# Lab 11: Adaptations

## Purpose

To infer the function of adaptive traits using empirical evidence and theoretical analysis.

## Learning Objectives

At the conclusion of this exercise, students will be able to:

* Observe examples of adaptations from the plant and animal kingdoms addressing aquatic, terrestrial, and variable environmental constraints,
* Use research and inference to describe the function of adaptations, and
* Hypothesize the selective pressure(s) that might have favored a certain adaptation.

## Why It’s Relevant

The environment poses challenges that limit an organism’s ability to survive. Adaptations serve as solutions to these constraints, helping species thrive in their surroundings. Studying adaptations reveals how organisms overcome survival challenges, providing clues that help scientists solve agricultural, medical, and environmental challenges.

## Introduction

The struggle for existence is alleviated by organisms’ tendency to evolve characteristics that are complementary to their environment. Demonstrated by Charles Darwin’s work on Galapagos finches, individuals possessing features that are closely matched to their environment have a higher likelihood of leaving offspring. This is called differential reproductive success, and it determines which traits are most likely to become common in a population. Traits that enhance an individual’s reproductive success are called adaptations. Heritable genetic variation in populations creates a pool of traits from which adaptations may arise through natural selection. Traits are neither good nor bad, until acted upon by the environment. Thus, any trait can potentially be an adaptation when selected favorably by the environment. Selection is a dynamic process and traits that are a good fit during a particular timeframe are not guaranteed to persist when environmental changes occur. For example, earth has experienced five mass extinctions related to environmental change, and the fossil record indicates that each event brought about considerable changes to species composition. In essence, the only constant on earth is change.

New traits arise when gene expression is changed, as may be the case in mutations, epigenetic modifications, and changes to chromosome number. The genetic code may change randomly or at regular intervals, producing genetic diversity, the basic fabric of all adaptations. The environment can also influence which traits function as adaptations, such as when environments change or due to species interactions. Traits favored by the environment are said to be “selected for” while those that are rejected are “selected against.”

Since environments can change rapidly, no trait is universally known to be advantageous or deleterious. Thus, adaptations are best described as tradeoffs because as traits achieve a greater match to a specific environment, they may experience diminished benefits in alternate environments. Adaptations may even have tradeoffs from inception. For example, the extremely moveable human shoulder joint permits tremendous dexterity, but is very prone to injury. Furthermore, not all traits are adaptive. Consider the large plumage of male peacocks. While this trait increases their reproductive success with mates, it is maladaptive because it makes them more conspicuous to predators.

Adaptations may be morphological, behavioral, or physiological. They might be related to obtaining food or water, defending against predators, finding a mate, or coping with abiotic environmental stress. For example, cacti have many adaptations for living in a dry environment, such as a waxy covering that prevents water loss and a pleated shape that allows for the cactus to expand when water is available to absorb. Adaptations may also involve behaviors. For example, many desert animals are only active at night, a behavioral adaptation that protects them from high daytime temperatures.

It is useful to study adaptations because they help us understand the evolutionary history of life and may provide insight that allows us to solve problems. The genetic editing tool CRISPR was developed based on a virus-fighting adaptation discovered in *Escherichia coli* (Gostimskaya I, 2022). This early iteration in evolution of the immune system saw bacteria and other ancient organisms acquire special proteins that can execute a “cut and paste” function on foreign genetic material. Scientists have discovered a way to control these molecular scissors to edit the genome at will to cure disease. In this exercise, you will investigate adaptations in organisms found in a variety of environments and make inferences about how they enable survival.

## Part A. Life in Water

### Materials

* An internet connection
* Microscope
* Lab specimens

### Procedure

1. Working in groups of 2-3, review and respond to each “research and present” and “observe and analyze” activity in your lab report, then complete **Table 11.1** by classifying each adaptation as structural, behavioral, or physiological. Your instructor may assign a specific number of activities for you to complete based on the time available.
2. Prepare a group presentation explaining three adaptations using information you gathered from your “research and present” responses. Your goal is to describe how these adaptations help the organism survive in its environment. Include the following in your presentation for each species:
	1. Introduce the species you have chosen.
	2. Provide brief background information (habitat, role in the ecosystem, and other pertinent details, i.e., diet/reproduction).
	3. Clearly describe each adaptation.
	4. Explain how each adaptation helps the organism survive in the environment where the organism is found.
	5. Hypothesize the environmental conditions and/or selective pressures acting on the adaptation.

Before you begin, list some challenges of living in an aquatic environment in your lab report. In other words, what might make it difficult for life to survive in water?

#### A.1 Research and Present

Aquatic organisms must solve the metabolic challenges imposed by living in water. Most life-forms use chemicals available in water and air to generate energy. Aquatic environments lack air and thus gases critical to growth are often limited. Adaptations that solve problems posed by the lack of air in water may be found in anaerobic and parasitic organisms. Identify an adaptation found in an aquatic organism that is anaerobic or parasitic.

#### A.2 Observe and Analyze

##### Specimen #1—Prepare a wet mount of the water lily *Nymphaea (*alternatively you may view a prepared slide).

1. Using a scalpel, remove a small section of a leaf from *Nymphaea.*
2. Place the leaf on a microscope slide with the lower surface facing the objective lens. Make your observations using the high power (40X) objective lens (400X total magnification).
3. Observe the stomata and count the number of stomata in the field of view. Note the magnification used to perform the count.
4. Calculate the number of stomata per square centimeter of the *Nymphaea* by performing the following calculations (review the microscope lab if a refresher on calculating the diameter field of view is needed):
	1. Calculate the diameter field of view at 100X total magnification in mm
	2. Calculate 
5. Repeat steps 1-4 with the upper surface facing the objective lens.
6. Are the stomata most abundant on the upper or lower surface of the leaf?
7. Calculate the percentage difference between the upper and lower surfaces of the leaf. Start by subtracting the lower surface value from the upper surface value. Then, divide that difference by the lower surface value. Multiply by 100 to obtain the percentage value.
8. Develop a hypothesis to provide a possible explanation for a difference, if observed.
	1. Hypothesis:
	2. How could your hypothesis be tested?
9. In addition to stomata, certain plants manage gas exchange using air pockets found in leaves and stems. Air pockets are more commonly found in plants that live in aquatic environments where gas exchange is limited. What difference in the number of air pockets would you expect to see in an aquatic plant like a water lily compared to a terrestrial plant?
10. Examine the tissues of the water lily under the microscope. Pay special attention to the abundance of air pockets. Sketch the appearance in your lab report.
11. Calculate the percentage of the cross-sectional area of the water lily leaf that includes air spaces by dividing the area covered by air spaces by the total area of the cross section.

#### A.3 Observe and Analyze

##### Specimen #2—Examine a prepared slide of the aquatic green alga *Closterium* sp.

1. Describe the location and appearance of the vacuoles.
2. Within each vacuole there are barium sulfate (gypsum) crystals, the purpose of which is unknown. They are hypothesized to be statoliths (involved in balance/orientation of the body), like what one might find in the human ear.
3. Use your observations to come up with a hypothesis explaining the arrangement, position, and structure of the vacuoles and their relationship to the gypsum crystals.
4. How would you test this hypothesis?

#### A.4 Research and Present

Certain fish have adapted gill structures that establish and maintain a gradient that increases gas exchange between their body and the environment. Describe and draw the adaptive features of gills that support gas exchange in your lab report. Are gills the only structures fish use to exchange gas with the environment? Explain.

#### A.5 Observe and analyze

##### Specimen #3—Examine a prepared slide of Daphnia (water flea) or Cyclops (copepod) gills.

Describe the gill structures. How are these structures like or different from those found in fish?

#### A.6 Research and Present

Aquatic organisms employ different strategies to float in the water column. Why might floating be an adaptive trait? In your lab report, describe and draw 2 adaptations designed to support buoyancy in the water.

#### A.7 Research and Present

Deep-sea creatures must deal with the lack of light availability. Describe an adaptation found in an aquatic organism that deals with the challenge of low light availability or exploits the lack of light to its advantage.

#### A.8 Research and Present

Freshwater and saltwater environments can be highly toxic to life. Discuss an adaptation found in an aquatic organism that counteracts the dangers of living in hypotonic or hypertonic environments.

#### A.9 Observe and analyze

##### Specimen #4—Examine a prepared slide of paramecium.

What function does the contractile vacuole play?

#### A.10 Research and Present

Mangrove trees grow on coastal mudflats that are inundated by saltwater during high tides. Describe adaptations of one plant and one animal that enable survival in these environments.

## Part B. Life on Land

Before beginning, list some challenges of living in a terrestrial environment that might be solved by adaptations. Compare the list of terrestrial constraints to the aquatic constraints you documented in part A.

#### B.11 Observe and analyze

##### Specimen #5

Prepare a wet mount slide of *Tradescantia zebrina* (inch plant) leaf cross section that shows common structural adaptations for gas exchange. Locate the stomata (pores) that allow gas exchange at the leaf surface.

1. Using a scalpel, remove a small section of a leaf from *Tradescantia*.
2. Place the leaf on a microscope slide with the lower surface facing the objective lens.
3. Observe the stomata and count the number of stomata in the field of view. Note the magnification used to perform the count.
4. Calculate the number of stomata per square centimeter of the *Tradescantia* by performing the following calculation:
	1. Calculate the diameter field of view at 100X total magnification in mm
	2. Calculate 
5. Repeat steps 1-4 with the upper surface facing the objective lens.
6. Are the pores most abundant on the upper or lower surface of the leaf?
7. Calculate the percentage change between the upper and lower surface of the leaf. Start by subtracting the lower surface value from the upper surface value. Then, divide that difference by the lower surface value. Multiply by 100 to obtain the percentage value.
8. Develop a hypothesis to provide a possible explanation for this phenomenon.
	1. Hypothesis:
	2. How could your hypothesis be tested?
9. Examine the tissues of the inch plant under the microscope and compare them to your drawings of the water lily cross section.
10. Notice that the leaf interior is not a solid mass of cells. What percentage of the cross-sectional area is open space for gas movement? Be sure to examine three or four prepared slides to provide an accurate estimate.
11. Calculate the percentage of the cross-sectional area of the inch plant leaf that includes air spaces by dividing the area covered by air spaces by the total area of the cross section.
12. Is there a difference in the percentage of stomata between the aquatic water lily and terrestrial inch plant you observed?
13. Do the tissues of the terrestrial plant appear to be structurally different from those of the aquatic plant you observed earlier? If so, explain how.
14. Explain the conclusion you have drawn from your data in your lab report.

#### B.12 Observe and analyze

##### Specimen #6

Examine lenticels on fruit surfaces, such as mango, apple, avocado, or a prepared slide of an elderberry stem (*Sambacus*).

Lenticels are raised pores in the stem of a woody plant or on fruits that allow gas exchange between the atmosphere and the internal tissues.

1. Describe the shape and arrangement of lenticels. Do they appear to be adaptive for gas exchange? Why or why not?
2. View the cortical (cortex) tissue, which lies between the epidermis (surface cells) and vascular (conducting) tissues. Are the cortex cells just inside the lenticels loose with small air spaces?

#### B.13 Observe and analyze

##### Specimen #8—Examine a cross section of a pine (*Pinus*) or basswood (*Tilia*).

The stems of trees are rarely photosynthetic.

1. If not directly for photosynthesis, why do you think trees have stems? Does the microscopic cross section offer any clues?
2. How might stems contribute to photosynthesis even while lacking the capacity to perform photosynthesis directly?

#### B.14 Research and Present

Ambient temperature and water availability go hand in hand. High temperatures place limitations on water retention. Describe an adaptation found in a plant or animal dealing with temperature-related water stress.

Would you classify the adaptation as occurring in different spaces (spatial) or over different times (temporal)?

#### B.15 Research and Present

Despite living on land, terrestrial animals must also balance their water/salt balance. Describe an adaptation that specializes in managing a terrestrial animal’s osmotic balance.

#### B.16 Research and Present

Many species of terrestrial ectotherms adjust their heat balance behaviorally. Discuss an adaptation that uses this strategy to manage body temperature.

#### B.17 Research and Present

Blood shunting is an adaptation that has evolved in many ectotherms and endotherms. During blood shunting, blood vessels can shut off at locations called precapillary sphincters so that less of the animal’s warm blood flows out to the extremities, such as the forelimbs and hindlimbs, where the heat would be lost to the cold environment. Describe an animal and the conditions under which it utilizes blood shunting to maintain optimal core body temperature.

## Part C. Adaptations to Variable Environments

How might variation in seasonality, habitats, predators, and competitors pose significant challenges to an organism’s survival?

#### C.18 Research and Present

Access to food is a persistent challenge for most animals. Searching for food requires significant energy expenditure. The Burmese python (*Python bivittatus*) exhibits a phenotypically plastic adaptation that allows it to extract more nutrients from food when it is available and conserve energy when it is not. The Burmese python can modify several aspects of its body to do this. Describe and explain the three plastic traits in the Burmese python.

#### C.19 Research and Present

Mate availability can induce hermaphroditism or even asexual reproduction in certain animals. Investigate and describe an adaptation related to mode of reproduction.

#### C.20 Research and Present

Discuss migration as an adaptive strategy. Provide a specific example.

#### C.21 Research and Present

Dormancy is a form of phenotypic plasticity geared toward conserving energy during difficult times. Describe a specific organism that uses dormancy as a strategy for survival. What conditions does this strategy appear to favor?

## Summary Table

Throughout this lab you have discovered how natural selection has shaped available genetic variation. Adaptive features are an organism’s interface with its environment and are subject to strong selective pressures. Identify each adaptation you studied and classify them in **Table 11.1**. Complete the table below summarizing the classification of adaptations you examined.

**Table 11.1: Summary of adaptations.**

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Organism / Species | Type of Adaptation | Adaptation Category | Description | Environment | Variable Environmental Condition | Notes / Comments |
| Example: *Daphnia* | Structural | Gas exchange | Gills adapted for countercurrent exchange for efficient oxygen uptake | Aquatic | Oxygen availability (variable) | Saltwater species, requires low oxygen levels for proper function |
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## Part D. Field Observation

### Local Environments (at least 3 specimens)

The College of DuPage’s natural areas have one land feature and two actively managed biomes, including a freshwater marsh, tallgrass prairie (grassland), and woodland “savanna.” Savannas, also called tropical grasslands, are typically only found in southern latitudes at and below the equator, but on campus they highlight the understory diversity of temperate grasslands that require shade.

#### Instructions

Using the natural areas on campus or a location near your home, observe and identify unique adaptations in 3 specimens. They may be sourced outside (e.g., fallen leaves, flowers, tree bark, insects, birds, fungi, etc.). Develop a hypothesis to describe selective pressures that may have driven the formation of each trait. Provide a sketch of the adaptive trait for each specimen.

## Alternate Procedure for Online Courses

Complete 2-3 “research and present” responses from each part, A through C. Complete part D on your own in your backyard or other natural area. Prepare a group or individual presentation explaining 5 of your favorite adaptations using information you gathered from your “research and present” responses in parts A through C and your field observation in part D. Your goal is to describe how these adaptations help the organism survive in its environment. Include the following in your presentation for each species:

* Introduce the species you have chosen.
* Provide brief background information (habitat, role in the ecosystem, and other pertinent details, i.e., diet/reproduction).
* Clearly describe each adaptation.
* Explain how each adaptation helps the organism survive in the environment where the organism is found.
* Hypothesize the environmental conditions and/or selective pressures acting on the adaptation.

## Questions

1. Identify and describe any two characteristics that may be adaptive in some situations but harmful (maladaptive) in others.
2. Reproduction is a vital process for all organisms. List and briefly describe a few common adaptations in plants and animals that promote successful reproduction.
3. Could it be argued that every trait in existence has some potential adaptive value? Explain.
4. Explain whether the following statement is correct or incorrect: “Giraffes evolved longer necks to promote food acquisition.”
5. If a trait is adaptive, what might prevent a species from becoming increasingly specialized for that trait over time? What is this called?