

Unit 1: The Living World: Ecosystems

Unit 1 covers how ecosystems work. It covers the ways species interact, the world's terrestrial and aquatic biomes, the carbon, nitrogen, phosphorus, and water cycles, primary productivity, and how energy moves through trophic levels and food webs.

AP Environmental Science

The Living World: Ecosystems

About 14 minutes to read

How to use this guide

Read it in order the first time. Species interactions come first, then the biomes those species live in, then the cycles that move matter through them, and finally the energy flow that powers the whole system. The four cycles and the 10% rule get the most exam questions, so plan to spend extra time on topics 1.4 through 1.10.

After the first read, use the trap boxes and the comparison tables to review the distinctions that exam questions test most often. Finish with the practice questions, then complete the recall check on the last page out loud and note any items you cannot explain yet.

What this unit is worth. The Living World: Ecosystems is about 6 to 8 percent of the AP Environmental Science exam. It also carries more weight than that number suggests, because the cycles and energy flow in this unit are assumed knowledge in the units on land use, pollution, and global change.

1.1 Introduction to Ecosystems

Species in an ecosystem interact in predictable ways, and the exam tests whether you can name the interaction and say who gains and who loses. **Symbiosis** is a close, long-term interaction between two species. It comes in three types. In **mutualism**, both species benefit. In **commensalism**, one benefits and the other is neither helped nor harmed. In **parasitism**, one benefits at the expense of the other, which is called the host. A **predator-prey relationship** is not a type of symbiosis. It is a separate interaction in which one organism hunts, kills, and eats another.

Competition is rivalry for limited resources. It happens within a species, called **intraspecific** competition, or between species, called **interspecific** competition. **Resource partitioning** is one way competition eases. Species use resources in different ways, in different places, or at different times, which reduces the negative effect of competition on survival. Warblers feeding at different heights in the same tree are the classic example.

Trap. Predator-prey is not symbiosis. Symbiosis requires a close, long-term interaction, and its three types are mutualism, commensalism, and parasitism. If the question describes one organism killing and eating another, the answer is a predator-prey relationship, not parasitism or commensalism.

Trap. Commensalism and parasitism are separated by what happens to the second species. In commensalism the second species is unaffected. In parasitism the second species is harmed. The question will usually describe the effect on both species, so check the second one before you choose.

1.2 Terrestrial Biomes

A **biome** is a large region whose characteristic plant and animal communities result from, and are adapted to, its climate. The major terrestrial biomes to know are taiga, temperate rainforest, temperate seasonal forest, tropical rainforest, shrubland, temperate grassland, savanna, desert, and tundra. The **distribution of terrestrial resources** like water and lumber trees is not random. It varies with climate, geography, latitude and altitude, nutrient availability, and soil.

Biome boundaries are not fixed. **Biome shifts** happen because the worldwide distribution of biomes is dynamic. It has changed in the past, and it may shift again as the global climate changes. A warming climate can push the taiga poleward and shrink the tundra, which is the kind of directional shift the exam asks about.

Trap. Climate is what defines a biome, not country borders or human land use. If a question asks why two distant regions share the same biome, the answer is that they share a climate pattern, even if they are on different continents.

1.3 Aquatic Biomes

Freshwater biomes are streams, rivers, ponds, and lakes. They are a vital resource for drinking water.

Marine biomes are the oceans, coral reefs, marshland, and estuaries. Algae in marine systems supply a large portion of Earth's oxygen and also absorb carbon dioxide from the atmosphere, which ties this topic directly to the carbon cycle in topic 1.4.

The **distribution of marine resources** such as fish varies with salinity, depth, turbidity, nutrient availability, and temperature. Notice how this list differs from the terrestrial list. Salinity, depth, and turbidity replace latitude and soil, because light and dissolved conditions are what structure life in water.

Trap. An estuary is a marine biome, not a freshwater one. It is where a river meets the sea and the water is brackish. Questions like to put estuaries near freshwater biomes in the answer choices to see if you notice the salt.

1.4 The Carbon Cycle

The **carbon cycle** is the movement of carbon atoms and molecules between sources and sinks. A **source** is a process or location that releases carbon, and a **sink**, also called a reservoir, stores it. Some reservoirs hold carbon for long periods, like fossil fuels and ocean sediments, while others hold it for short periods, like living organisms and the atmosphere.

The biological engine of the cycle is the pair of **photosynthesis and respiration**. Photosynthesis removes carbon dioxide from the atmosphere, and cellular respiration releases it back. Over geological time, dead plant and animal material decomposed and stored carbon underground as **fossil fuels**. Burning those fuels quickly moves millions of years of stored carbon into the atmosphere as carbon dioxide, which is why fossil fuel combustion is a source in this cycle.

Trap. Fossil fuels are a carbon sink until they are burned. The coal and oil underground store carbon for millions of years. Combustion turns that stored carbon into a source. Questions that ask about the effect of burning fossil fuels are asking about moving carbon from a long-term sink into the atmosphere.

1.5 The Nitrogen Cycle

The **nitrogen cycle** moves nitrogen atoms and molecules between sources and sinks through nitrogen fixation, assimilation, ammonification, nitrification, and denitrification, with soil microorganisms doing much of the work. **Nitrogen fixation** is the step that makes nitrogen usable. Certain soil bacteria convert atmospheric N_2 into ammonia (NH_3), which quickly becomes ammonium (NH_4^+) in soil and is then available for biological uptake.

Two facts about nitrogen show up constantly. First, the **atmospheric nitrogen reservoir** is the largest nitrogen reservoir on Earth, yet most nitrogen reservoirs hold their compounds for relatively short periods. Second, there is a **nitrogen limitation**. Nitrogen availability in soil is limited by the rate of nitrogen fixation, and in many ecosystems nitrogen availability limits how much primary production plants and other producers can do.

Trap. Plants cannot use atmospheric N_2 directly, even though nitrogen makes up most of the atmosphere. The N_2 has to be fixed into ammonia or ammonium first. If a question asks why plants do not run out of nitrogen when the air is full of it, the answer is that fixation, not abundance, is the bottleneck.

1.6 The Phosphorus Cycle

The **phosphorus cycle** moves phosphorus atoms and molecules between sources and sinks. It has one feature that sets it apart from the other cycles. It **lacks a significant atmospheric component**.

Phosphorus does not move through the air the way carbon and nitrogen do. The major **phosphorus reservoirs** are rock and ocean sediments containing phosphorus-bearing minerals, and phosphorus-bearing minerals are released as rocks weather.

Because rocks weather slowly, **phosphorus is relatively scarce** in ecosystems. It is often a limiting nutrient for plants and other producers, particularly in freshwater and some terrestrial ecosystems. This is the contrast the exam loves. Nitrogen limitation is common in terrestrial systems and is tied to fixation rates, while phosphorus limitation is common in freshwater systems and is tied to the slow weathering of rock.

Trap. Phosphorus has no significant atmospheric component. If a question asks which biogeochemical cycle in this unit does not involve the atmosphere in a major way, the answer is phosphorus. Do not pick nitrogen, which has the largest atmospheric reservoir of any nutrient cycle here.

1.7 The Hydrologic (Water) Cycle

The **hydrologic (water) cycle** is the movement of H₂O in its solid, liquid, and gaseous phases between sources and sinks. It is powered by the sun, which drives evaporation and transpiration and keeps the cycle moving. The **oceans are the primary reservoir** of water at Earth's surface, with ice caps and groundwater acting as much smaller reservoirs.

Trap. The sun powers the water cycle, not internal Earth processes. Evaporation and transpiration run on solar energy. If a question asks what drives the hydrologic cycle, the answer is the sun, even when the other choices sound geological.

1.8 Primary Productivity

Primary productivity is the rate at which solar energy is converted into organic compounds via photosynthesis over a unit of time. It is measured in energy per unit area per unit time, for example **kcal/m²/yr**. The two forms of productivity matter more than the units. **Gross primary productivity (GPP)** is the total rate of photosynthesis in a given area. **Net primary productivity (NPP)** is the rate of energy storage by photosynthesizers in that area after subtracting the energy lost to respiration. In symbols, $NPP = GPP - \text{respiration}$. NPP is what is actually available to the next trophic level.

Light limits productivity in water. **Most red light is absorbed in the upper 1 m** of water, and blue light only penetrates deeper than 100 m in the clearest water. Photosynthesizers in aquatic ecosystems have adapted to the lack of visible light at depth, which is why most aquatic photosynthesis happens near the surface.

Trap. NPP is always smaller than GPP, because respiration has to be subtracted. If a question gives you a GPP of 5,000 kcal/m²/yr and respiration of 2,000, the NPP is 3,000, not 5,000 and not 7,000. Read which productivity the question asks for.

1.9 Trophic Levels

All ecosystems depend on a **continuous inflow of high-quality energy** to maintain their structure and to move matter between the environment and organisms through the biogeochemical cycles. Energy enters from the sun and flows to **producers** in the lowest trophic levels, then upward to primary consumers, secondary consumers, and tertiary consumers. Matter behaves differently. The **conservation of matter** means that biogeochemical cycles demonstrate that material is neither created nor destroyed as it cycles. Energy flows through an ecosystem once and is lost as heat. Matter cycles.

Trap. Energy flows one way through an ecosystem and matter cycles. A question that asks what returns to the environment has matter as the answer. A question that asks what is lost at each transfer has energy as the answer. Keep the two straight and half the cycle questions answer themselves.

1.10 Energy Flow and the 10% Rule

The **10% rule** says that energy transfer between trophic levels passes on only about one-tenth of the energy to the next level. If producers capture 10,000 kcal/m²/yr, primary consumers get about 1,000, secondary consumers about 100, and tertiary consumers about 10. The rest is lost as heat and used in metabolism along the way. The **thermodynamics** behind this is the reason the rule exists. Energy moving from lower to higher trophic levels loses usable energy at each step, as the laws of thermodynamics require.

This is why food chains are short and why eating lower on the trophic pyramid feeds more people. Each added level throws away roughly 90 percent of the energy that entered it.

Trap. The 10% rule applies between trophic levels, not within one level. The transfer from producers to primary consumers keeps about 10 percent, and the transfer from primary to secondary consumers keeps about 10 percent of that. If producers hold 10,000 units, secondary consumers hold about 100, not 1,000. Count the transfers.

1.11 Food Chains and Food Webs

A **food chain** traces the flow of energy and matter from producers (autotrophs) to primary consumers (herbivores) and on to secondary and tertiary consumers (omnivores and carnivores). A **food web** is the more realistic model. It depicts the interlocking pattern of energy and matter flow in two or more feeding sequences. Real ecosystems are webs, because most organisms eat and are eaten by more than one species.

Detritivores and decomposers close the loop. They return nutrients to the soil and play an essential role in food chains and webs. Without them, the matter in dead organisms would stay locked up instead of cycling back to producers.

Populations in a web push and pull on each other through **feedback loops**. A change in one species' population feeds back through the feeding links. A **negative feedback loop** dampens the change, as when predators decline because their prey declined. A **positive feedback loop** amplifies it. Removing a predator can let prey explode, which is a change that reinforces itself through the web.

Trap. A food web is not just a longer food chain. A chain follows one feeding sequence. A web shows the interlocking pattern of two or more sequences. If the question shows organisms with multiple feeding connections, it is describing a web.

Confusions That Cost Points

PAIR	HOW TO KEEP THEM STRAIGHT
Mutualism vs commensalism vs parasitism	Count the effects on the second species. Helped: mutualism. Unaffected: commensalism. Harmed: parasitism.
Predator-prey vs parasitism	Predator-prey means the predator kills and eats the prey. Parasitism means the parasite benefits while the host stays alive, at least for a while.
Intraspecific vs interspecific competition	Intra is within one species. Inter is between species. The prefix tells you.
Carbon source vs carbon sink	A source releases carbon, like burning fossil fuels. A sink stores it, like unburned fossil fuels or the ocean. Burning flips a sink into a source.
Nitrogen vs phosphorus limitation	Nitrogen limitation comes from slow fixation rates and is common in terrestrial systems. Phosphorus limitation comes from slow rock weathering and is common in freshwater systems. Phosphorus has no significant atmospheric component.
GPP vs NPP	GPP is total photosynthesis. NPP is what remains after respiration is subtracted. NPP is the energy actually available to the next level.
Energy flow vs matter cycling	Energy flows one way through an ecosystem and is lost as heat at each transfer. Matter cycles and is neither created nor destroyed.
Food chain vs food web	A chain is one feeding sequence. A web is the interlocking pattern of two or more sequences.
Negative vs positive feedback loop	Negative feedback dampens a change. Positive feedback amplifies it.

Practice Questions

Original questions written for this guide in the style of the AP exam. Answers and explanations are on the next page, so complete the questions before checking them.

1. A small fish lives among the tentacles of a sea anemone. The fish gains protection from predators, and the anemone is neither helped nor harmed by the fish's presence. This interaction is best described as
 - A. mutualism
 - B. commensalism
 - C. parasitism
 - D. a predator-prey relationship

2. In a grassland ecosystem, producers capture $20,000 \text{ kcal/m}^2/\text{yr}$ of energy. According to the 10% rule, approximately how much energy is available to secondary consumers?
 - A. $20,000 \text{ kcal/m}^2/\text{yr}$
 - B. $2,000 \text{ kcal/m}^2/\text{yr}$
 - C. $200 \text{ kcal/m}^2/\text{yr}$
 - D. $20 \text{ kcal/m}^2/\text{yr}$

3. Which of the following best explains why phosphorus, unlike nitrogen, lacks a significant atmospheric component in its biogeochemical cycle?
 - A. Phosphorus is released into the atmosphere by denitrifying bacteria
 - B. Phosphorus reservoirs are mainly rock and ocean sediments, and it moves through ecosystems via weathering rather than through the air
 - C. Phosphorus is fixed directly from the atmosphere by photosynthesizers
 - D. Phosphorus cycles between photosynthesis and respiration in living things

4. A forest has a gross primary productivity of $12,000 \text{ kcal/m}^2/\text{yr}$. The producers in the forest use $7,000 \text{ kcal/m}^2/\text{yr}$ in cellular respiration. The net primary productivity of the forest is
 - A. $19,000 \text{ kcal/m}^2/\text{yr}$
 - B. $12,000 \text{ kcal/m}^2/\text{yr}$
 - C. $7,000 \text{ kcal/m}^2/\text{yr}$
 - D. $5,000 \text{ kcal/m}^2/\text{yr}$

Answer Key

- 1. B.** The fish benefits and the anemone is unaffected, which is the definition of commensalism. A is wrong because mutualism requires both species to benefit, and the anemone gains nothing. C is wrong because parasitism requires the second species to be harmed, and the anemone is not. D is wrong because neither organism kills and eats the other, and predator-prey is not a type of symbiosis.
- 2. C.** The 10% rule applies at each transfer. Producers hold 20,000, so primary consumers get about 2,000, and secondary consumers get about 200. B stops after one transfer and reports the primary consumer level. D applies the rule three times, which would be the tertiary consumer level. A ignores the rule entirely.
- 3. B.** Phosphorus reservoirs are rock and ocean sediments, and phosphorus enters ecosystems as rocks weather. It has no significant gaseous phase. A describes denitrification, which releases nitrogen (N₂), not phosphorus, into the atmosphere. C confuses phosphorus with carbon, which photosynthesizers do take from the atmosphere as CO₂. D describes the carbon cycle's photosynthesis-respiration loop.
- 4. D.** $NPP = GPP - \text{respiration}$, so $12,000 - 7,000 = 5,000 \text{ kcal/m}^2/\text{yr}$. A adds respiration to GPP instead of subtracting it. B reports GPP rather than NPP. C reports the respiration value alone, which is what is subtracted, not what remains.

One-Page Recall Check

- Define symbiosis and name its three types, stating who benefits and who is harmed in each.
- Explain why a predator-prey relationship is not classified as symbiosis.
- Distinguish intraspecific from interspecific competition and explain how resource partitioning reduces competition.
- List the major terrestrial biomes and the factors that determine the distribution of terrestrial resources.
- Explain what a biome shift is and what can cause one.
- Distinguish freshwater from marine biomes and name the factors that determine marine resource distribution.
- Define a carbon source and a carbon sink, and explain how burning fossil fuels moves carbon between them.
- Describe the steps of the nitrogen cycle and explain why fixation is the bottleneck for plant nitrogen uptake.
- Explain why phosphorus has no significant atmospheric component and where its major reservoirs are.
- State what powers the hydrologic cycle and name the primary water reservoir.
- Define GPP and NPP, give the equation that relates them, and state the units of productivity.
- Explain how light penetration limits aquatic photosynthesis.
- Contrast the direction of energy flow with the cycling of matter.
- Apply the 10% rule across two trophic transfers and explain the thermodynamic reason for the loss.
- Distinguish a food chain from a food web and explain the role of detritivores and decomposers.
- Define negative and positive feedback loops in a food web.

Where to go next. Turn every missed item above into flashcards and drill them spaced out over several days rather than in one sitting. In Rycal, open the AP Environmental Science deck. The deck covers the terms in this guide, and its practice questions target the same traps named here. If you have a test date, add it in the Test Planner. You can also start your next review with a Brain Dump, then check what you missed against this guide.

Key terms for this unit

Predator-prey relationship, Symbiosis, Mutualism, Commensalism, Parasitism, Competition, Resource partitioning, Biome, Major terrestrial biomes, Distribution of terrestrial resources, Biome shifts, Freshwater biomes, Marine biomes, Distribution of marine resources, Carbon cycle, Carbon sources and sinks, Photosynthesis and respiration, Fossil fuel carbon release, Nitrogen cycle, Nitrogen fixation, Nitrogen limitation, Atmospheric nitrogen reservoir, Phosphorus cycle, Phosphorus reservoirs, Phosphorus as a limiting nutrient, Hydrologic (water) cycle, Ocean water reservoir, Primary productivity, Gross primary productivity (GPP), Net primary productivity (NPP), Units of productivity, Light and aquatic photosynthesis, Energy inflow requirement, Conservation of matter, Direction of energy flow, 10% rule, Thermodynamics and energy loss, Food chain, Food web, Detritivores and decomposers, Feedback loops in food webs.

About this guide. Written for Rycal and aligned to the College Board AP Environmental Science course framework, Unit 1. All questions and explanations are original Rycal writing. Rycal is independent and is not affiliated with or endorsed by