choose to make it their home. Let's say you have a community of beans, lettuce, and cucumbers. Each requires some amount of light, water, and nutrients. You may supply water through irrigation and nutrients in the form of fertilizer or compost. *Rhizobia* bacteria associate with the bean roots enabling them to use nitrogen from the air. Some of the excess nitrogen leaches out of the roots benefitting the lettuce and cucumbers. Mexican bean beetles and cucumber beetles arrive to eat the bean and cucumber plants. Aphids appear and in turn attract ladybugs. A mockingbird drops in to snap up a bean beetle. The lettuce benefits from the shade of the beans and cucumbers. When the lettuce flowers, it attracts pollinators. Your garden has become habitat for a community of plants, insects, bacteria, birds, and more.

Even though all these organisms share a habitat, they do not have exactly the same environmental and resource requirements. A species' *niche* describes all of the environmental conditions and resources required for it to maintain a viable population. It does not refer to a physical space, but rather to the whole set of conditions under which the species can survive and reproduce.

The idea of a niche was first described by ecologist Robert MacArthur in 1955. MacArthur wanted to know how five different species of warblers could all live together in the spruce forests of the northeastern U.S. All of the warblers are about the same size and all feed on insects. Why didn't they compete with each other for food? MacArthur's observations led him to find that the different warbler species fed in different parts of the spruce tree. For example, the Cape May warbler fed near the tops of the trees, looking for insects in new buds and needles. The bay breasted warbler fed mainly on interior branches. Later studies showed that since the birds nested at slightly different times of the year, their peak requirements for insects differed and that some of the birds had different feeding strategies, such as chasing flying insects rather than picking them out from among the foliage.

Learning the niche requirements for plants you want to grow will require a little research on their life cycle, resource needs, and other organisms they associate with. The idea of companion planting and intercropping comes from learning what plants' niches complement each other.

Microclimates

In choosing the perfect spot for a plant, it is important to assess the microclimates in your landscape. Microclimates occur when some feature of the landscape creates a difference in temperature, moisture, or sun exposure. On a large scale microclimates are affected by:

- Topography—Since cold air flows downhill, valleys can be cooler than ridge tops. But hilltops are exposed to high winds that can dry out plants and cause wind damage;
- Large bodies of water—Water moderates temperatures making winter and summer temperatures less extreme; and
- Urban areas—A heat-island effect occurs in urban areas as buildings and pavements absorb heat and radiate it back into the air at night. Temperatures in winter and summer are hotter in urban areas compared to nearby rural areas.

On a backyard scale, the house, driveway, fences, decks, water features, raised beds, rocks, and soil type affect microclimates. For example, the north side of a house gets less sunlight

and has slightly cooler temperatures because of the shade cast by the building. Surface temperatures next to a grassy lawn will be slightly lower than surface temperatures next to an asphalt driveway. A rock or fence can provide shelter from wind. Small scale microclimates are most affected by:

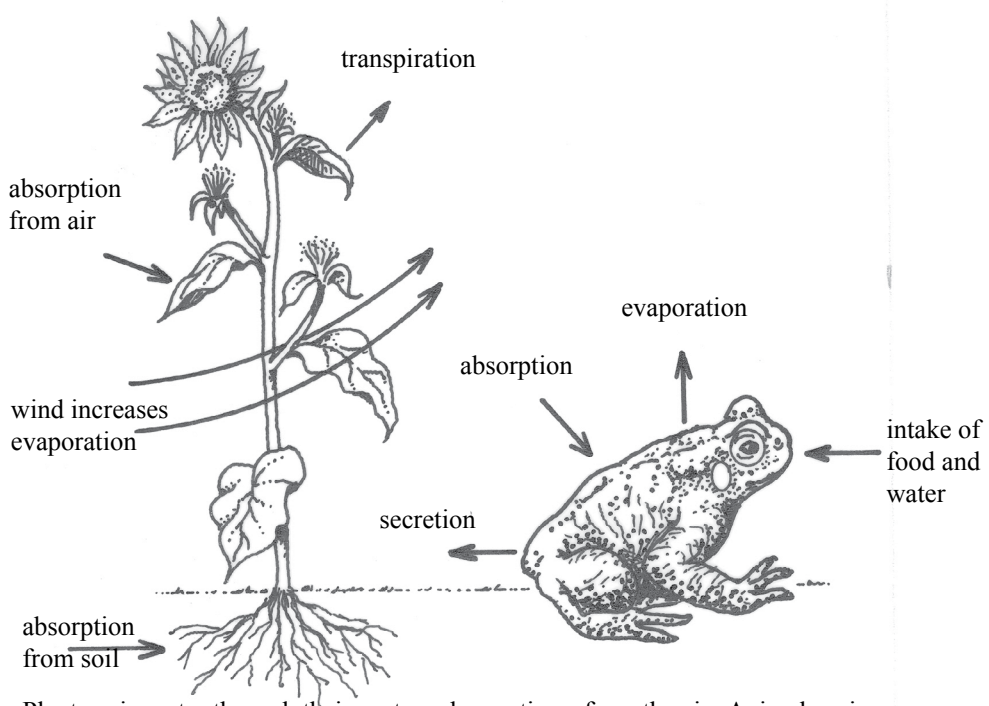
- Aspect—direction a slope or wall faces;
- Temperature—presence of vegetation, surface color, and surface evenness; and
- Water—relative humidity or soil moisture.

Water

All organisms need water to survive, but they require different amounts and have different ways of obtaining and conserving it. Plants obtain most of their water from the soil through their roots. A few plants, like bromeliads, can absorb some of their water from moist air. Plants in dry environments often have adaptations for conserving water, including storing water in their roots, stems, or leaves or reducing evaporation by having small leaves or leaves with hairy or waxy leaf coatings.

Animals obtain most of their water by eating and drinking. Most animals conserve water by finding shelter, but some have special adaptations. The hard shells of beetles help reduce evaporation, and some have an extra waxy coating to reduce water loss. Desert-dwelling kangaroo rats concentrate their urine to retain more water.

Fig. 2-G. Water gain and loss in plants and animals



Plants gain water through their roots and sometimes from the air. Animals gain water through what they eat and drink. Plants lose water through evaporation and transpiration, whereas animals lose water principally through evaporation and excretion.

Energy and Nutrients

All organisms must obtain energy and carbon from some source. Most plants obtain their energy from sunlight and obtain carbon molecules from the air through the process of photosynthesis. During photosynthesis energy from the sun is used to convert carbon dioxide to carbohydrates. Plants obtain nutrients from the soil through their roots. A few plant families like the pea family (Fabaceae) have bacteria associated with their roots to help the plant obtain nitrogen. About 90% of plant species associate with fungi called mycorrhizae, which help obtain nutrients for the plant in exchange for the plant providing carbon in the form of sugars to the fungi. You will learn more about the metabolic processes of plants in Chapter 3 (Botany).

Animals obtain carbon and energy from organic molecules. The organic molecules and nutrients come from whatever food the animal eats. Much of animal behavior centers on the

search for food because it costs energy to find and consume food. For example, squirrels will immediately eat sweet, white oak acorns when they find them but will only partially eat or will bury the tannin-laden red oak acorns. They dig up some of the acorns they cached when food is scarce in winter.

Physiology

An organism's physiology determines its needs for energy, water, and nutrients. Adaptations to obtaining and conserving water, energy, and nutrients described above will determine what habitat requirements an organism needs. Matching "the right plant to the right place" means understanding a plant's physiological requirements and matching those to the right habitat. Providing wildlife habitat for specific animals also requires understanding that animal's physiological needs.

Species Interactions

Organisms never live independently. They all serve different purposes within a community. This section explores the roles species play within the community and how they interact with each other.

Functional Groups

Sometimes it is useful to think of different organisms by the functions they perform in the environment. One way to group species is to think about how they obtain their energy and nutrients:

- Producers—produce their own energy, e.g., grass;
- Herbivores—eat plants, e.g., rabbit;
- Carnivores—eat other animals, e.g., fox; and
- Decomposers—feed on dead organic material, e.g., earthworm.

You could also group organisms by the type of interactions they have. Interactions that benefit both organisms such as pollination and seed dispersal are called mutualisms:

- Pollinator—moves pollen from one flower to another, e.g., bumblebee;
- Seed disperser—moves seeds away from the parent plant, e.g., blue jay;
- Parasite—one organism benefits by causing harm to another, usually by feeding on it, e.g., ticks and dodder; and
- Competitor—competes with another species for limited resources, e.g., gardeners vs. slugs.

Think about the groups of species present in your garden. You may have herbivores like cucumber beetles, aphids, and voles. Predators might include spiders, ladybugs, and birds. Decomposers dwelling in the compost include earthworms, fungi, and bacteria. Bumblebees pollinate the tomatoes and peppers. You act as a seed disperser, eating fruits and saving seeds for next year's crops, as well as a competitor to other fruit and seed eaters.

Native Pollinators

Gardening success depends on pollination. In our region, most plants are either wind- or insect-pollinated. Wind-pollinated flowers are often relatively inconspicuous and produce large amounts of pollen. Examples of wind-pollinated plants include pines, oaks, grasses, and ragweed. There is an incredible diversity of insect pollinators. Native insect pollinators include species of solitary bees, bumblebees, butterflies, beetles, wasps, butterflies, and flies. Honeybees were introduced from Europe in the early 1600s. The ruby-throated hummingbird acts as one of the few vertebrate pollinators in Maryland. Some pollinators are generalists, pollinating many species of plants, whereas others specialize and pollinate only one or a few plant species.

The economic value of crops pollinated by native pollinators in the United States is estimated at $3 billion per year. Fruits and seeds from insect-pollinated plants provide the major diet for 25% of birds and for fruit-eating mammals. Pollinators often act as a keystone species, a species in a community that has a disproportionate impact on its environment compared to its abundance (Shepherd et al. 2008).

Habitat loss, pesticide use, and diseases are contributing to the decline in populations of native pollinators. You can provide shelter, nesting sites, food, and water to attract and support pollinators (Marks, R. 2005). You can also minimize the use of pesticides that can kill pollinators.

Table 2-A. Food and shelter requirements for common native pollinators

Pollinator	Food	Shelter
Solitary bees	Nectar and pollen	Nest in hollow stems or tubes; bare patches of well-drained soils; make nests of mud, plant resins, or saps on rocks or bark.
Bumblebees	Nectar and pollen	Nest underground, under clumps of grass, or in tree cavities.
Butterflies	Larval host plants, nectar, mud puddles for minerals	Shelter in bushes, tall grasses, piles of sticks.
Hummingbirds	Nectar, tree sap, insects	Nest in trees, shrubs, and vines. Can provide cotton or willow catkins for nesting material.

Changing Interactions

The species that make up different functional groups often change in urbanized areas, or sometimes functional groups may be missing entirely. Whitetail deer populations have exploded in the last 40 years in part because there are no longer wolves or other large predators to keep their populations in check. These large predators cannot survive in fragmented urban environments. Vehicles driven by people now act as a major accidental predator of deer, birds, and amphibians.

Introduced invasive plants, pests, and diseases have dramatically changed communities in both urban and rural areas. Chestnut blight resulted in oaks and maples becoming more common forest trees. Emerald ash borer could cause a significant decline in ash tree populations in Maryland. Ash trees support 150 species of butterflies and moths alone (Tallamy 2007). Garlic mustard, an introduced plant species from Europe, covers the forest floor and floodplains and reduces the growth of tree seedlings and alters soil chemistry. These changes could alter the long-term regeneration patterns within forests.

Invasive species are successful for many reasons, but one reason is that they have left behind the pests and diseases that recognize them as food. Increasingly, land managers are looking towards biological controls that introduce an insect or disease from the invasive species home range that specifically feeds on the invader, essentially reestablishing a lost interaction. You will learn more about invasive species in Chapter 12.

Gardening and farming change species interactions too. Within the garden you create bare ground where weed seeds can germinate. Weeds are often adapted to growing in highly disturbed areas. A crop monoculture is a banquet to pests and diseases that specialize on that crop. Pesticides can kill beneficial insects as well as insect pests potentially leading to pest outbreaks. The idea behind Integrated Pest Management is to monitor and manage pest populations with minimal use of pesticides, preserving natural predator-prey interactions. More about weeds and Integrated Pest Management will be covered in Chapters 11 and 9.

Succession

All plant and animal communities change over time, and the process of succession is measured by the change in species composition over time within a community. We see succession when an abandoned field gradually becomes a forest or when a shallow pond fills in with plants to become a marsh. Primary succession happens as organisms colonize where there is no pre-existing community, such as on rocks or bare mineral soil. Secondary succession happens when there is a disturbance to an existing community. Designed landscapes undergo succession too as plantings mature, new plants are added, and overgrown plants are removed. Animal communities change in response to changes in the plant community.

Typically the first colonizers will be annual plants that grow and reproduce rapidly. These are gradually replaced by perennial grasses and other herbaceous plants that are more tolerant

of competition. Fast growing shrubs and trees follow, particularly those whose seeds are dispersed by wind or birds. As trees begin to shade out the sun-loving annuals and perennials, shade-tolerant perennials and tree species establish. As these late-successional trees mature, the forest species composition may remain relatively constant for a long period of time, until another major disturbance. It can take 100 to 200 years for a mature forest in Maryland to develop from a field.

Table 2-B. Typical early and late successional species in Maryland.

Early - Plants	Late – Plants	Early - wildlife	Late - wildlife
Pokeweed	Solomon's seal	Cottontail rabbit	Flying squirrels
Horseweed	Cranefly orchid	Meadow vole	Wood ducks
Calico aster	Summersweet	Red fox	Spotted salamander
Ragweed	Mountain laurel	Groundhog	Ovenbird
Broomsedge	Hickory	Bluebird	Pileated woodpecker
Blackberry	Oak	Bobwhite quail	Box turtle
Trumpet creeper	Black gum	Bobolink	
Loblolly pine	Dogwood	Deer	
Yellow birch	Sourwood		
Red cedar	American Beech		

It is not just species that change over time. The structure of the community becomes more complex as layers of vegetation form. A mature forest has canopy trees, understory trees, and a layer of shrubs and herbaceous plants. These layers of vegetation generally support greater species diversity. Habitats in transition zones between successional stages and edge habitats tend to support high species diversity. Many animals, such as turkey and deer, use more than one successional stage to find food and shelter. When designing a landscape, consider adding layers of understory trees, shrubs, and perennials to enhance plant and animal diversity.

Disturbances

Natural disturbances include volcanic eruptions, landslides, wind, fire, ice storms, and floods, as well as serious pest and disease outbreaks. There are also many human-caused disturbances, such as logging, farming, dredging, mining, pollution, and introduction of invasive species. All these disturbances can result in a different course of succession and ultimately formation of a different type of community.

The frequency and intensity of disturbances also has a big effect on succession. The more frequent or intense a disturbance, the greater the change it is likely to have on the community. Repeated flooding along a river, for example, can cause a wet meadow to form rather than a forested floodplain. Suppression of wildfires by people has led to less frequent, but more intense, forest fires.

Many human activities mimic natural disturbances. To maintain a meadow, an early successional community, we must mow or burn it to kill off woody plants. Most agricultural crops are annuals that must be planted every year. Cultivation and herbicides kill off competing weeds or other early successional annual and perennial plants that seed themselves into the field. If you want to speed up succession, plant perennials and woody plants that would take longer to arrive and establish if you waited for natural processes to happen.

Species and Populations

This section reviews the adaptations and genetics of species and populations.

Species

You have been learning about changes within communities of species, but what is a species? In practice, species are groups of individuals that are similar physically, behaviorally, and genetically. Generally, individuals of one species do not interbreed with individuals of a different species either because they are isolated from them geographically, or they have physical or behavioral traits that limit interbreeding. New species arise through the process of evolution, a change in the gene frequencies of a population over time, and it is this gradual change that makes defining species so difficult.

Evolution and Adaptation

Charles Darwin's theory of natural selection, a mechanism for evolution, was largely influenced by his voyage to the Galapagos Islands in 1835. There he observed many very similar finches living on the islands, but varying greatly in the sizes and shapes of their beaks. He proposed that the birds had adapted to eating different food sources on the islands. Under natural selection:

1. Offspring are similar to their parents;
2. There is some chance variation among individuals and some variation can be passed from parents to offspring;
3. More offspring are produced each generation than can be supported by the environment; and
4. Some individuals have a greater chance of surviving and reproducing than other individuals in the population because they have some physical or behavioral trait that makes them better suited.

So Darwin concluded the finches had evolved into different species because there was competition for food and individuals who specialized on a different food could have more offspring. Over time the beak sizes changed as, for example, birds with larger beaks could better crack open large seeds and small-beaked birds could better handle smaller seeds.

Shortly after Darwin's voyage, an Augustinian monk named Gregor Mendel discovered through his work on garden peas that genes are the unit of inheritance and that genes come in alternative forms called alleles. Often one allele will be dominant over another causing the expression of the dominant trait to be more common. For example in garden phlox, dark-pink flower color is the dominant color over white. If you have pink and white phlox in your garden, all seedlings with one pink and one white parent will have pink flowers.

New species can arise through genetic mutations, but often new species evolve gradually as populations of the same species are isolated from one another. There are many examples of plants that have evolved into different species in the United States because of geographic isolation. Spring beauty (*Claytonia* spp.) is represented by different species in the eastern and western United States. Isolation does not have to be geographical. Insects normally specializing on one host plant may switch to feed on a new host plant. The offspring of those insects feeding on the new host plant gradually may change over generations into a new species.

Human Influences on Evolution

Evolution happens over generations, but of course some insects, bacteria, and viruses can produce many generations in just one year, whereas other organisms like oak trees and elephants take more than 20 years to reproduce. It also relies on a flow of genes carried by individuals, or of pollen and seeds in the case of plants, among populations in the landscape.

- Fragmentation of habitats leads to restrictions in the ability of organisms to disperse to new areas and to exchange genes among populations. Without the free exchange of genetic material, more species are likely to become inbred and susceptible to pests, diseases, and changes in the environment.
- The rate of introduction of new species has increased dramatically through global trade. Intentional introductions of species for horticulture, aquaculture, and the pet trade and accidental introduction of species in packing materials, grains, and ballast water lead to changes in evolutionary relationships. Often new species are introduced without the pests and diseases or competitors that kept them in check in their native habitats, and they become invasive, spreading rapidly in their new environment. Insects and animals here do not recognize the new organisms as food or prey because they do not share an evolutionary history. Over time these relationships often change, but the consequences to native communities could be devastating in the short term. Some introduced species with close North American relatives hybridize and lose the genetic makeup that made them a distinct species. Learn more about invasive species in Chapter 12.
- Rapid climate change also affects species' ability to adapt. If climate changes faster than species can change their habits to survive warmer, wetter, or drier environments, then the species will go extinct. Many species shift their ranges in response to climatic

changes, but plants can only move as far as their seeds are dispersed, and animals must be able to physically move to a new habitat. In increasingly urbanized landscapes it is difficult for species to move to new habitats. For those that move up in elevation to cooler environments, they may reach an upper limit if temperatures warm too much.

- Agricultural practices have led to changing evolutionary relationships. Some weeds have evolved to mimic crop appearances so they are less likely to be weeded out. Other weeds and insect pests have developed resistance to pesticides. Genes from genetically engineered crops have moved in pollen to become incorporated into the DNA of wild relatives.

Population Dynamics

Populations are groups of individuals of the same species that live in the same place and are at least somewhat isolated or distinct from other populations. For example, a neighborhood is likely to be home to a population of squirrels if it is somewhat isolated from surrounding neighborhoods. To compare populations we look at several attributes:

- Density -- the number of individuals in a given area;
- Birth rate -- the rate at which new individuals are born;
- Death rate -- the rate at which individuals die;
- Dispersal -- the rate at which individuals leave (emigrate) or arrive (immigrate); and
- Age distribution -- the proportion of individuals of different ages in the population.

In plants, the life history of the plant in large part determines the population dynamics. The birth rate is represented by viable seeds produced. Seeds may disperse out of the population or into the population. Pollen may also be carried into and out of the population allowing for gene exchange among populations. In a population of annuals, all the individuals will be about the same age. Biennials take two years to grow and reproduce before they die. A new population of biennials will have all one-year-old plants, then all two-year-old plants. More mature populations of biennials will start to have a mix of one- and two-year-old plants as seeds collect and form a seed bank in the soil. Some seeds may take more than one year to germinate, leading to a mixed-age population. Perennials live for three or more years, and some may live hundreds of years.

Animals can also have wildly contrasting population dynamics. Compare the life of two-spotted spider mites to that of white-tailed deer. Spider mites can go from egg to adult in 1-3 weeks depending on temperature. Each female can produce a dozen eggs a day for up to a couple weeks, about 148 eggs over the female's lifespan. Populations explode within just a few warm weeks if there are plenty of leaves around. White-tailed deer females mature within one to two years. Each has one to three fawns a year and lives for 3-5 years on average in the wild, averaging eight fawns over her lifespan. Resource availability also has a tremendous effect on deer populations. Deer will reproduce earlier, have more offspring each year, and live longer if there are plenty of resources available and few predators.

Population Genetics

The life history and population dynamics of species influence the genetic diversity within populations. Pollen and seeds travel different distances depending on how they are dispersed, although most seeds land relatively close to the parent plant.

Wind dispersal distances are affected by:

- The size and weight of the pollen or seeds;
- Wind speed and turbulence;
- Openness of the environment (e.g., meadow vs. forest understory); and
- Height of the plant above the ground.

Animal dispersal distances are affected by:

- Length of time to digest fruits;
- Average flight or travel distance (e.g., migratory bird vs. box turtle); and
- Territory size.

Gene flow among populations can keep populations more genetically similar to one another or can introduce new genetic variation. Small populations tend to lose genetic variation.

Random events, such as which individuals mate and which offspring survive, can change the proportions of different genetic traits dramatically in a small population through a process called genetic drift. If a population was started by a small number of individuals, the founders are likely to have less genetic diversity than the larger population they came from, and subsequent matings are likely to occur between genetically-related individuals.

Plant Breeding

Gardeners often debate the merits of planting straight or open-pollinated species, cultivars, and hybrids. In agriculture there is increasing interest in the conservation and preservation of a wide variety of cultivars and of a crop's wild relatives so that there will be a source of new genes for future adaptations. Some cultivars and hybrids no longer produce nectar, pollen, or seeds and thus have lost much of their wildlife value.

- Straight species refers to open-pollinated seeds or plants collected from a natural population. Straight species will have more genetic variation, so some plants may have traits that will allow them to resist new diseases or to adapt to climactic change.
- A cultivar is a genetic selection of a plant that is often originally reproduced asexually through cuttings or tissue culture. In this case individuals of a cultivar are genetically identical to one another. Many crop and ornamental plants are cultivars. For example, on a conventional farm, a field of corn will be a single genetic strain of corn the farmer has selected to grow that year for its yield, insect resistance, or drought resistance. You might choose to grow 'Rutgers' tomatoes, 'Blue Lake' green beans, and 'Nantes' carrots. Your perennial garden might feature 'Stella d'Oro' daylilies, Echinacea 'White Swan,' and Phlox 'David.' Hybrids are most often crosses between two species. Some hybrids occur in nature, particularly in plants. In plants sometimes hybrids are more vigorous than their parents, but other times they are less vigorous or produce no viable seeds. The outcome depends on how the genes from the different species interact. In horticulture the term hybrid is also sometimes used to refer to crosses between two cultivars of the same species. Hybrid tomatoes bred for disease resistance are an example of a hybrid between two cultivars of the same species. Pluots and plumcots are hybrids between two species, plums and peaches.

Rare Plants

More than 600 plant species are on Maryland's rare plant list, although their degree of rarity varies. Some species may be at the northern or southern limits of their ranges and have only a few populations in Maryland. Others may only occur in Maryland and may also be listed as federally endangered species. To learn what plants are rare in your county, visit the Maryland Department of Natural Resources website listed in references at the end of this chapter. Examples of Maryland rare plant species that can be purchased in nurseries include pink coreopsis (*Coreopsis rosea)* and wild lupine (*Lupinus perennis)*. If a species is rare in your area, avoid planting it in your garden. Although a few plants may not cause harm, they may accidentally introduce a disease that could spread to the wild population and transfer pollen and seeds to the wild population. Botanists trying to conserve rare wild populations need to be able to study the genetics of the wild populations without genes from introduced populations present. Avoid buying any wild-collected rare plants because it is illegal to collect and sell endangered plant species.

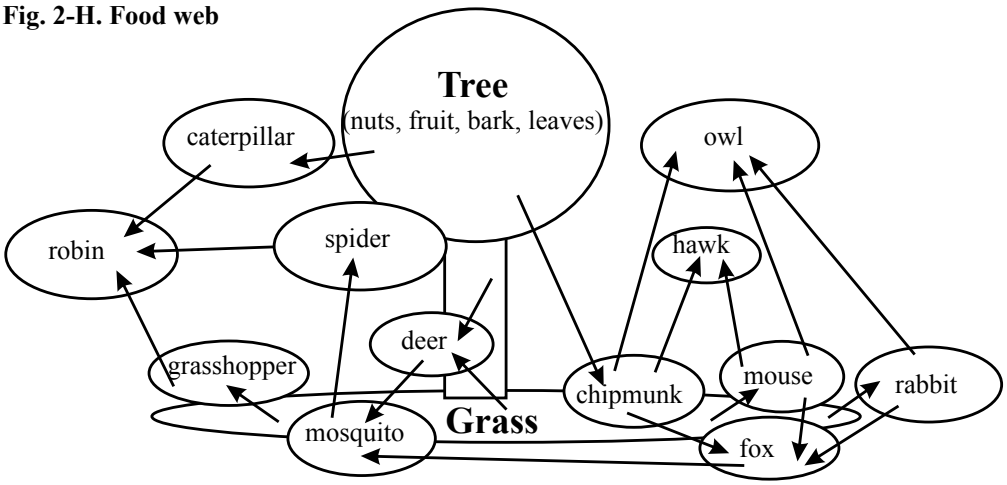
Ecosystems

The concept of an ecosystem brings together the living community and the non-living, abiotic factors influencing that community such as soils, water, nutrients, and climate. The study of ecosystems looks at the flow of energy, water, and nutrients through the living system.

Food Webs

Earlier in this chapter you read about functional groups that obtain energy in particular ways. Food webs describe how these functional groups fit together in the ecosystem through their feeding interactions (Fig. 2-H). Energy flows from the producer to the consumer to the decomposers and back to the producers.

Fig. 2-H. Food web



In this food web, the arrows represent the direction of energy flow through the web.

Disrupting Food Webs

Disrupting a food web can lead to one species gaining dominance or to an entirely new community forming:

- Loss of a keystone species—If a keystone species, or group of species such as pollinators, were lost, it would lead to a loss of fruit production in plants pollinated by those pollinators. Birds and other animals that rely on those fruits would disappear. If the pollinators did not recover, plants relying on wind pollination and other forms of pollination would begin to dominate, and those plants would attract their own suite of animal species.
- Insect outbreaks—Lack of predators (e.g., birds and spiders) or pathogens can lead to explosive reproduction of insects. If the insects exhaust their food source though, their population will crash. Recent introductions of insects such as the brown marmorated stink bug and the emerald ash borer can lead to outbreaks because they have no natural enemies outside their home range.
- Introduction of invasive plant species—Invasive species often outcompete native plant species for light, water, and nutrients. Changes in the plant community can lead to changes in food sources and types of shelter for animals favoring a different community of animals. For example, robins experience higher nest predation when nesting in Amur honeysuckle (*Lonicera maackii*) compared to nesting in native shrubs because the architecture of the shrub leads them to build their nests closer to the ground, where they are more accessible to predators. The sugary fruits of invasive shrub honeysuckles are favored by some birds but displace the high fat content fruits of plants like spicebush (*Lindera benzoin*) and viburnum (*Viburnum* spp.) that migratory birds rely on.

Carbon Cycle

Carbon occurs mostly as carbon dioxide (CO_2) in the atmosphere, but there are also trace amounts of methane and carbon monoxide. Plants take up carbon in the form of CO_2 in photosynthesis. The uptake is approximately equal to the amount of carbon released through respiration by primary producers, consumers, and decomposers. Carbon becomes stored in terrestrial and aquatic systems for the long-term in fossil fuels, peat, soils, and carbonate rock. For shorter periods of time carbon is stored in plant and animal biomass, including what that biomass is used to produce, such as paper or wood-frame houses.

Carbon dioxide levels in the atmosphere have risen substantially since 1750 due to human activities. The primary contributor to increasing CO_2 levels has been the combustion of fossil fuels. Deforestation contributes to CO_2 increases as well, but often these increases are offset by re-growth of crops or new tree cover. The loss of vegetation also results in the release of carbon stored in soils however. Although a relatively minor contributor to CO_2 levels globally, the use of peat moss also releases carbon that would have been in long-term storage, and this resource is widely used in the gardening industry.

Rising CO_2 levels have had the following ecological consequences:

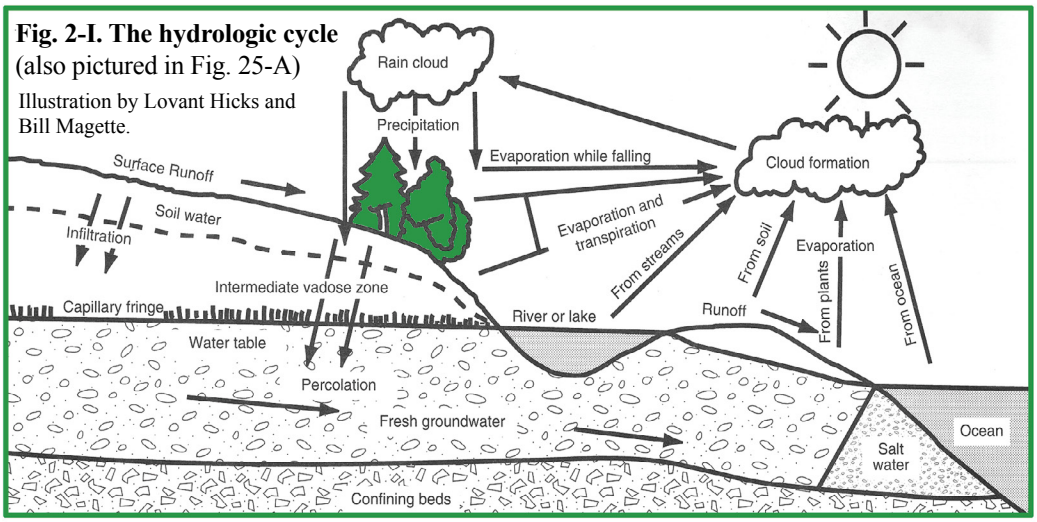
- Rising temperatures leading to shifts in species ranges and earlier flowering;
- Higher plant growth rates until water and nutrient limitations are reached;
- Increased pollen production, including in ragweed;
- Greater toxicity of the oils in poison ivy; and
- Increased growth of vines.

Water Cycle

Water plays a critical role in ecosystems (Fig. 2-I). It is necessary for all living organisms and provides important habitat for a huge diversity of fish, amphibians, waterfowl, aquatic insects, and aquatic plants. Water evaporates from lakes, oceans, and rivers and is transpired by plants and respired in every breath animals and plants take. That water condenses in the atmosphere and is returned to earth as rain or snow. Water runs downhill into lakes and rivers. Some of it infiltrates into the ground and is stored there as groundwater, filing in pores in the soil or it percolates into underground aquifers. If groundwater reaches the surface through a spring, or just because of a high water table, that water rejoins the surface waters of lakes, streams, and rivers. You will learn more about water quality and conservation in Chapter 25.

In urbanized areas, the flow of water in the landscape has changed because there is less plant cover and more impervious surfaces, compacted soils, and channelized streams. More water reaches the ground, less soaks into the ground, and greater quantities of polluted water reach wetlands and waterways. Groundwater and water stored in aquifers is used up as people pump water from wells and there is less recharge of groundwater.

Fig. 2-I. The hydrologic cycle
(also pictured in Fig. 25-A)
Illustration by Lovant Hicks and Bill Magette.



Nitrogen Cycle

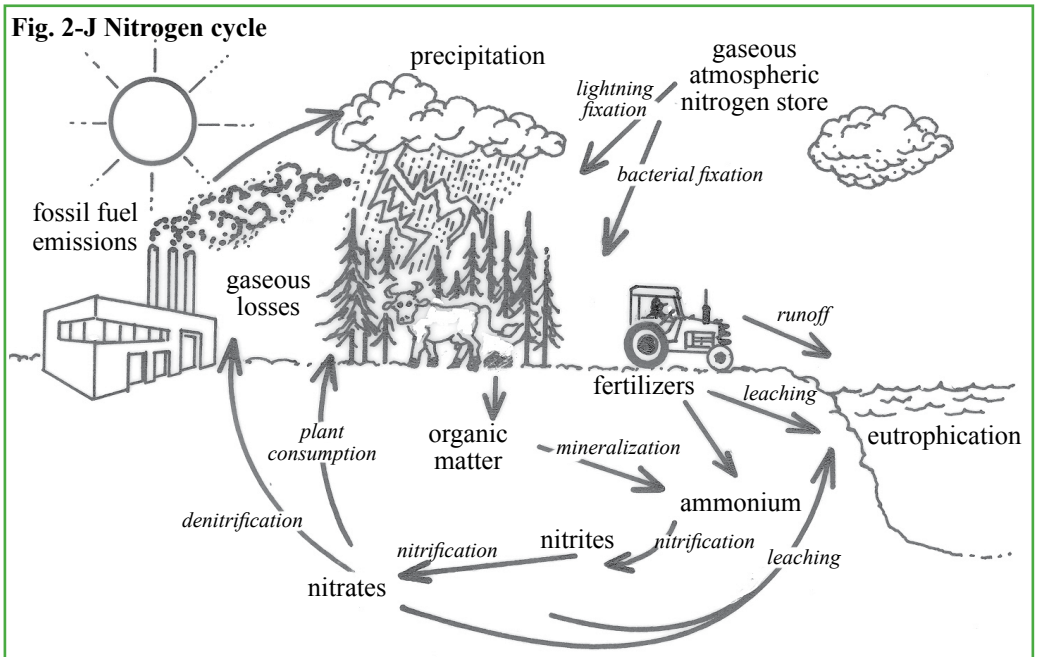
Nitrogen is not the only nutrient important in ecosystems, but it is one of the more complex systems and illustrates what a large effect humans have on ecosystem processes (Fig. 2-J). You will learn about the nitrogen cycle in Chapter 4 and about other nutrients important in plant nutrition in Chapter 5. Nitrogen exists in the atmosphere in gaseous forms. It is fixed or converted to forms usable by plants and animals through the action of bacteria or lightning. Plants take up nitrogen in the form of nitrates mainly. That nitrogen is passed along to animals that consume plants, and when plants and animals die it cycles within the terrestrial system. Some is also lost to the atmosphere however as other bacteria convert it back to a gaseous form.

People have significantly altered the nitrogen cycle:

- Doubling the amount of fixed nitrogen through the production of fertilizer and by planting nitrogen-fixing crops such as soybeans;
- Burning fossil fuels adding to gaseous nitrogen, one element causing acid rain;
- Enriching soils with chemical fertilizers, manure, and deposition of atmospheric nitrogen;

- Losing biodiversity in ecosystems with plants adapted to low nutrient soils;
- Increasing nitrate flow in streams and nitrous oxide in the atmosphere through deforestation; and
- Eutrophying (over-fertilizing water) streams and wetlands with nutrient-enriched runoff.

Fig. 2-J Nitrogen cycle



For an explanation of the processes see table 4-H.

Recycling in the Garden

To make your garden a sustainable ecosystem, consider how water, energy, and nutrients are recycled. Composting uses decomposition to keep nutrients on site and avoids the addition of chemical fertilizers (Chapter 6). Cover crops protect soil from erosion by slowing water flow and they add nutrients back into the soil when they are cut or plowed under (Chapter 17). Rain barrels store water for future use. The loose soil and vegetation of gardens helps to slow the flow of rain water and allows water to filter slowly into the soil. Rain gardens help capture and cleanse runoff (Chapter 25).

Biodiversity in the Garden and Landscape

Biodiversity is often used as a buzzword, but what does it really mean? Biologists measure biodiversity as the number and distribution of species in an ecosystem. If you have a community with 10 species, but one species is super-abundant and the rest are relatively rare, that community has less biodiversity than a community with 10 species all approximately equal in abundance. Biodiversity can also encompass everything from the diversity of genes to the diversity of ecosystems.

We are still learning about the value of a particular gene, species. or ecosystem, but there are enough examples where they have been critical that preserving biodiversity should have a high priority. A gene could make American chestnut resistant to chestnut blight and return this ecologically and economically valuable tree to our forests. Taxol, first extracted from the western yew (*Taxus brevifolia)*, provided a new cancer drug. The tree grows best in western old-growth forests threatened by clearcut logging. Preserving forested watersheds saves municipalities in New York State millions of dollars in water treatment costs. Ecosystems with more diversity are more resilient to disturbances and are able to recover faster after natural or manmade disasters. They are also more stable, changing less over time. Harvard biologist Dr. E.O. Wilson has written eloquently on biodiversity, “We should preserve every scrap of biodiversity as priceless while we learn to use it and come to understand what it means to humanity.”

Gardeners can promote biodiversity by including more native plant species in gardens, providing wildlife habitat, and controlling invasive species. Using sustainable gardening techniques that conserve water and energy, that minimize the use of pesticides and fertilizers, and that re-use materials will have a broad effect helping to conserve biodiversity in the region, and even around the world. Volunteering at parks where rare plant communities are protected on-site and at botanic gardens that cultivate endangered plant species from around the world (ex-situ conservation) can also be meaningful contributions.

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Illustrations: Figures 2-E, 2-F, 2-G, 2-H, 2-J by Don Wittig, University of Maryland Extension Master Gardener, Montgomery County.

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