Animal Adaptations

There is a tremendous diversity among the world's animals, and they live nearly everywhere, from high above the tree line to hydrothermal vents at the bottom of the sea. There are approximately 1.3 million named species of animals, but we don't really know how many are yet to be discovered. One estimate is that we may have as many as 30 million animal species, leaving the vast majority of the earth's biodiversity still to be discovered.

An animal's shape, size, and appearance can reveal a great deal about its environment and how it lives. An adaptation like thick fur, for example, suggests that an animal is exposed to cold temperatures. Body shape, coloration, forelimb structure, and jaw or beak shape are other examples of evolutionary adaptations that help an animal survive and reproduce.

This lab will introduce you to the diversity of animals displayed in the Conner Museum (WSU's Natural History Museum) and to some of the adaptations that enable these animals to successfully live and reproduce in their environments. In the first part of lab, you will study specimens from the research collection of the museum, identifying various feeding adaptations and adaptations for flight. Next, you will visit the public exhibits of the Conner Museum to observe adaptive features in a variety of animals. Then, you will use the knowledge you gained to invent a mammal, using adaptations observed in lab.

PART I - Adaptations for Feeding

Animals have developed distinct anatomical structures diagnostic of the food and the type of feeding they use. For example, the number, size, shape and location of teeth, and the movement of the jaw differ in mammals according to the type of food they eat. The beaks of birds are highly specialized for food gathering and provide examples of the great diversity of diets even among related species. We will focus on teeth and beaks, but keep in mind that other structures in the head are also involved in successful acquisition of food, such as strength and arrangement of jawbones, size and placement of muscles, and structure of the tongue. Of course, many other traits, such as the ability to hover, chase, or pounce, are integral to animals ability to get food.

Mammalian Teeth

The number and type of teeth an animal has reveals much about its diet and feeding methods. For example, the long canines of a carnivore, like a cougar, are used to bite and tear at prey. A beaver, on the other hand, is herbivorous, lacks canines, and uses its long incisors to strip bark and gnaw wood. Some teeth are ***rooted***, meaning that once they come in, they do not continue to grow. Rooted teeth wear down with use (you might know of some old dogs that have very worn down rooted teeth). In contrast, ***rootless*** teeth keep growing throughout an animal's life. For example, the long incisors of the beaver are rootless. Beavers must continue to gnaw or their incisors will grow too long and cause problems, even death.

Four types of teeth are found in mammals. Each type of tooth is adapted to perform a particular function. The ***incisors***, which develop at the front of the jaw, are used for biting and stripping. The ***canines***, located behind the incisors, are generally designed for seizing, piercing, and tearing. Behind the canines are the ***premolars***, used for crushing, grinding and shearing. Furthest back on the jaw are the ***molars***, designed for crushing and grinding.

Not all mammals have all four types of teeth or the same number of each type. The number of different types of teeth an animal has is called its ***dental formula***. Since mammals are bilaterally symmetrical, the same numbers of teeth are located on both the right and left side, so the formula states the number for half of the mouth, upper and lower. For example, the dental formula of a woodchuck is 1/1, 0/0, 2/1, 3/3 – that is, 1 upper incisor/1 lower incisor, no canines, 2 upper premolars/1 lower premolar, 3 upper molars/3 lower molars (Fig. 2). The total number of teeth is 22. In contrast, coyotes have 42 teeth, with a dental formula of 3/3, 1/1, 4/4, 2/3 (Fig. 1). Notice differences in the shape of the teeth and that the jaw needs to be longer to accommodate more teeth if they are to be of a similar size.

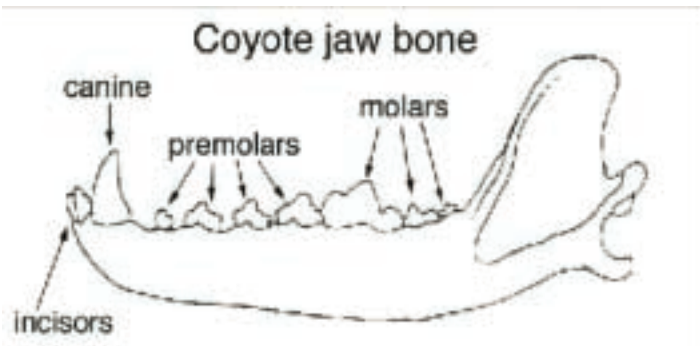


Figure 1. Coyote jaw bone

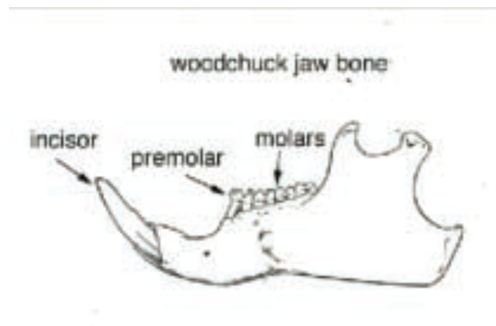


Figure 2. Woodchuck jaw bone

The dental formula in humans is 2/2, 1/1, 2/2, 3/3. How many teeth do humans have?

Bird Beaks

There are numerous structural features of bird beaks that vary in adaptation to food and how it is obtained, although the relationship between bill structure and diet is not as predictable as it is for tooth structure in mammals. For example, woodpeckers have long, tough, pointed beaks, along with a very robust skull that allows them to hammer holes in trees in search of food (when you visit the museum, look for the display of the woodpecker skull and its innovative tongue structures in the north gallery of the museum). In general, the thicker the beak, the more appropriate it is for cracking large seeds, but even small, deep beaks are used to crack seeds (for example, the house sparrow). Thin beaks are generally useful for manipulating prey, like caterpillars. Wide beaks are useful for catching flying prey, like mosquitoes. Hooked beaks can be used in a similar way to a mammal's incisors (biting and stripping), and long slender beaks can be used to gather nectar from flowers, like those seen in hummingbirds. Other variations observed in beaks include serrated edges for holding prey (like fish), or filter-like structures used to strain food particles from water.

In lab, you will see examples of three groups of birds: ducks, shorebirds, and raptors. The species within each group occupies very similar ecological niches. An **ecological niche** is the total sum of a species' use of abiotic and biotic resources in the environment. However, similar species cannot use exactly the same set of resources in the environment but occupy slightly different niches. This phenomenon is known as **resource or niche partitioning**. For example, all raptors are carnivores that feed on other animals. However, each species of raptor occupies a different niche because each one specializes on a particular type or size of prey, relies on a different method of hunting, or hunt in different times of the day. Similarly shorebirds utilizes different depth of water and different types of prey and ducks can be either be herbivores, omnivores or carnivores.

Activity A: This first activity is to explore niche partitioning by pretending to be an animal trying to eat materials using common eating utensils. Various "food" items, dry pasta, are placed in a tray. Your goal is have the highest total value of "captured food" in one minute.

First, turn the cards with names of utensils upside down on the table and mix them up. Then each member of the team choose one card. Whatever utensil is on the card is the tool you will use. Each member of the team has one minute to capture food items. You must capture them one at a time. If you break a food item in an attempt to capture it, it does NOT count. When one team member has run out of time, count the number of different category of food items (**S**paghetti, **M**ostaccioli, **T**wist, **L**asagna) and then return them to the tray replacing any broken items, and the second member can try with their utensils. When all members have finished, multiply the "value" of each food item listed in the table at your bench with the number each member captured, and calculate the total value of the captured food of each member. Was one utensil more successful than another in the total value captured?

What differences would you expect if all the team members competed with each other for the food items? Test your prediction by having all team members with their different utensils trying to capture the food at the same time for one minute. Was there both a qualitative and quantitative difference in the amount of food each team member captured? That is, were more or less of different food captured during competition than alone?

Results Table for Activity A

utensils	without competition					with competition				
	S	M	T	L	total value	S	M	T	L	total value
spoon										
fork										
knife										
chopstick										

Activity B: There are 6 groups of animals in lab. You and your lab group will spend approximately 5-10 minutes at each lab table determining the feeding adaptations observed within each group of animals. Note that you will see variation in feeding structures within each group. Be sure to follow the posted guidelines for handling the specimens. Summarize your findings in the tables below.

For those tables with mammal skulls, compare the sizes and shapes of different types of teeth between the animals. Your goal is to determine how different numbers, types, and sizes of different teeth correlate with the food that the animals eat. Notice in particular the molars and premolars of animals that eat vegetation versus those that are omnivores or carnivores. Make educated guesses about what you think each specimen eats. How do different teeth types relate to the animal's diet?

For those tables with bird specimens, compare the different shapes, structures, or sizes of beaks that correlate with eating habits and food. Make educated guesses about what you think each specimen eats - how does the size and shape of the bill relate to its diet?

Table 1: Ducks

Common and scientific names	What may it eat? Why?
Surf scoter, *Melanitta perspicillatta*	
Mallard, *Anas platyrhynchos*	
Northern shoveler, *Anas clypeata*	
Common merganser, *Mergus merganser*	
Snow goose, Chen caerulenscens	

Table 2: Shorebirds

Common and scientific names	What may it eat? Why?
Least sandpiper, *Calidris minutilla*	
Long-billed curlew, *Numenius americanus*	
American avocet, *Recurvirostra americana*	
American oystercatcher, *Haematopus palliatus*	
Greater yellowlegs, Tringa melanoleuca	

Table 3: Raptors

Common and scientific names	What may it eat? Why?
Cooper's hawk, *Accipiter cooperii*	
Northern harrier, *Circus cyaneus*	
Red-tailed hawk, *Buteo jamaicensis*	
Ospry, *Pandion haliatus*	
American kestrel, Falco sparverius	

Table 4: Rodents

Common and scientific names	What may it eat? Why?
Beaver, *Castor canadensis*	
Muskrat, *Ondatra zibethicus*	
Marmot, *Marmota flaviventris*	
Porcupine, *Erethizon dorsatum*	
Kangaroo rat, *Dipodomys* sp.	

Table 5: Carnivores

Common and scientific names	What may it eat? Why?
Bobcat, *Lynx rufus*	
Coyote, *Canis latrans*	
Racoon, *Procyon lotor*	
Striped skung, *Mephitis mphitis*	
American black bear, Ursus americanus	

Table 6: Grazers/Browsers

Common and scientific names	What may it eat? Why?
Pronghorn, *Antilocapra americana*	
Horse, *Equus caballus*	
Bison, *Bison bison*	
White-tailed deer, *Odocoileus virginianus*	
Collard peccary or domestic hog, *Tayassu tajacu or Sus scrofa*	

Kinetic Skull – Feeding Adaptation

Most birds, fish, and reptiles are able to move both the upper and lower jaw. This type of skull, called a kinetic skull, allows for a much larger gape or jaw opening than is possible with a mammalian skull, where only the lower jaw moves. A larger gape allows larger prey to be taken and/or an increased area to be swept by the open mouth, either in air or water. It also allows the animal to keep focused on the prey and still move the upper jaw. In contrast, the mammalian jaw is structured to maximize biting and chewing force.

Examine the metal reptile jaw model on display in lab. Close the jaws of the model and hold the upper jaw in place while you open the lower jaw only. Now notice the difference in gape when you open the upper jaw as well, using the two upper jaw hinges in the skull.

Also examine the alligator skull on display in the lab, but remember to be extremely careful with this fragile specimen! (Note its teeth. How do they differ from those of the mammals you have examined?)

Part II: Adaptations for Flight - Wing structure

Wings of birds are modified forelimbs that function as airfoils, that is, convex on top and concave on the bottom so that the air going above the wing moves faster than the air below the wing. This creates an air pressure difference that provides an upward lift. In addition, many birds flap their wings to create lift and thrust for flight. The ability of birds to glide or fly depends on the ratio of the body mass to the surface area of the wings, called wing loading. In addition, the shape of the wing, the relative length vs. the width of the wing (called the aspect ratio), and feather arrangement all have effects on the wing's performance and suitability for different types of flight. Birds have other special features that are important for flight. Their bones are hollow with interior bracing and thus are both light and strong. Active, powerful flyers have skeletal adaptations of a large breastbone with a deep keel for flight muscles to attach. The relative size of this keel is an indicator of the strength of flight (look for an example of a deep keel when you visit the museum, find the swan skeleton on display in the hall gallery of the museum).

Several types of wings are on display in lab. Please handle these carefully!
Briefly describe the shape of two different wings you observed in lab (based on features described above). In your answer, include the type of flying used with each wing shape you describe. How well do you think wing shape is adapted to the bird's habitat?

1.

2.

Part III - Body size, Metabolic Rate

What can the size and shape of an animal tell us about its environment? As we have discussed in lecture, an animal's size can affect almost every aspect of an organism's biology, including the rate of heat gained or lost to the environment. One key way to consider an animal's size is in terms of its surface area to volume ratio. A large surface area to volume ratio facilitates exchange of heat and materials with the environment. For example, larger animals have smaller surface area to volume ratios and retain more body heat than smaller animals that have larger surface area to volume ratios. Thus organisms in colder climates or at higher latitudes tend to have larger body sizes (and thus higher heat retention). An example of this is White-tailed deer, which are considerably larger in northern North America than they are in the south.

In addition to the overall body size, extensions of the body, such as ears, tails, and legs, tend to be shorter in cooler climates (less surface area exposed to the cold) and longer in warmer climates (to maximize heat loss). Birds and mammals that live in cold climates also tend to have heavier coats of fur or downy feathers for insulation. Animals also use adaptations such as fat insulation and countercurrent exchange for heat retention.

Activity A: **Use the following table to compare the surface area to volume ratios between a small mammal and a medium mammal.**

Table 7. Comparison of size, surface area and volume for a small versus medium rodent.

size	Mass (g)	Surface area (cm^2)	Volume (cm^3)	surface area to volume ratio
small (mouse)	22	46	21	2.19
medium (squirrel)	250	150	150	1.00

How does mass relate to the surface area to volume ratio?

Metabolic Rate and Body Size

How does size affect ***metabolic rate***, the amount of chemical energy used per unit time? The most common measurement for metabolic rate is ***basal metabolic rate (BMR)***, a measure of the amount of oxygen consumed per hour under resting conditions. Larger animals have more body mass and therefore require more chemical energy. In general, as body mass increases, metabolic rate increases proportionally. However, the metabolic rate per unit of body mass compared to body size is inversely related. This inverse relationship affects the rate of energy consumption by body cells and tissues (Figures 40.19a and b from your textbook).

Fig 40.19a: Relationship of BMR to body size

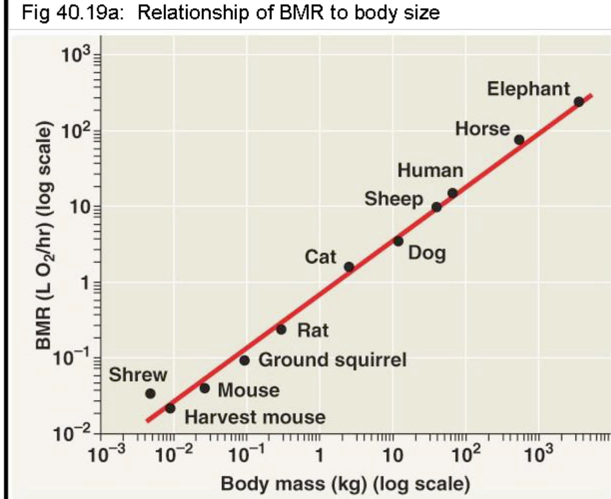
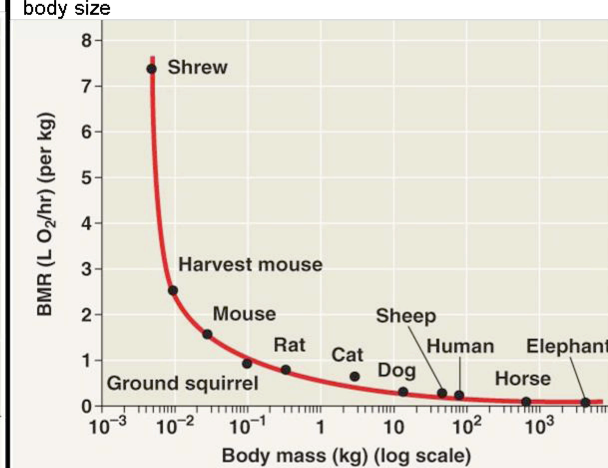


Fig 40.19b: Relationship of BMR per kg of body mass to body size



Activity B: To examine this relationship, we will compare the rate of food consumption per day to the mass of two mammals.

The pygmy shrew is the smallest known mammal (by mass) and has a lifespan of about 15 months. It has a voracious appetite, primarily eating a variety of insects. Shrews are active both day and night because they have to eat about three times their body weight in food each day.

Mammal	mean mass (kg)	food eaten/day (kg)	#days required to eat its mass in food
pygmy shrew	0.004	0.012	
human	68	2	

1. Calculate the number of days (or fraction of a day) required for each mammal to eat its own body mass in food. Use the equation listed below. Record your values in the table above.

$$\# \text{ days} = \frac{\text{Mean mass}}{\text{Mass of food eaten per day}}$$

2. How much food would a 68 kg (150 lb) human consume, if the human consumed food at the same rate (kilograms food consumed/day/unit body mass) as that of a shrew? HINT: For example, if the rate of consumption for animal is to consume 3 times their body weight, then multiply the rate of consumption by the animal's body weight.

3. If a typical hamburger has a mass of 0.2 kg, how many hamburgers would a person consume per day if he/she had the metabolic rate (kilograms food consumed/day/unit body mass) of a shrew?

4. What can you conclude about the relationship between the size (mass) of a mammal and the amount of food eaten per day per unit body mass?

Activity C: Visit the Conner Museum to view the variety of animals and identify adaptations associated with body shape and size.

Many factors are involved in optimum body size and shape. Animals that face cold temperatures tend to have larger body size and lower surface area to volume ratio to retain heat. Animals that live or hunt in burrows often have an elongated shape and short legs to enable them to move readily through small openings. Birds and many swimming organisms have streamlined body shapes. This decreases resistance as the body moves through air or water.

Adaptation to what environmental factor(s) may be involved in the shape of the otters? moles? cormorants?

Part IV - Visual Adaptations, Eye position

Look at examples of raptors, songbirds, and shorebirds in the east gallery, hall, and north gallery of the Conner Museum and note the the location of eyes on the bird that determines which direction they can see and whether they have monocular or binocular vision.

Raptors - With both eyes facing forward from a relatively flat face, owls have the best binocular vision of any bird. Owls and other raptors need excellent binocular vision for depth perception to accurately gauge distances as they hunt moving prey. To see to the side or rear, raptors must turn their heads. Acuity, or sharpness of vision, is also highly developed in these birds.

Why is peripheral vision less important for owls and other raptors?

Songbirds - The eyes of the white-crowned sparrow – and those of other songbirds displayed in the east gallery (see display titled "Little Brown Birds") – are set more to the sides of the head. These birds feed on seeds and insects and need some forward vision, but they must also be able to see far to the side at all times (i.e., peripheral vision) to avoid predators.

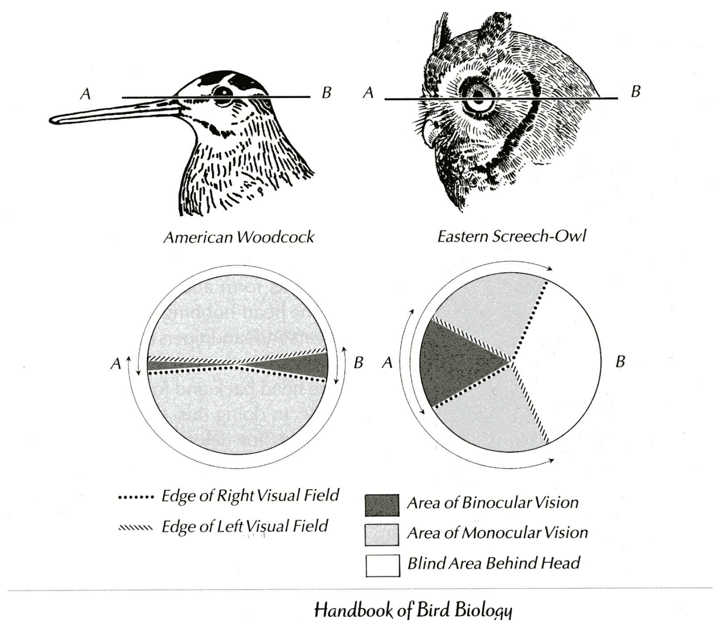


Figure 4. Visual field comparison of woodcock vs. owl.

Shorebirds -The shorebirds, or wading birds, have less of a need for forward vision. They often feed underwater by probing into the mud with a flexible bill. Their eyes are set far to the rear, enabling them to see in a complete circle with some overlap in the rear without moving their head. Similarly American Woodcock probe for earthworms in the soil.

The visual adaptation described above for birds also apply to mammals. Compare the eyes of grazers such as deer, antelope, rabbits and moose to predators such as cougars, raccoons and otters. **Are there common features among grazers that contrasts with the common features of predators?**

Part V - Coloration

Just as we discussed with flower colors, many animals, except mammals, can see both the visible and ultraviolet light. In addition, many birds exhibit structural coloration, due to microscopic structure of the feather so that depending upon the angle of illumination and view. You might have noticed this on hummingbird throat or in a Peacock's plume (easier to see this in the larger bird).

Some examples of adaptive coloration include:

Camouflage – This type of coloration allows an animal to visually blend in with its environment. This is both useful for predators to not be detected by the prey and for the prey not to be detected by the predator.

Disruptive coloration – Contrasting bold patterns tend to break up the outline of an animal so that it is difficult to identify. Although small to us, dark or light lines near the eyes tend to disguise the position of the eye, which is an important organ to be protected.

Deflective coloration - Many camouflaged birds have bright contrasting markings on the tail, wing or body part which become visible when the bird flies which may startle a predator and cause it to miss.

Counter-shading – Many birds have a darker top and white below. The effect of this is that the dark is lit by the sun and the light is in the shade. Further the light bottom side may reflect the color of the ground, further making it difficult to see the bird until it moves.

Reduce glare - Just as some athletes put eye-black grease or black adhesive strip under their eyes to reduce glare so that they can see the ball better, birds have dark eye strip or dark head and upper beak for the same purpose.

Warning coloration – Bright, contrasting colors warn predators that an animal is unpalatable or poisonous. Some animals mimic the warning coloration of poisonous animals to take advantage of the wariness of predators.

Attractive coloration - Not all coloration is for concealment or to keep other animals away!
Many animals display attention-getting coloration to attract mates or to lure prey.

For each of the category of birds listed below, identify what type of adaptive coloration they have. You only need to look at one of several birds listed in each category. Circle the species which you base your identification of different type of adaptive coloration. Of course, some may have a combination of categories of coloration.

ptarmigan, grouse, great gray owl	
merganser, widgeon, grebe	
killdeer, dark-eyed junco, flicker	
thrasher, flycatcher	
arctic tern, phalarope	

Part VI - Invent a Mammal

Now that you have explored a variety of animal adaptations by observing museum specimens provided in lab and by visiting the animals on display in the Connor Museum, you and your lab group will create a mammal. Be creative! Use some ideas from the different examples you saw on the tour of the Conner Museum. Remember that form should fit function. Make sure that the adaptations work together so your mammal is well suited to its habitat and lifestyle. **After you create your mammal you will present your mammal and its adaptations to the rest of the class.**

For your mammal include the following:

1. What is its dental formula? Explain WHY? (For example, what does it eat? and why does it need that formula?)

Sketch the jaw of your mammal:

2. What is its *body size and shape, eye position, coloration*? Explain WHY? (For *example, where does it live, is it a predator or would it be a prey item for another animal?)*