Lab 7: Animal Diversity

How is diversity in animal form a reflection of function?

Although 1.3 million extant animal species have been named and described, widely circulated estimates suggest that earth currently harbors approximately 10 million different animal species. Even among the small fraction of animal species with which we are currently familiar, tremendous variation in form is apparent. Recall that variation arises as a result of random mutations in the DNA that result in new alleles. These new alleles code for novel proteins, and as a result, novel traits that were not present in the population before. In some cases, the new traits allow individuals to reproduce more than individuals without the trait. The trait may benefit reproduction through the individual's ability to acquire more resources, avoid predation, attract more mates, or out compete others. As a result of reproducing more, individuals with beneficial traits will pass their alleles on to subsequent generations, thus increasing the abundance of those beneficial alleles in the populations. Over millions of years of natural selection favoring the most beneficial traits, we see many instances of organisms that appear to be well suited to their environments. As a result, we observe the broad principle that "form fits function". In other words, the vast majority of phenotypes organisms exhibit are adaptations to either their ancestral or current ecological niches. An organism's ecological niche is the manner in which it lives, including the habitat it occupies and its relationships with other organisms within that habitat.

All animals must deal with substantial challenges to their fitness (i.e., relative reproductive success), and how formidable each of these challenges is for an animal depends upon its ecological niche. All animals must obtain oxygen for respiration and acquire energy and nutrients from other organisms or inorganic sources for cellular maintenance and growth. Additionally, since animals are multicellular organisms, they require systems for transporting resources and wastes and for coordinating the activities of cells and tissues throughout their bodies. As animals inhabit dynamic ecosystems, they must also deal with biotic (e.g., avoid predation and parasitism) and abiotic challenges (e.g., avoid desiccation and maintain thermoregulation). Finally, if these challenges have been overcome, animals must then successfully reproduce, the vast majority of them doing so via sexual means. An animal's relative ability to cope with each of these challenges directly affects its fitness. Since different ecological niches pose unique suites of challenges, and since different animal species have evolved various solutions to these challenges, there exists incredible variability in form within the animal kingdom.

Please recognize that animals do not identify the challenges they face and then adapt to overcome them. Instead, evolution via natural selection acts on heritable variability, and a major source of this variability is the occurrence of random genetic mutations during meiosis. These mutations occur in organisms regardless whether they face unique challenges or not. If mutations result in phenotypes that confer a fitness advantage, they increase in frequency in succeeding generations. If mutations do not confer a fitness advantage, as is true of most mutations, then they decrease in frequency in succeeding generations.

Form and function in four aquatic animals

In this laboratory exercise, your group will dissect four aquatic animals: squid, lamprey, blue crab and sea star. Although each of these animals has an aquatic lifestyle, they have substantially different ecological niches. Below, we have provided you with a natural history account for each of these animals. As you read through the accounts, try to recognize the challenges these animals face given their respective niches, and consider the morphological and behavioral adaptations these animals have evolved to overcome the challenges they face.
**Squid:** Phylum Mollusca, Order Teuthida

Molluscs (snails, clams, octopuses, squids) are composed of four main body regions: a head, a ventral muscular foot, a visceral mass and the mantle. The mantle is a thin layer of tissue that secretes the shell or internal skeleton. In molluscs, as opposed to arthropods for instance, these regions are not marked by clear divisions. In squid, the ventral foot is modified to form the tentacles and arms. Squid have eight arms and a single pair of retractile tentacles, with two rows of suckers on each. In males, one arm is elongated. This arm is used to transfer a spermatophore to a female’s sperm receptacle. The female then uses one of her own arms to fertilize her eggs with sperm in the spermatophore, and then attaches the eggs to an object in the ocean.

Squid live in open, offshore waters and are found at variable depths. They are fast free-swimmers that move via jet propulsion, generating thrust by forcing water through their siphons. They are also capable of emitting ink clouds through the siphons. Additionally, as squid have pigment cells (chromatophores) over most of their bodies, they are able to rapidly change color. Not surprisingly, squid have excellent vision.

Squid mouths contain a formidable predatory beak, a 'toothed' tongue (radula), and their saliva contains a poisonous secretion. Squid predate on fish, shrimp, crabs and other molluscs. Their primary predators are fish, although the giant squid is a common prey animal of sperm whales.

**Lamprey:** Phylum Chordata, Order Petromyzontiformes

Lampreys are jawless fish that have an eel-like shape. Their skin is scale-less and covered in mucus. Lampreys have conspicuous sucker-like mouths with horny teeth and rasping tongues. They parasitize fish, drinking their blood and other body fluids, and they also scavenge opportunistically. They have eyes, a pineal organ (photoreception), a nasal olfactory system, and a lateral line system that allows them to sense changes in water pressure in the nearby environment.

Although lampreys are marine species, adult lampreys are capable of living in freshwater, and lamprey larvae generally require it for development. Adult lampreys migrate up freshwater streams to spawn. When spawning, males and females dig shallow depressions in gravel stream beds and the eggs are externally fertilized in these nests. Larvae live in the soft sands of stream beds for several years before transforming into adults and moving out to the open ocean. Lampreys are currently found in the coastal areas of the northern hemisphere and within the Great Lakes. In the Great Lakes, they have very few natural predators.

**Blue Crab:** Phylum Arthropoda, Order Decapoda

Arthropods (insects, spiders, crustaceans) have a segmented body plan, hard chitinous exoskeleton, and jointed appendages. Crabs have the bulk of their body (head/thorax) encased in a hard shell (carapace). They have five pairs of legs, and the different pairs have become specialized to function in locomotion, feeding, reproduction and/or defense. They have eyes on long stalks, chemical and touch receptors on their antennae, and additional touch receptors on their legs.

Male crabs compete vigorously for mating opportunities with females. Mating often requires that they perform elaborate courtship displays. When males and females mate, they each open their aprons to accommodate the transfer of sperm. Crab eggs hatch into larvae and, after several molting events, individuals are transformed into adults and settle on the ocean substrate.

Crabs are mostly marine animals, and are found from coastal estuaries to deep sea vents. They are primarily omnivorous, feeding on detritus, plants and animals, including clams and other crabs. In fact, conspecifics are primary predators for many crab species. Crabs are also preyed upon by fish, turtles, birds and raccoons.
**Sea star:** Phylum Echinodermata, Order Forcipulatida

Adult sea stars are radially symmetrical. Their bodies are composed of a central disc and five rays (arms), with four rows of tube feet per ray. They are able to contract these tube feet and cover them up with protective spines. The 'dorsal' surfaces of their bodies contain calcareous spines, each of which is surrounded by tiny pincers (pedicellariae). Sea stars do not have any well-developed sense organs, but they do have eyespots at the tip of each ray and some of their tube feet have been modified into sensory tentacles. Additionally, they have chemical and touch receptors over most of their skin surface.

Sea stars are dioecious, but it is very difficult to tell the two sexes apart. During the breeding period, sea stars release sperm or eggs out through their anus (on 'top' of the animal) into the water column. Fertilization occurs in the water and zygotes develop into bilaterally symmetrical motile larvae. The larvae swim to new habitats and develop into slow, sessile, radial adults.

Sea stars are widely distributed across coastal areas, especially intertidal zones, but some species can be found deep in the ocean on the sea floor. They prey upon clams, oysters, fish and shrimp. When feeding upon bi-valves, sea stars evert their cardiac stomach in between the two shells of their prey and externally digest their soft parts. Sea stars then consume the partially digested material and digest it further. Sea stars are themselves victims of predation by fish, rays and sharks.

**What you will do**

Each member of your group will be responsible for the dissection of one animal, so that as a group you may study all four. Therefore, to ensure that each member enters the laboratory prepared to efficiently conduct a quality dissection, you should decide ahead of time, as a group, which group member is going to dissect each animal. At the beginning of the exercise, before beginning dissections, each group should come to a consensus over the shared challenges these four aquatic animals face. This will require that you synthesize the background material you have been provided. While dissecting your specimen, focus on the morphology of your animal within the context of the challenges your group has identified. Once dissections are complete, group members will share their findings with one another. Specifically, each group should discuss the adaptations each of the animals has for overcoming fitness-related challenges, and furthermore to reflect upon how diversity in animal form is a reflection of function.

**Laboratory Objectives**

As a result of participating in this laboratory activity, you will:

1. Come to better understand the evolution of animal diversity by:
   a. Comparing and contrasting structural features in members of different animal phyla
   b. Integrating observations of animals' morphologies with information about their natural histories and ecological roles
2. Explain how different organisms can develop different structures to carry out common functions
3. Develop animal dissection skills that are required for participating in biological fields of study such as human and veterinary medicine, ecotoxicology and wildlife conservation, among others
Methods

Part 1: Observing External Anatomy

Each member of your group will dissect one of four animals. Before you begin to dissect your animal specimen, you should make observations about its external features. You may need to use relative terms in your descriptions. See Appendix A for common terms of orientation used to describe animal anatomy.

1. Collect one specimen of the animal species that you will be dissecting. Place it in your dissection tray.

2. Observe the external features of your organism. You may use a blunt probe to find external openings.

3. In the raw data and field notes section of your guidebook, sketch the external view of your organism and label the external structures listed in the appropriate appendix (C through F) for your animal specimen. Use the labeled diagrams and photos provided in the lab to help you identify these structures.

4. In the data analysis and results section of your guidebook, for each structure you labeled in #3 give one suggestion for the function of that structure in terms of movement, food acquisition and digestion, respiration and circulation, and/or reproduction.

Part 2: Observing Internal Anatomy

Once you have finished documenting your observations on the external anatomy of your animal specimen, you are ready to begin your dissection. See Appendix B for tips and techniques for dissection.

1. Follow the instructions in Appendices C through F to dissect your animal specimen.

2. In the raw data and observations section of your guidebook, sketch the internal view of your organism and label the structures listed in the appropriate appendix for your animal specimen. Use the labeled diagrams and photos provided in the lab to help you identify these structures.

3. In the data analysis and results section of your guidebook, for each structure you labeled in #2, give one suggestion for the function of that structure in terms of movement, food acquisition and digestion, respiration and circulation, and/or reproduction.

Part 3: Comparing Animal Species

Once you have finished documenting your observations on the internal anatomy of your animal specimen, you should share your observations with the members of your group.

1. As a group, come to a consensus about the shared challenges the four aquatic animals face. Summarize your thoughts in your conclusions section.

2. Take turns showing the other members of your group the external and internal features of your specimen and discuss the functions of each structure.
3. Take notes on the similarities and differences between your animal specimen and the other three in your **data analysis and results** section. In your **conclusions** section of the guidebook, organize these notes into a formal description of the similarities and differences amongst the four organisms. This might be in the form of a table, chart, written paragraph, or other creative way to clearly present your ideas.

4. As a group, discuss why these four marine species evolved different structures to achieve the same end goals of moving, acquiring and digesting food, acquiring and transporting gases, and reproducing in an aqueous environment. Also, if you found any similarities, discuss whether these might be due to convergence or instead to shared ancestry. Summarize your answers in the **conclusions** section of the guidebook.

5. **Reflect** upon how diversity in animal form is a reflection of function. What else did you learn in lab today?

**Post Lab**

Arrange your data, analyses and conclusions using the following headers and respective items under each heading:

**Raw Data, Field Notes and Observations (3 pts)**
1. Sketch the external view of your organism and label external structures. Clearly label your sketch as “External View”.
2. Sketch the internal view of your organism and label internal structures. Clearly label your sketch as “Internal View”.
3. 

**Data Analysis and Results (3 pts)**
1. Create a table (Table 1) to capture a list of external structures you listed on your sketch and your predicted function for each particular structure. Clearly label your table with a title and description.
   a. Predictions should be in one of the following 4 categories: movement, food acquisition and digestion, respiration and circulation, and/or reproduction.
2. Create a table (Table 2) to capture a list of internal structures you listed on your sketch and your predicted function for each particular structure. Clearly label your table with a title and description.
   a. Predictions should be in one of the following 4 categories: movement, food acquisition and digestion, respiration and circulation, and/or reproduction.

**Conclusions (3 pts)**
1. Record the challenges all four aquatic animals face as your group determined them.
2. Organize your thoughts on the similarities and differences among these 4 organisms into a formal description. This might be in the form of a table, chart, written paragraph, or other creative way to clearly present your ideas.
3. Include your response to why these four aquatic species evolved different structures to achieve the same end goals of moving, acquiring and digesting food, acquiring and transporting gasses and reproducing in an aqueous environment.
Reflection (3 pts)
1. Reflect upon how diversity in animal form is a reflection of evolution and how form reflects function.
2. Reflect upon the similarities and differences in the challenges animals and plants face. Explain your understanding of these similarities and differences.

*Please view the post-lab rubric for additional details.
Appendix A. Terms of Orientation

Scientists use terms to describe the relative location of anatomical structures. The following terms are the most commonly used dichotomies and will be useful to help you describe the anatomy of your dissected organism. Each pair represents opposite directions along some part of the animal. Try using some of these terms when you draw and label your observations in the laboratory.

**Anterior.** In the direction of the head of a bilaterally symmetrical animal.

**Posterior.** In the direction of the rear, or tail, of a bilaterally symmetrical animal.

Example: The front limbs are anterior to the hind limbs of the ferret (as seen in Figure 1).

**Dorsal.** In the direction of the back of a bilaterally symmetrical animal.

**Ventral.** In the direction of the underside, or bottom, of a bilaterally symmetrical animal.

Example: The spinal column is dorsal to the internal organs of the ferret (as seen in Figure 1).

**Proximal.** In the direction of the core or main body of an animal.

**Distal.** In the direction of the extremities (away from the body) of an animal.

Example: The tail tip is distal to the tail base of the ferret (as seen in Figure 1).

**Medial.** In the direction of the midline of a bilaterally symmetrical animal.

**Lateral.** In the direction of the sides of a bilaterally symmetrical animal.

Example: The ears are lateral to the nose of the ferret (as seen in Figure 1).

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Figure 1. Illustration of terms of orientation. Photograph courtesy of Jessica and Steven Schrader.
Appendix B. Dissection Technique and Tips

1. Before dissecting the organism, make observations of the external anatomy. Use the blunt probe to find any openings.

2. Before cutting, make sure the animal is pinned securely to the dissecting pan so that it does not move while you are making incisions.

3. Always make incisions (cuts) away from yourself when using a scalpel or scissors, so you do not cut yourself. Look to see where your fingers are before cutting.

4. Be conservative and delicate when cutting. Cut less deeply than you think you should and make repeated, careful, shallow cuts. Repeated cuts will result in a better incision than just hacking away at your specimen.

5. When cutting with scissors, pull up and away from the internal organs so that you do not accidentally cut them.

6. Carefully separate the tissue around the incisions so you can see the interior of the organism. Leave all organs inside the organism so you can observe where each organ is located.

7. Intentional mutilation of any animal specimen will NOT be tolerated in this class.

8. Be careful not to cut yourself when cleaning the scalpel or razor.

9. If you cut yourself, notify your TA immediately.
Appendix C. Dissecting the Squid

Use the reference materials in lab to locate structures.

1. Remove the squid from the storage bucket and place it on a dissecting tray. Draw, examine, and label the external anatomy.

2. Lay the squid down so that the siphon is facing up and the fins are at the top of the tray. Pin the fins securely to the dissecting pan.

3. Refer to the diagram below. Using scissors, start cutting a flap of the body wall off the squid by making a cut along one side of the body and working your way to the back fin on that side. Cut the other side of body in the same way. Lift off this portion of the squid so that you can see the internal anatomy. Sketch the internal view.

4. Locate the structures listed below and label them on your sketches. You will need to cut open the buccal bulb to find the beak.

![Dissecting pin](Dissecting pin)

**Figure 2. Squid dissection. Cuts are indicated by dotted lines and arrows.**

**Squid Structures**

*Locomotory and Support Structures*

1. tentacles and suckers
2. arms
3. fin
4. pen
5. siphon (funnel)
6. retractor muscles

*Sensory/Respiratory Organs*

1. eye
2. tentacles
3. suckers
4. mantle
5. ink sac
6. gills

*Digestive and Excretory Systems*

1. tentacles and suckers
2. buccal bulb
3. beak/radula (in buccal bulb)
4. esophagus
5. stomach
6. pancreas
7. digestive gland/caecum
8. rectum
9. anus

*Reproductive System*

**Male:**

1. penis
2. spermatophoric sac and gland
3. testes

**Female:**

1. nidamental gland
2. oviduct gland
3. ovary
4. eggs
Appendix D. Dissecting the Sea Lamprey

Use the reference materials in lab to locate structures.

1. Remove the lamprey from the storage bucket and place it on a dissecting tray. Draw, examine, and label the external anatomy.
2. Using the knife located on the tray, make a mid-sagittal cut (long line in the diagram). You will need to cut all the way through the lamprey down the length of the organism as far as the anus. Cut the rest of the organism off (cross section). You will now have three sections: left, right and tail.
3. Use a blunt probe to locate and trace the internal organs. Sketch the internal view.
4. Locate the structures listed below and label them on your sketches.

![Lamprey dissection](image)

Figure 3. Lamprey dissection. Cuts are indicated by dotted lines and arrows.

**Lamprey Structures**

**Sensory Organs**
1. eye
2. pineal eye
3. spinal cord

**Locomotory and Support Structures**
1. myomere
2. caudal fin
3. posterior dorsal fin
4. notochord

**Reproductive System**
MALE: testis
FEMALE: ovary and eggs

**Digestive and Excretory Systems**
1. buccal funnel
2. horny teeth
3. tongue
4. mouth
5. oral cavity
6. esophagus
7. intestines
8. liver
9. anus

**Circulatory and Respiratory Systems**
1. heart
2. aorta
3. pharyngeal gill pouches (internal)
4. external gill slits
5. gills
Appendix E. Dissecting the Blue Crab

Use the reference materials in lab to locate structures.

1. Remove the crab from the storage bucket and place it on a dissecting tray. Draw, examine, and label the external anatomy. A good deal of the structures listed below are external.
2. Insert scissors into the lateral posterior edge of the dorsal carapace. Cut around the entire dorsal carapace roughly 5 mm from its edge (see figure 4). Using a scalpel, scrape away the underlying tissue, and remove the carapace, in pieces if necessary.
3. Remove the thin, dark body wall (epidermis) to expose the internal organs.
4. Use a blunt probe to locate and trace the internal organs. Sketch the internal view.
5. Locate the structures listed below and label them on your sketches.

![Crab dissection. Cuts indicated by dotted lines and arrows.](image)

Figure 4. Crab dissection. Cuts are indicated by dotted lines and arrows.

Blue Crab Structures

**Sensory Organs**
1. eye stalks
2. antennae
3. antennules

**Locomotory and Support Structures**
1. abdomen
2. carapace
3. lateral spines
4. periopods- walking (3 prs) - swimming (1 pr)
5. apron

**Circulatory and Respiratory Systems**
1. heart
2. gills
3. gill cleaners

**Digestive and Excretory Systems**
1. mouth/ mandibles
2. periopods- chelips (1 pr)
3. chela (claws)
4. cardiac and pyloric stomachs
5. hepatopancreas
6. intestine

**Reproductive System**
1. gonadopores (f)
2. pleopods (f: 4 swimmerets, M: 2 prs, 1st - gonadopods)
3. penis (m)
4. sponge (egg mass in some females)
5. testes (m)/ ovaries (f)
Appendix F. Dissecting the Sea Star

Use the reference materials in lab to locate structures.

1. Remove the sea star from the storage bucket and place it on a dissecting tray. Draw, examine, and label the external anatomy.
2. Take a cross section of ONE arm only and examine the organs and structures found within it.
3. Place the sea star with its mouth down in the tray. Use fine point scissors to cut along the side of each arm and carefully remove the top of the body leaving the internal organs in the bottom portion. You should see the stomach in the center of the disk with the pyloric caeca attached.
4. Carefully remove the pyloric caeca from one arm; the gonads should now be visible.
5. Carefully remove the gonads from one arm to expose the radial canal, which connects to ring canals in the central disk. Following these canals, you can find the stone canal and madreporite.
6. Locate the structures listed below and label them on your sketches.

Sea Star Structures

Sensory Organs
1. spines
2. eye spot

Locomotory/Circulatory Structures
1. madreporite
2. ampullae (2 locations)
3. tube feet/sucker
4. ring canal
5. radial canals
6. spines
7. skin glands
8. water vascular system (describe)

Digestive and Excretory Systems
1. mouth
2. oral spines
3. pyloric stomach
4. cardiac stomach
5. pyloric (intestinal) caeca (digestive glands)
6. anus
7. pedicellariae
8. ambulacral groove

Reproductive System
1. gonads (2 locations)
Appendix G. Reference Section


