# CHAPTER 4 EVOLUTION, BIOLOGICAL COMMUNITIES, AND SPECIES INTERACTIONS

## Chapter Overview

This chapter contains four main ideas from the AP course outline. Evolution, species interactions, community structure and ecological succession account for about 5-10% of the material on the AP exam. Students need to show knowledge of evolution and natural selection, how species interactions shape community structure and how ecosystems renew after a disturbance.

## Topics and Key Concepts

The Living World

- Discuss the difference between niche and habitat.
- Categorize the types of species interactions based upon the impact of the two organisms. Include predation, commensalism, mutualism, parasitism, and coevolution in your analysis.
- Analyze the role of keystone species in an ecosystem.
- Delineate the tenets of the theory of natural selection.
- Illustrate and label a range of tolerance curve.
- Compare and contrast primary and secondary succession. Explain the term climax community in the context of a biome.

Land and Water Use

- Explain how disturbance can affect an ecosystem. Cite specific examples of disturbance adapted species.

Global Change

- Summarize the differences in the types of spatial distribution of living organisms.
- Explain the relationship between ecotones and edge effects.

## Key Terms

abundance
adaptation
allopatric speciation
Batesian mimicry
climax community
coevolution
commensalism
disturbance
ecological niche
ecotones
edge effects
endemic species
evolution
generalist
geographic isolation
*gross primary productivity
habitat
*indicator species
interspecific competition
intraspecific competition
keystone species
Müllerian mimicry
mutations
mutualism
natural selection
*net primary productivity
parasitism
pioneer species
predator
predator-mediated competition
primary productivity
primary succession
principle of competitive exclusion
resource partitioning
secondary succession
*selective pressures
symbiosis
sympatric speciation
tolerance limits

* *These key terms are not boldfaced in the chapter text, but are still important for the AP Exam.*

## Pacing Guide

Plan to spend 8-10 days on this chapter.

## Approach and Tips

Stress that Darwin's theory of natural selection explains why species become more suited over time to their environment, as they undergo adaptations due to selective pressures. Remind them that change takes place very slowly over several generations. Stress that an organism cannot "evolve," nor can it want to adapt. Emphasize that mutations that occur only in gametes are passed on to offspring. Over time, selective pressures modify populations so they are better adapted for the environment. Using the example of the squirrels separated by a canyon, explain how a population that is isolated can change enough to become different species. Finally explain how evolution is an ongoing process.

A good approach to covering many of the concepts in this chapter is to use activities. Activities that involve discovery and inquiry will prove to be the most valuable.

An activity using different kinds of beans goes a long way in having the students discover/realize the concept of natural selection. Using various backgrounds and trying to eliminate all variables other than coloring the beans effectively mimic insects of varying coloration. Essentially the students discover that the "insects"

with a coloration that blends in with the background are the ones that survive to reproduce.

Why do living things live in certain areas? How do they interact with each other and the environment? To answer these questions, abiotic factors can also be investigated. Pill bugs are a great organism to use. They are fairly innocuous and most students have seen them. The students also have some idea where they live. Students design inquiry based labs to determine the abiotic factors that pill bugs prefer.

If possible, have students collect data on community structure using an outdoor area, such as a grassy area or even a playing field. Using one meter square quadrats, stake out the area. Identify 4-5 different species of grasses/weeds by using common or simple names. Have students count the number of different species in each quadrat. Species diversity, abundance and density can be calculated. Another approach is to have students toss out a paper plate like a Frisbee. Have students draw the distribution of the members of the population under the paper plate and determine if the pattern is random, uniform, or clustered. Ask students to explain why a park or field would have fewer species and be more organized in the distribution of organisms.

Understanding of the basic terminology used to describe ecosystems and ecosystem interactions can be accomplished by using examples. Organisms are heterotrophs or autotrophs. Heterotrophs include herbivores, carnivores, omnivores, detritivores and decomposers. Use examples of each category to explain these terms. Recall the food webs/food chains from the previous chapters. If students know that an organism's habitat is simply its address and that its niche is its job, students should be able to connect habitat and niche to almost any organism named. Stress the Competitive Exclusion Principle and the idea of resource partitioning. In addition, the importance of umbrella species, charismatic species, flagship species, indicator species and keystone species are vital concepts for the AP exam. Knowing examples of each will help students understand these concepts.

Through the process of succession, organisms modify the environment. Explain to the students that there are two kinds of succession; primary succession and secondary succession. If you have access to outdoors, show students lichen either on rocks or trees and explain its role as a pioneer species in primary succession. Discuss this process of modification and have students explain how a living thing can change an abiotic factor. You may need to refer the student back to previous knowledge of nutrient cycling and energy flow. Emphasize that the culmination of the succession process forms a climax community. Finally discuss the importance of invasive exotic species. Using examples, either local or national, discuss the ramifications of introducing a non-native species. Be sure to

emphasize that many non-native species outcompete the native species and become invasive. Examples of invasive species in the United States include the zebra mussel, hydrilla, water hyacinth, European starling, nutria, Burmese python, and lionfish.

Devote additional time to species interactions: predation, symbiosis, and parasitism. Later in the course, students will need this knowledge when investigating pests and pesticides, nature preserves, and sustainable development. Knowing the difference between a generalist and a specialist species should be learned. Start by talking about a cockroach and a giant panda. What do they eat? Where are they found? Eventually, the students will be able to put together the idea of generalist vs. specialist. Basic species interactions, such as, predator/prey, symbiosis, and parasitism, need to be introduced citing specific examples. Explain how predator/prey relationships have led to coevolution.

Primary productivity is the rate of biomass production. Explain how productivity is related to abundance and diversity. Make sure students understand that abundance is the total number of organisms in a community and that diversity is the measure of the number of different species. Quite often, abundance and diversity are inversely related. Using pictures of species ask the student how those organisms are arranged, clustered, uniform, or random. This should lead to a discussion of spatial distribution. These patterns of distribution are what define the ecological structure of a community. Explain that the ecological structure is determined by the physical environment and by biological interactions. Using your pictures from before, ask students to explain the environment and the interactions that might take place in each community. An edge effect can be either gradual or distinct. Stress that abiotic factors, such as temperature and wind, differ at these boundaries.

## Common Mistakes and Misconceptions

Students often don't understand natural selection and the concept of adaptations. Students may confuse natural selection with evolution, and the difference needs to be addressed. Also, some students will resist the concept of evolution, but the term natural selection is less polarizing. Make sure that you provide several examples of how natural selection takes place and the role of adaptations of organisms in nature.

## Activities

Several natural selection activities are available in the College Board Publication Special Focus: Ecology.

http://apcentral.collegeboard.com/apc/public/repository/Environmental_Science_Ecology_Special_Focus.pdf

**Population Size Activity**

A good activity for this chapter is to have students do a sampling technique in the classroom to learn how to determine population size. Many items can be used such as goldfish crackers, beans, candy (M&M's, Skittles), etc.

Explain to the students that the best way to determine the species of plants or animals living in an area would be to count each and every one. However, that is usually impossible, especially if the item being counted is an animal that moves. So, instead scientists use the Lincoln Index to estimate population size.

Knowing population size is important in protecting ecosystems. The size of populations can tell the scientist if there are invasive species in the area, if an animal or plant is becoming scarce, and it can help determine if an environmental decision needs to be made to protect the area.

Using a mark and capture technique is one way to estimate animal populations. The idea behind this method is to capture a portion of the population, tag them and re-release them into the wild. You sample the population later to see how many you "catch" that are tagged and how many new individuals you caught. Using a formula you then estimate the population size. Knowing three of the four values; recapture size ($N_2$), number marked in first "catch" ($N_1$ ), and the number marked in the recapture sample (R), you can estimate the population size (P). This method is called the Lincoln Index.

$$P = \frac{(N_1)(X)(N_2)}{R}$$

P = Size of the population
$N_1$ = Size of the first sample (all marked)
$N_2$ = Size of the second sample (recapture)
R = Number of marked individuals recaptured in second sample

Have students perform this activity by handing out the worksheet located at the end of this teacher's manual chapter.

**Estimating Population Size**
An additional activity on sampling and estimating population size can be found at the end of this chapter.

**Natural Selection Activity**

In this exercise the students will simulate natural selection using beans that represent "beetles" in two environments. The "beetles" will be easy or hard to find depending on how well they can be concealed by the environment. If they are successful (not eaten by a predator) they will be able to produce more offspring with the same advantageous trait.

Navy, great northern, pinto and kidney beans are the beetles. Each group of 2 students will be given 30 beans, 1o of each of 3 types. The students will be given 2 environments. For example, the environments could be grass, sand pit, asphalt, concrete or red brick. The students spread the 30 beans over 1 square meter. One student is the predator. As the predator, he/she captures 20 beetles, trying to pick the most obvious ones. For each of the ten remaining beetles add 2 more of that type (offspring). Repeat the process for 3 generations.

For each environment or habitat have the students address the findings. They should be able to explain natural selection and which "beetles" were successful.

Have students complete this activity by handing out the worksheet located at the end of this teacher's manual chapter.

**Mechanism of Evolution Activity**

This activity is very similar to the Natural Selection activity; however, it includes the four major mechanisms of evolution that include: natural selection, genetic drift, gene flow, and mutation. A minimum of four groups is required to represent each mechanism. Each group will begin with a total of 100 M & M's. Count out 40 brown, 20 orange, 20 yellow, 10 green, and 10 red. Students should record the frequencies for each color M & M in a data table. For the natural selection group, students should remove half of the brown M & M's to represent natural selection against the brown M & M's. To illustrate genetic drift, the group should place their candies in a brown paper bag and remove 80% of their candies to represent a population crash. The gene flow group will add 20 yellow and 20 orange M & M's to illustrate immigration. The last group will remove 10 brown candies and replace them with aqua M & M's to illustrate mutation. Once each mechanism has occurred, students need to recalculate their frequencies and record in a data table. If time allows, reproduction could also be simulated by adding the same color of M & M's to their bag. Students should determine how the frequencies will lead to evolution over long periods of time.

The teacher should stress that in order for a species to be successful (ie…adapt and evolve) the species must reproduce or illustrate biological fitness. Biological

fitness is a relative measure of reproductive success of an organism in passing its genes to the next generation.

**Fossil Record Activity**

Create a geological time scale by providing students with calculator tape or butcher paper, with a total of 5 meters of paper. Have students draw a line through the middle of their paper, and create a key where one centimeter = 10 million years. . Students should label the time frame and the major appearance and disappearances of organisms for each. Use table included at the end of this chapter as a reference, or search for "University of Wisconsin geological time line activity" for a more detailed lesson.

**Succession at your High School Activity**

Have students identify examples of primary and secondary succession occurring on school grounds. Students can record their examples by taking photos with digital devices or making sketches. While students take photos, they should keep in mind that the photos taken should be representative of the chronological changes that occur during succession. Each photo should represent early, middle, late and climax communities.
The goal of the activity is to have students place their photos in a series that illustrate a story of how succession took place at their school. Students can be given a data table to complete in which they explain the individual changes that occurred in each photo. Once students have placed photos into a storyboard, then they should explain what the area resembled 10 years before and what the area would resemble 100 years later.

**Aquatic Succession**

Provide students with an image of a pond undergoing eutrophication. Students should describe the changes and discuss a rationale as to why the pond has overgrown with plant material. Students should place the following steps in chronological order of the succession of the pond.

Nutrients enter a pond
Increased decomposition
Plants die
Fish and other organisms die
Oxygen is depleted
Excessive algae growth
Sunlight is blocked

Students should also be able to relate the nitrogen cycle to the changes in the pond. Revisiting the steps of the nitrogen cycle would be a great benefit to students**.**

## Questions for Review

1. White moths and black moths can be found on trees covered with lichen. Birds prey on the moths for food. Which moths will have a better chance of survival? How does this example illustrate natural selection?
   *The white moths will have a better chance of survival because they will blend in with their surroundings making it harder for the birds to see. This is an example of natural selection because this coloration trait will allow this species to thrive and to reproduce.*

2. What are two adaptations that help organisms avoid predators?
   *Adaptations the help organisms to avoid predators could be coloration that allows an organism to blend in with its surroundings (camouflage), speed to run its predator defensive protection such as spines or thorns.*

3. What are the three types of symbiotic relationships? Give an example of each type.
   *The three types of symbiotic relationships are parasitism, mutualism and commensalism. An example of parasitism is a tapeworm living inside the digestive tract of a mammal – the tapeworm benefits at the expense of the host. An example of mutualism would be lichen since it is a fungus and an alga living together where both benefit. An example of commensalism is moss growing on a tree. The moss benefits but the tree is neither benefited nor harmed.*

4. A sea otter is often referred to as a keystone species. What is the role of a keystone species with specific reference to the sea otter? Also, what would happen to the sea urchin population if the sea otter is removed from the ecosystem?
   *Keystone species play a critical role disproportionate to their abundance in their environment. With reference to the sea otter, the sea otter keeps the sea urchin population in check. Without the sea otter eating the sea urchins, the kelp forests would cease to exist and the ecosystem would collapse.*

5. How does spatial distribution affect community structure?
   *Since spatial distribution is determined by the physical environment and the biological interactions that take place within the environment, patchiness may be the result of the community structure. This is because spatial distribution may be clustered, random, or uniform.*

6. How can edge effects be either gradual or distinct?
   *A border between two communities can be extremely distinct. For example it is clear where a forest begins and an agricultural field ends. A border*

*between two communities may not be very distinct; almost like a blending of two communities.*

7. What is ecological succession? What are the differences between succession that starts with bare rock and one that starts after a wildfire has moved through an area.
   *Ecological succession is the history of the biological communities in an area. Organisms occupy an environment and change environmental conditions. Succession that starts with bare rock is primary succession. It begins with lichens and mosses colonizing bare rock and aiding in the formation of soil. Secondary succession takes place after a disturbance, such as a wildfire. The soil remains and species colonize the soil.*

## Practice Questions

<u>Multiple Choice:</u>

*Directions questions 1-5:* The lettered choices below correspond to the descriptions given in questions 1-5. Select the one lettered choice that best fits each statement. Each choice may be used once, more than once, or not at all.

(A) Secondary succession
(B) Primary succession
(C) Climax community
(D) Pioneer species
(E) Disturbance

1. Mosses or lichens

2. The re-growth of plants after an agricultural field is abandoned

3. A forest fire

4. A temperate deciduous forest

5. Growth of organisms after a volcanic eruption

*Directions:* For each of the following questions, select the one lettered choice that best answers the question.

6. A deer tick on a dog is an example of ____________________
   (A) parasitism
   (B) commensalism
   (C) mutualism
   (D) predation
   (E) symbiotic relationship

7. The functional role of a species in its environment is its ________________.
   (A) habitat
   (B) niche
   (C) trophic level
   (D) natural selection
   (E) indicators

8. Several species of warblers live in the forest and feed on insects at different levels within the forest. This is an example of _____________.
   (A) adaptation
   (B) natural selection
   (C) ecological niche
   (D) allopatric speciation
   (E) resource partitioning

9. Ruby throated hummingbirds fight over access to a flowering plant species. This demonstrates _______________.
   (A) resource partitioning
   (B) competitive exclusion principle
   (C) interspecific competition
   (D) intraspecific competition
   (E) symbiosis

10. Which of the following illustrates a clustered population distribution pattern?
   (A) Rows of corn in a cornfield
   (B) A pod of dolphins resting in a bay
   (C) Osprey nesting near the shoreline
   (D) Penguins nesting on the shore
   (E) Dandelions in a soccer field

<u>Free-Response Question:</u>

*Directions:* Answer all parts of the following question. Where explanation or discussion is required, support your answers with relevant information and/or specific examples.

1. Beavers build dams in rivers and are considered a keystone species.
   (a) Identify the beaver's habitat and its niche.

   (b) Describe the type of freshwater ecosystem that results when the beaver dams the river.

   (c) Explain why a beaver is considered a keystone species.

   (d) Suppose the beaver becomes extinct. What might happen to the ecosystem in the absence of the beaver?

   (e) Name and describe one United States federal law that is intended to prevent the extinction of species.

**Answers to Practice Questions**

Multiple Choice:

1. D
2. A
3. E
4. C
5. B
6. A
7. B
8. E
9. D
10. B

Free-Response Question:

This question is a total of 10 points.

1. (a) 2 points total. 1 point for identifying the habitat as the river and riparian area and 1 point for identifying that the niche is the building of dams to make a pond.

   (b) 2 points total. 1 point for describing the holding back of water and 1 point for the resulting pond.

   (c) 2 points total. 1 point for explaining the nature of a keystone species. Beavers play a critical role in the ecosystem. By damming a river or stream they provide a habitat in the form of a pond. 1 point for explaining the role of the beaver in creating an environment for other species.

   (d) 2 points total. 1 point for describing that the ponds would cease to exist and 1 point for describing how the organisms that rely on those ponds would be affected. If there were no ponds, migratory species of birds would not have a place to nest.

   (e) 2 points total. 1 point for the name and 1 point for the description. The Endangered Species Act which protects endangered species and their habitats.

## Answers to questions in the Student Edition:

### Case Study AP Document-Based Question (page 74)

(A) Darwin would have to rule out the following before being able to determine that competition for limited food resources drove natural selection on the Galapagos Island: 1) physiological stress due to environmental tolerance limits, 2) competition, 3) predation.

(B) Natural selection can be X, Y, or Z. Darwin's finches experience Q type.

(C) Darwin knew about the the idea of "survival of the fittest" from the work of Malthus in *Essay on the Principle of Population*, which allowed him to borrow the idea of food scarcity checking human population growth and apply it to finches. This led to his proposal that individual finches were the best competitors when they had traits most suitable for the environment they lived in, and that these individuals survived to increase the presence of that trait in their population.

### Use the Math (page 87)

Close to 2,000 kcal/$m^2$/year of biomass accumulates in the tundra, and between 4,000 and 5,000 kcal/$m^2$/year accumulates in coniferous forests. Rainforests accumulate much more each year: around 20,000 kcal/$m^2$/year. One driver behind these differences is solar energy: the more sunlight available, the more primary producers can grow. Other factors, such as rainfall and available nutrients also play a role in biomass accumulation.

## AP Connections Review Answers (pages 30-32)

### Multiple-Choice

1 d. The red-winged blackbirds are filling their realized niche, as they are driven from their fundamental niche by the yellow-headed blackbird. The terms classical and competitive niche are not used. The ecological niche is the role played in the community.

2 c. Survival of the fittest explains that the most suited (the darker moths) would predominate as the other moths die out because they are eaten before they can reproduce. Mutations are random and are not induced by the presence of a chemical, nor because the organisms decide to mutate. There is no evidence in the question that the dark moths are able to outcompete the lighter moths for resources or mates.

3 c. convergent evolution. Coevolution is based on predator-prey interactions. Adaptive radiation means they would not have similar adaptations because they have filled different niches. Homologous and analogous structures are not concepts.

4 d. The hardwoods will tolerate some conifers in a late successional forest. Grasses would predominate in the early successional stages, and biodiversity is greatest later in succession. A pine forest community inhibits the growth of the hardwoods because they acidify the soil, and lichens facilitate grass growth because they help to make soil from bare rock.

**Data Analysis and Free-Response Questions**

1A After 24 days of growth in a mixed population, the volume of *P. aurelia* was approximately 150 micrometers$^3$; the volume of *P. aurelia* grown separately was about 210 micrometers$^3$. There was a (210 - 150)/[(210 + 150)/2]*100 = 33% difference between the volume with more growth exhibited by the species when grown separately.

1B The rate of decrease in cell volume is equal to the slope of the “in mixed population” line for *P. caudatum. This* is approximately (25 – 110)/(24 – 8) = -5.3 between days 8 and 24.

2A Competive exclusion means that no two species can occupy the same ecological niche for long. The species that is more efficient in using available resources will exclude the other.

2B *P. aurelia* is the stonger competitor. Reasons include that both species grew to similar volumes when separate, but when together, the volume of *P. caudatum* decreased faster and stayed low, while the volume of *P. aurelia* increased for longer and stayed level after around 14 days.

2C Answers may vary, but should talk about one of the following scenarios – either *P. caudatum* would be wiped out of existence by the stronger competitor or would adapt through resource partitioning.

## Population Size Activity

*Student:*__________________________________________________________

Materials: 50 dried white beans, permanent marker, butter tub w/ lid

Procedure:

1. Mark 20 of the beans with the marker.
2. Place the 50 dried beans in the container and withdraw 10 beans from random.
3. Record the number of marked beans you "caught" in the table.
4. Put the beans back into the container, put the lid on, and shake the container.
5. Again, sample the container recording how many marked beans you caught.
6. Continue to do this until you have sampled 10 times.

DATA:

| Trial # | # marked beans in sample | population estimate |
|---|---|---|
| 1 | | |
| 2 | | |
| 3 | | |
| 4 | | |
| 5 | | |
| 6 | | |
| 7 | | |
| 8 | | |
| 9 | | |
| 10 | | |

7. Now find the population size estimate for each sample by multiplying all the number of originally marked beans (20) by the number of each sample (10) and dividing that number by how many marked beans you "caught" each trial. This gives you a sampling size for each trial.
8. Finally divide the samples by 10 to get an average of the population size.

**Conclusions:**

1. You know the original population size was 50 beans. How close to the actual population size did your estimation get?

2. Why was your estimation not exact?

3. What problems would real animals pose to a scientist while he/she was out sampling a population?

4. In what ways does the fact that animals do not always stay scattered evenly in an environment cause the population estimates to vary?

Devise away to test this sampling technique out in the wild.

## Natural Selection Activity Worksheet

*Student:*____________________________________________________________

Materials:

10 of each bean (pinto, navy, kidney or great northern) 30 beans total
Extra beans for offspring
Plastic bag

Procedure:

1. Have your teacher assign two different environments for your experiment.
2. Take your 30 beans to one of your assigned environments. Spread them over a 1 meter square area.
3. One student will be the predator and will capture 20 beetles (beans), trying to pick the most obvious ones. Place the beans collected in the plastic bag.
4. For the each of the remaining 10, add 2 more of that type. These are the offspring of the survivors.
5. Repeat 2 more times.
6. Repeat #1-5 for a second environment.

Data Table:

Environment 1 ____________________________________

| Generation | # of pinto/ kidney | # of navy | # of Great Northern |
|---|---|---|---|
| **1st generation initial population** | 10 | 10 | 10 |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| **2nd generation (add # remaining + # offspring)** | | | |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| **3rd generation (add # remaining + # offspring)** | | | |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| Final Population **(add # remaining + # offspring)** | | | |

Environment 2 ______________________________________

| Generation | # of pinto/ kidney | # of navy | # of Great Northern |
|---|---|---|---|
| **1st generation initial population** | 10 | 10 | 10 |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| **2nd generation (add # remaining + # offspring)** | | | |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| **3rd generation (add # remaining + # offspring)** | | | |
| # captured | | | |
| # remaining | | | |
| # offspring | | | |
| Final Population **(add # remaining + # offspring)** | | | |

Conclusions:

1. For each environment, which population, if any, was successful? Why or why not?

2. What role, if any, did the coloration of the beetles play?

3. How does this activity exemplify the idea of Natural Selection?

## Five Major Extinctions and Future Extinction

**1. Cretaceous-Tertiary extinction, ~65 million years ago**
- **asteroid**
- 17% of families, ½ of species extinct, **including dinosaurs but not mammals**, **over a time period of 100,000 years.**

**2. End Triassic extinction**, ~ **205 million years ago**
- **massive floods of lava**; may have led to deadly global warming
- 23% of all families, ½ of species extinct

**3. Permian-Triassic extinction, ~240 million years ago**.
- **comet or asteroid impact?** flood volcanism and related loss of oxygen in the seas?
- **Earth's worst mass extinction** - 90% of all species, 54% of all families

**4. Late Devonian extinction**, ~ **370 million years ago**
- cause unknown
- 19% of all families

**5. Ordovician-Silurian extinction**, about **444 million years ago**,
- drop in sea levels as glaciers formed, then by rising sea levels as glaciers melted
- 25% of all families

Extinction Rates:
- Pre- Humans: about 1 species per year per million species = 0.0001% per year
- Current rate 0.1% (best estimate): 1000x the rate before humans
- Rates of loss are exponentially multiplied over periods of 100 years or more

Biologists consider the loss of 1 million species over <u>100-200 year period an extinction crisis/spasm</u> that would lead to a mass depletion/extinction if kept up
- At rate of 0.1% and estimated 14 million species:

  How many species do we lose a year?
  Answer: 14,000 species/year
  How long before we lose 1 million species?
  Answer: 71 years