

## PHYLUM CHORDATA

The phylum Chordata includes many familiar animals such as fishes, frogs, snakes, birds, mammals and man. Also included in this phylum, but bearing little resemblance to the above animal groups, are the tunicates and the lancelets. Chordates display the following features at some time during their life cycle: 1) a notochord, 2) a dorsal hollow nerve cord, 3) pharyngeal gill pouches or slits, 4) a post-anal tail, 5) a ventral heart and 4) thyroid gland(s). Chordates also share many features with the invertebrates previously studied. These features include bilateral symmetry, segmentation, a true coelom, three germ layers, a complete digestive system and an endoskeleton.

The first chordates studied are often called “Lower Chordates” or “Invertebrate Chordates” and are grouped in the following taxonomic categories.

### Subphylum: Urochordata

Adult tunicates or sea squirts look nothing like the other Chordata. Tunicates are all marine animals that are solitary or colonial and sessile or planktonic. Most are sessile, attached to rocks, piling, and jetties. A non-living **tunic**, containing cellulose, encloses and protects their bodies. The name sea squirt comes from the fact that many individuals squirt a jet of water when squeezed.

Observe a tunicate and locate the two siphons projecting from their globose body. The smaller and anterior one is the **incurrent siphon**, and the larger, more posterior one is the **excurrent siphon**. Sessile forms have a long stalk that is fastened to a substrate. Inside the tunic is a large pharynx perforated by numerous **gill slits**. Ventral to the pharynx is the **digestive system** which courses dorsally to end at the anus near the excurrent siphon.

There are three classes of Urochordata; two will be displayed in class.

### Class: Ascidiacea

These are the tunicates and specimens are in the classroom.

### Class: Thaliacea

These are free-living planktonic forms called **salps**. These creatures form long chain colonies of translucent or orange individuals during the summer months and are commonly found off the California coast.

### Class: Larvacea

The planktonic larvaceans or appendicularians are small (a few millimeters long) and are very specialized. The fragile nature of these animals makes capture difficult. No examples are in the lab.

**Figure 1.** Draw a tunicate 6 cm. high and label their anatomy.

## Study Questions

1. What are the characteristics of chordates?
2. Do adult Urochordates possess any chordate characteristics?
3. What chordate characters are found in the adult human?

### Subphylum: Cephalochordata

The Cephalochordata contain twenty-eight species of small fish-like animals known as lancelets. **Amphioxus (Branchiostoma)** are found along American coasts in shallow marine waters with clean sandy bottoms. Although unimportant economically, they are interesting from an evolutionary standpoint because they form a link between the invertebrate chordates and the vertebrate chordates (see below). Lancelets possess the defining features of chordates and in many ways are the “blue print” for this phylum. Recent discoveries of fossil forms (**Pikaia** and **Yunnanozoa**) indicate that Cephalochordata existed 520,000,000 years ago and were possibly ancestral to the subphylum Vertebrata.

Lancelets have slender, laterally compressed bodies 4-6 cm long. A long **dorsal fin** extends around the tail forming a **caudal fin**. There is a short **ventral fin** supported by **fin rays** composed of connective tissue. Three openings in the body are the anterior **mouth**, the mid-ventral **atriopore** and the posteroventral **anus**. **Amphioxus** is a filter feeder employing approximately twenty **oral cirri (buccal tentacles)** surrounded by a membrane (**oral hood**) to draw in a current of water through the mouth and into the **pharynx**. Minute food particles in the water are trapped by mucus in the 100 or so gills, which also function as organs of respiration. Between the **gill slits** are **gill bars** each supported by a thin cartilagenous rod. The filtered water continues posteriorly to the **atrium** and then released out the **atriopore**. The food trapped by the gills is passed by ciliary mucal action posteriorly to the **esophagus** and on to the **intestine**. On the ventral side of the intestine is a sac, the **hepatic caecum**, which is thought to be equivalent to the vertebrate liver.

The **dorsal hollow nerve cord** lies ventral to the dorsal fin and dorsal to the notochord. A brain-like expansion occurs at the anterior end of the nerve cord. Extending longitudinally and dorsal to the intestine is the thin, rod-like **notochord** consisting of cartilage surrounded by a sheet of tough connective tissue. Notice the conspicuous V-shaped structures along each side of the body. These are **myomeres**, segmentally arranged muscles similar to those found in fishes. Contraction of these muscles against the rigid notochord produces lateral swimming movements similar to those of fishes. In addition to locomotion, the lancelets use muscle contractions when burrowing into sand.

**Figure 2.** Draw a lancelet 15 cm long and label the external features that you can locate.

**Figure 3.** Draw a lancelet 15 cm long and label the internal structures that you can locate.

## Study Questions

4. How does a lancelet feed?
5. Explain how Amphioxus respire.

### Subphylum: Vertebrata

Chordates characterized by the presence of ossified or cartilagenous vertebral elements making-up a vertebral column. Fishes and tetrapods are included in this subphylum.

### Superclass: Agnatha

These are vertebrates lacking jaws. The group includes lampreys, ectoparasitic vertebrates living in both marine and fresh waters, and the hagfish, marine scavengers feeding on the dead. Like fishes, agnathans have their muscles of locomotion arranged as bilaterally, repeating (segmented) W-shaped myomeres along the length of their bodies.

### Superclass: Gnathostoma

#### Class: Chondrichthyes

Elasmobranch fish include the sharks, rays, skates, and chimeras (ratfish). They possess cartilaginous skeletons, exposed gill slits (except in chimeras) and pelvic fins in males are modified as external copulatory organs (or **claspers**). Tooth-like, placoid scales that form a shagren of dermal denticles cover the body of most species. Pacific Islanders (New Zealand's Maoris, for example) used the skins of various sharks as "sandpaper" to smooth their beautiful woodworkings. An upturning of the vertebral column supports the asymmetrical **heterocercal tail**, common in this class. Examine various preserved elasmobranchs in class and learn their identity.

## Study Questions

1. What are the differences between the Agnatha and the Chondrichthyes?
2. Why are placoid scales and teeth similar?
3. What is the function of claspers?

#### Class: Osteichthyes

Members of this class are the 25,000 species bony fish--the greatest number of species in any group of vertebrates. They have evolved to occupy nearly every aquatic habitat (niche). Today the yellow perch, a common freshwater fish of the Midwestern United States, will be dissected.

**Study tips for the following dissections.** Review all parts of your specimens studied during the previous lab at the **beginning** of each lab period. Quiz your neighbor,

examine other specimens, learn both male and female reproductive systems of the species dissected, and perform a careful dissection of each species.

External Anatomy. Identify the **head**, which extends to the posterior edge of the gill cover or **operculum**. The **trunk** extends from the operculum edge to the **anus**. Posterior to the anus is the **tail**.

Examine the perch and locate the following fins: **pectoral**, **pelvic**, **anal**, two **dorsals** and a **caudal**. **Fin rays** support the thin membrane of each fin. Notice that some rays are **soft** and others are **spiny**. The nearly horizontal vertebrate column extends posteriorly to support the symmetrically shaped **homocercal tail**.

Unlike the chondrichthyans, the bony fish has a **terminal mouth**. The head is provided with paired **eyes** and paired **nostrils**. **Ears** lie deep inside the head posterior to each eye, and are not visible externally. Along the length of the body is the **lateral line**, a sensory system composed of a row of small pores or tubules connecting to a long, tubular canal. This system functions in the aquatic environment and is absent in all terrestrial tetrapods. On each side of the head, an operculum covers the **gills** and fits snugly against the body. Using a probe, lift the operculum and examine the gills lying within a chamber. Find the **anus** at the base of the anal fin and the small, slit-like **urogenital opening** posterior to the anus.

Examine the arrangement of scales. Remove a single scale and place in a drop of water on a glass slide and cover it. Use your light microscope at 40X to see growth lines and the intricate structure of a **ctenoid** scale.

**Figure 1.** Draw a fish scale 10 cm in diameter. **Show great detail.**

### Study Questions

4. How does the arrangement of scales aid swimming?
5. What are the major differences between sharks and bony fish?
6. How does each type of fin function?
7. Do fish have eyelids?
8. What is the function of the operculum?

Internal Anatomy. During your dissection be on the alert for parasitic nematode worms and flukes. To observe the myomeres (segmentally arranged body musculature) cut off all the fin spines on the perch. Make two shallow incisions from the ventral surface of the fish to the dorsal surface. The first incision is just posterior to the anus and the second about 3 centimeters nearer to the caudal fin. Join the two with a shallow, mid-ventral incision. Using a sharp scalpel, carefully separate the skin from the underlying musculature. When completed there will be a flap of free skin overlying the myomeres. Lift the flap, examine the myomeres and observe their resemblance to a W turned on its side and stacked close together. Now cut the tail off just anterior to the fin rays and observe that myomeres extend the length of the body.

**Figure 2.** Draw three adjacent myomeres 5 cm high. **Be sure to show the “W” pattern as seen in your specimen.**

To view the respiratory system cut away the left operculum and expose all the gills. Cut out a single gill and float it in a watch dish filled with water. Examine the gill using the dissection scope.

Return to the perch and cut through the remaining gill arches to expose the mouth cavity and pharynx. Open the mouth wide and note the gill slits in the pharynx. Study the figure below in order to understand how fishes respire. As water is forced over the gill filaments of bony fish, the oral valves close to prevent water from flowing back out of the mouth. After passing through the gills, the water flows out the operculum. Note the fine **teeth** located within the mouth.

## Figure

### Study Questions

9. Does the fish have a tongue?
10. How many gill arches are found in the yellow perch?
11. Would the teeth in a perch be effective in chewing prey? What are the feeding habits of a yellow perch?

Beginning just anterior to the anus, make a shallow incision anteriorly along the mid-ventral line to a point anterior to the pelvic fins. On the left side of the body, make two dorsal transverse cuts approximately one-half the width of the body, one from the region of the anus and another between the pelvic and pectoral fins. Now remove the body wall by cutting between the two dorsal incisions. The exposed area is the **abdominal cavity**, a part of the **coelomic cavity** (the other portion of the coelom is the **pericardial cavity**, containing the heart). **Peritoneum** is the smooth, shiny surface of the abdominal coelom. This smooth surface reduces friction as organs move against the cavity walls. In the case of a gravid female perch, it may be necessary to remove the eggs in order to better examine the organs. Do not to remove the portion of the egg mass nearest the **anus**. Place a blunt instrument through the **mouth** and into the opening of the **esophagus** at the termination of the **pharynx**. Now lift the **liver**, the cream-colored organ (dark red in life), and trace the esophagus from the pharynx to the **stomach**. The stomach ends in a blind pouch while the small intestine joins the middle portion of the stomach. Three **pyloric caeca** surround this union and secrete digestive enzymes in addition to aiding food absorption. The small intestine is often encased in yellow **fat** deposits. The liver secretes **bile** into the **gall bladder** for storage; later the bile will be released into the small intestine to emulsify fats to facilitate their digestion. An inconspicuous pancreas lies in the fold of the intestine. Open the stomach, place the contents in a Syracuse dish with water and examine for parasites.

The **swim bladder (air bladder)** is a long, shiny thin-walled sac occupying the dorsal portion of the abdominal cavity. Puncture it and examine the anteroventral wall for a network of capillaries (**red body**) that serves as a **gas gland** controlling the amount of gas in the swim bladder.

## Study Questions

12. Describe the stomach contents of your perch.
13. What is the function of the air bladder and how does it work?

Fishes are **dioecious** but **monomorphic**. In females the single **ovary** lies posterior to the stomach and dorsal to the intestine. It is connected posteriorly to a short **oviduct**, which opens at the **urogenital pore** posterior to the anus. The size of the ovary is seasonal. The bilobed **testes** of males attach to the air bladder via mesenteries. A **sperm duct (vas deferens)** runs posteriorly from each **testis** to end at the **urogenital pore**. Perch practice external fertilization. **The student is responsible for the reproductive system of both sexes.** Locate a fish of the opposite sex in the classroom.

Paired **kidneys** lie against the dorsal body wall and extend the entire length of the abdominal cavity above the air bladder and may fuse posteriorly. The dorsal aorta separates their anterior ends. The kidneys drain urine via **Wolffian ducts** that exit at the **urogenital pore**.

To expose the **heart**, extend the midventral incision anteriorly to where right and left jaws join. Enlarge the opening by removing a triangular piece of body wall on each side of the cut. The **pericardial cavity** (part of the coelomic cavity) is separated from the abdominal cavity by a **transverse septum**. Within the pericardial cavity lies the two chambered heart consisting of a thin-walled **atrium** and a thick-walled **ventricle**. Carbon dioxide rich blood from the body enters the atrium through the **sinus venosus**. From the atrium blood enters the ventricle and is pumped through the **bulbus arteriosus** to the **gills** for oxygenation and removal of carbon dioxide.

## Figure

### Class: Amphibia

This class includes 5400 species of frogs, toads, salamanders and caecilians. The Amphibia were the earliest tetrapods to invade the land. Although adapted to the terrestrial environment, many lead double lives requiring water or moist conditions for reproduction but spending much of their adult life on land. A number of species lay their eggs in water where **external fertilization** takes place. Larval stages breathe by means of gills and may reside for sometime in aquatic conditions before metamorphosing into an adult (see the life history of a frog on page ). Adults possess lungs, a three chambered heart, movable eyelids and internal nares. Nearly all species lack scales and have a moist skin permeable to water. Many are armed with cutaneous mucus glands often capable of producing extremely toxic poisons. No extant species are marine.

### Order: Gymnophiona or Apoda

These are the caecilians, an odd group of tropical amphibians resembling limbless salamanders or snakes. The tail is short and skin contains mesodermal scales. Caecilians burrow through the forest litter in tropical rain forests in search of worms. Their

burrowing habits have lead to blindness or near-blindness. Human rarely encounter these interesting creatures. See specimen(s) in lab.

### **Order: Urodela or Caudata**

Salamanders and newts possess four limbs, a long trunk and a long tail. In this respect they resemble lizards. There are approximately 300 species nearly all of which live in aquatic or moist circumstances. Most species are found in temperate North America, however a number of species inhabit tropics regions and old world temperate zones. They range in size from a few centimeters to nearly two meters (Japanese Giant Salamander). All are carnivorous, preying on worms, molluscs and arthropods.

### **Order: Salientia or Anura**

Frogs and toads are tailless amphibians with large mouths; a long trunk and hind legs specialized for saltatory (hopping) locomotion. Larval forms possess fully functional tails adapted for swimming. With over 2000 species, the Anurans represent the largest living order of Amphibia.

## **THE FROG**

Frogs are commonly utilized for dissection in Zoology classes because they: a) demonstrate many basic vertebrate features, b) illustrate the transition from aquatic to terrestrial life, c) are inexpensive and widely use as laboratory animals, important in many areas of biological research. Frogs are raised for research and classroom use; none are taken from wild populations. The frog species most often used are the leopard frog, **Rana pipiens**, and the bullfrog, **Rana catesbiana**. The former is more commonly used in laboratory studies, while the latter is a better animal for dissection due to its larger size. Illustrations included here are composites of the two species and are not entirely accurate.

External anatomy. Pigment cells or **chromatophores** account for the coloration of the frog's skin. Note the large head with a very large mouth. Pry open the mouth and locate the **maxillary teeth** on the margin of the maxilla and the **vomerine teeth** on the **palate** (i.e. the roof of the mouth). Frogs use their teeth to hold prey before swallowing, and not for chewing food items. On each side of the vomerine teeth are openings or **internal nares** which communicate to the outside as **external nares** (nostrils). Find the openings to the **vocal sacs** along the inside of the lower jaws. Notice how the **tongue** is attached. Posterior to the oral cavity is the muscular **pharynx**, which facilitates the passage of food into the **esophagus**. At the rear of the pharynx is the **glottis**.

Return to the exterior of the head and find a pair of **external nares**, two **eyes** and a **tympanic membrane** located posterior to each eye. The tympanic membrane, like the eardrum, is a structure receiving sound waves. The frog has three eyelids, two similar to other tetrapods, and a third or **nictitating membrane** located near the lower eyelid.

The body of the frog is streamlined for swimming. Frogs lack external sex organs and possess only a single posterior opening, the **anus**. The forelimb is divided into five regions (upper arm, forearm, wrist, palm and digits) as is the hind limb (thigh, lower leg, ankle, foot and digits). A web utilized for swimming connects the digits of the foot. A

vestigial thumb and four digits form the hand. In mature male frogs the forelimb is larger and more muscular than that of the female. During the breeding season the inner digit of each hand in male frogs becomes swollen, forming **nuptial pads** or **claspers** to help hold the female during mating. Observe the orientation of the limbs of the frog and you will appreciate how difficult it is for a frog to walk.

### Figure

The skeletal system. The vertebrate **endoskeleton** functions as 1) a framework and support for the soft parts of the body, 2) protection for vital organs, 3) attachment sites for the muscular system, 4) a site for the formation of blood cells and 5) storage for calcium and phosphate.

The skeleton is divided into an axial portion composed of the skull, vertebral column, sternum and ribs (notice that frogs lack ribs), and an appendicular portion made-up of the limbs and limb girdles (pectoral and pelvis).

Although it is unnecessary to learn the individual bones of the frog skeleton, it is important to compare (likenesses) and contrast (differences) between the frog and human skeletons (see figure ). The concept of **homology** conveys the idea that corresponding parts sometimes differ in function, but have a common evolutionary and embryonic origin.

Skinning the frog. See the diagram below. The skin of a frog is loosely attached to the body making skinning easy. Lay the specimen on its back in a dissection tray. Lift the skin in the midline one half-inch anterior to the anus and insert the point of the scissors forming a small hole. Now cut anteriorly to the lower jaw. Return to the initial puncture and cut posteriorly to the anus. Cuts should now be made along the ventral side of each limb and encircling the wrist and ankle. When all cuts are completed, carefully pull the skin from the rear toward the head. Leave the skin attached to the head anterior to the neck region. **Do not** remove the entire skin.

### Figure

Muscular system. Muscle contraction allows for movement. Superficial musculature is the goal for this portion of the frog dissection. Muscles are connected to bones via tough, white cords of connective tissue termed **tendons**. The end of the muscle attached to the bone that moves during contraction is the **insertion**. The fixed end of the muscle is the **origin**. Contracting muscles that bend a joint are termed **flexors** while those that straighten a joint are **extensors**. **Levators** are muscles that elevate appendages and **depressors** lower appendages. **Adductor** muscles move appendages toward the midline of the body while **abductors** move appendages away from the midline.

Locate the following muscles and separate each one using a probe. The instructor will demonstrate this technique. It is a good idea to color code (figure) the various muscles for later review.

**Gastrocnemius**—is the largest muscle of the lower leg and originates at the lower end of the femur (thigh bone) and inserts on the **Achilles tendon**.

**Sartorius**—lies on the ventral side of the thigh and runs diagonally across the inner thigh. It originates on the **ilium (hip bone)** in front of the **pubis** and inserts below the



head of the **tibio-fibula**. The sartorius flexes the lower leg upon the thigh and pulls the entire thigh forward, flexing the thigh to the pelvis.

**Adductor magnus**—appears as a triangular muscle near the groin and the sartorius muscle. This muscle originates on **pubic symphysis** and inserts on the distal end of the femur.

**Triceps femoris**—is a very large muscle covering the entire frontal aspect of the thigh. It originates at three points on the pelvis and inserts by a large tendon crossing the knee joint and attaching to the proximal end of the tibio-fibula bone in the lower leg. The triceps femoris extends the lower leg and flexes the thigh against the pelvis.

**Rectus abdominus**—lies on the ventral surface of the abdomen separated by the **linea alba**, a white, mid-ventral band of connective tissue. Originating along the border of the pubic bones this muscle inserts on the **sternum**.

**Pectoralis major**—is a broad, flat fan-shaped muscle covering most of the chest and part of the abdomen. The upper portion originates on the sternum and inserts on the **humerus**. It acts to adduct the humerus. The lower portion of the pectoralis major supports the abdomen.

**External oblique**—This muscle is located on each side of the body and serves as support for the viscera. It originates on the vertebrae and inserts on the linea alba.

**Latissimus dorsi**—is a fan-shaped muscle originating on the thoracic vertebrae and inserting on the proximal of the humerus. When in function it draws the arm dorsocaudad (upward and backward).

**Triceps brachii**—Located on the back of the arm, this muscle originates on the scapula and inserts on the radio-ulna just below the elbow. It functions to extend the forearm.

**Deltoid**—The deltoid adducts the arm. Originating at the base of the scapula and the clavicle, the deltoid inserts on the proximal end of the humerus.

**Myohyoid**—Ventrally the mouth is covered by this muscle, which attaches to both lower jaws.

## Figure

Internal anatomy: The internal anatomy of the frog is similar to other tetrapods except frogs (unlike man and other mammals) lack a diaphragm separating the thoracic and abdominal cavities.

To open the body cavity, place the frog on its back in the dissecting tray. **WARNING: Make all cuts as shallow as possible to avoid damage to the internal organs.** Snip a small hole in the abdominal wall just below the sternum, cut anteriorly through this portion of the skeleton to the throat. Now reverse directions and cut posteriorly to the pubis. At the lower abdomen cut laterally on both sides just above the thigh, ending near the vertebral column. Rinse out the abdominal cavity to remove any fluids present.

In the center of the thoracic cavity lies the heart enveloped within the sac-like **pericardium**. Locate the two thin-walled **atria** and the muscular **ventricle**. Exiting the ventricle and passing between the atria is the **truncus arteriosus** or **conus arteriosus** on its way to the lungs and body.

The large, dark **liver** surrounds the heart, hides the lungs, portions of the stomach and small intestines; this organ dominates the body cavity. There are usually three lobes of

the liver, left, median and right. Under the liver lies the **gall bladder**, a storage sac for **bile** secreted by the liver and important for the digestion of fats.

Lying on either side of the heart are the two deflated **lungs**. Compared to other tetrapods, the lungs are small because amphibians utilize a number of auxiliary methods of respiration.

Protruding from under the left lobe of the liver you will find the **stomach**. The entrance of the **esophagus** into the stomach is controlled by the **cardiac sphincter** (a valve). At the other end of the stomach the **pyloric sphincter** controls the passage of food into the **small intestine**. The curved stomach's outer (left) side forms the **greater curvature** while the opposite side forms the **lesser curvature**.

The portion of the **small intestine** leaving the stomach is the **duodenum**. This runs parallel to the stomach and then becomes the **ileum**, which unites with the **large intestine**. Locate the semi-transparent **mesentery** supporting and holding the small intestine in place. The short **large intestine**, consisting of the **rectum** and the **cloaca**, passes through the pelvic canal to exit as the **anus**.

A flat, leaf-shaped gland lying in the U-shaped loop between the stomach and the duodenum is the **pancreas**. The pancreas secretes digestive enzymes into the small intestine.

Below the stomach lies the pea-sized, reddish **spleen**. The spleen is part of the immune system and the circulatory system. It stores many kinds of blood cells.

In the dorsal portion of the body cavity next to the vertebral column lie the lima bean sized **kidneys**. Move the viscera to find these two organs. A delicate white tube, the **ureter**, exits each kidney and carries urine to the **urinary bladder**, a thin transparent sac-like structure at the end of the **coelomic cavity**. Immediately anterior to each kidney is the thin elongated, yellowish **adrenal gland**.

**Fat bodies** are the yellowish, glove-shaped structures extending into the abdominal cavity to the right and left of the kidney.

### Figure

Urogenital system: Male frogs have no copulatory organ, therefore fertilization is external. During mating the male frog climbs on the female's back and firmly clasps her around the chest. The male nuptial pads facilitate clasping. This act stimulates spawning by the female and the male frog releases sperm as the eggs are laid.

Sperm are produced by two bean-shaped **testes**, which are attached to the upper one-third of the kidney. Minute **vasa efferentia** carry sperm to the kidney. Lacking a separate genital tract, the ureters convey sperm from the kidney to the cloaca for release during mating.

The **ovaries** vary in size depending on the season. During the mating season the ovaries appear as a mass of black and white beads filling the body cavity. It is best to remove these to allow for clearer observation of the viscera. There is no direct connection between the **ovary** and the **oviduct**. Adjacent to each ovary is a funnel-shaped structure called the **ostium**, which sweeps the eggs into the oviduct via ciliary action. Eggs pass through the oviduct and are stored in the **uterus** prior to mating.

## **Class: Reptilia**

This class includes lizards, snakes, turtles and crocodylians in addition to a number of extinct groups of spectacular creatures. Among these lost reptiles are the dinosaurs, pterosaurs, pliosaurs, ichthyosaurs and plesiosaurs. In addition, to these Mesozoic marvels, there were an assortment of little known but bizarre Late Paleozoic (280,000,000 years ago) reptiles. Dinosaurs appear to have been the dominant land animals for over 150,000,000 years. Reptiles have horny epidermal scales covering their body forming a kind of exoskeleton. Their legs are adapted for locomotion on land, allowing for a complete terrestrial existence. Of utmost importance, reptiles have evolved a land egg allowing reproduction without dependence on water. Students will be responsible for the following extant (living) reptilian orders.

### **Order: Squamata**

Lizards and snakes are included here but the order is divided into the suborder Lacertilia (lizards) and Ophidia (snakes). Both have horny epidermal scales, which are periodically shed. Each jaw is equipped with teeth but only snakes are strict carnivores; some lizards are vegetarians.

The lizards include the geckos, some of which possess minute ridges on their feet that allow walking on glass surfaces or on ceilings. A group of New World lizards, the iguanas, are brightly colored and carry ornamental crests, frills and fans. The most remarkable iguana is the Galapagos Marine Iguana. This is the only living lizard that regularly dives into the ocean to feed on marine algae. Other lizards include skinks, chameleons, horned lizards, and a legless lizard often found in coastal sand dunes. Unlike snakes, legless lizards have movable eye lids.

All snakes lack limbs and eyelids. The scales on their ventral surface are greatly enlarged. Snakes in the family Crotalinae (rattlesnakes) possess a special heat sensor on their head for detection of warm-blooded prey. Other venomous snakes lack these sensors. Sea snakes are a group possessing extremely virulent venom. Many snakes are constrictors that capture prey and subdue them by suffocation. Many snakes simply bite their prey and swallow them.

### **Order: Testudines (Chelonia)**

Turtles are aquatic members of this order while tortoises are terrestrial. All are enclosed within a shell consisting of a dorsal **carapace** and a ventral **plastron**. The shell is composed of fused modified vertebrae and expanded ribs covered by enlarged **scales** or **scutes**. Their jaws lack teeth but are covered by a sharp-edged, horny **beak**. All members of the order are oviparous and eggs are laid in shallow holes or at the termination of borrows. Marine turtles can weigh 725 kg. and reach two meters in length. Galapagos land tortoises are known for their great size and longevity (100 plus years). Our local desert tortoise, **Gopherus agassizi** is a protected species.

## **Order: Crocodilia**

There are approximately 25 species of extant crocodilians. The huge and very dangerous salt water crocodile, **Crocodylus porosus**, may reach 8 meters in length and weight over 2000 kilograms qualifying this species as the largest living reptile. In the United States there are two crocodilian species, **Crocodylus acutus** found only in southern Florida and **Alligator mississippiensis**, found in waterways throughout the Southern United States. Crocodiles have relatively long, slender snouts while alligators have shorter, broader snouts. When the jaws are closed certain teeth are visible in crocodiles but not in alligators. Of the two animals, crocodiles are the more aggressive and possess more powerful jaws.

## **Order: Rhynchocephalia**

This order included numerous species of Mesozoic reptiles but today only a single species exists, the tuatara (**Sphenodon**) residing on small islands off the New Zealand coast. **Sphenodon** is sometimes considered a “living fossil” because it resembles species alive 150,000,000 years ago.

### **Study Questions**

1. List the structural characteristics that distinguish reptiles from other tetrapods.
2. Why are crocodilians considered by some to be the most advanced extant reptiles?
3. Indicate three features that distinguish snakes and lizards.
4. How is it possible for a snake to swallow prey larger in diameter than itself?
5. A number of snake species give birth to living young. Explain how this differs from mammalian birth.
6. What is the only poisonous lizard and where is it found? Why would a government agency pass legislation protecting this species?
7. California has strict laws prohibiting the sale of any native reptile. How does this protect native species?
8. What advances do reptiles show over amphibians with regard to life on land?
9. What is the function of the pits on the heads of rattlesnakes?

## **Class: Aves**

Of all the vertebrates, birds (L., pl. of Avis, birds) are the easiest to recognize because they possess feathers. Many people equate birds to flying but not all birds fly. Flight has evolved three times in the subphylum Vertebrata, birds, bats and the extinct pterosaurs. Birds are probably the best-studied animals due perhaps, to their flight, beautiful color patterns, melodious songs and astonishingly diversity (9,900 species, second only to fishes among the vertebrates). No doubt, bird watching is the largest spectator sport in

the world. More people watch birds than watch football games, basketball games, baseball games and hockey games combined.

The body of a bird is divided into four regions: head, neck, trunk, and tail. A disproportionately long neck functions for balance and food gathering. The tail is not especially long but it carries long feathers useful for balancing and to act as a rudder during flight. The forelimbs are usually modified for flight and the hind limbs adapted for walking, wading, perching, swimming, grasping, etc. Thus the bird is bipedal (walking on the hind limbs). Three of the four toes are directed forward while the fourth is directed posteriorly. In addition to feathers on the body, reptilian-like scales cover the legs of birds.

The skeleton is completely ossified, however the bones are hollow and contain air sacs. As in reptiles, the skull has a single occipital condyle. The sternum has a large ventral **keel** for attachment of the pectoralis muscle used for flight. Teeth are absent in modern birds but a horny beak covers the jaws. Newly hatch chicks retain a tooth-like projection from the upper beak used to crack the shell when hatching. This pseudo-tooth disappears soon after they are free from the egg.

Birds enjoy excellent vision as shown by the well-developed **optic lobes** of the brain. They also possess an acute sense of hearing. Their heart is four chambered and the right aortic arch persists. As in reptiles, the red blood cells are nucleated. They are **homeothermic endotherms**, maintaining a body temperature between 40° and 42° C., a result of the insulating effect of feathers and a high metabolic rate. The well-developed respiratory system connects to the numerous air sacs located in the visceral organs and skeleton. Birds lack a bladder and excrete semi-solid uric acid. Birds are **dioecious** and often **dimorphic**. Fertilization is internal however; birds do not possess a copulatory organ. Females possess a single ovary (the left) and lay hard-shelled eggs--all species are **oviparous**. The parents usually incubate the yolk-rich egg externally. Newly hatched young are either precocial or altricial (see below).

Nest and care of young. Most nests are cup-shaped, constructed from small twigs and vegetation then lined with soft materials such as moss and down feathers. Birds of the order Galliformes (family Megapodiidae) bury their eggs in mounds of sand or vegetation and allow solar radiation or the heat of decomposition to incubate them. Nests are species specific and vary from simple depressions on the ground to very elaborate affairs. Nesting may be solitary, colonial or occasionally communal. Colonial nesting shore birds occupying predator free offshore islands simply lay their eggs on the ground. When construction a nest these species scrape a small depression in the ground and remove troublesome pebbles. Offshore islands often lack sufficient nest-building materials but are predator free thus permitting this nesting behavior. More elaborate nests include the pendent nests of orioles, tidy lichen and spider web nests of humming birds, mud nests of swallows and floating reed nests of the grebes.

Most birds go to great lengths to conceal their nests from danger. Woodpeckers and blue birds nest in cavities or holes in trees, while kingfishers and burrowing owls nest in holes along river banks (kingfishers) or utilize rodent burrows (burrowing owls). Birds of prey (**raptors**) use tall trees or cliffs to build stick or branch nests often exceeding 100 pounds in weight. African hornbills nest in the cavities of trees. The male covers the nest opening with mud leaving a narrow slit through which he feeds the female hornbill as she

incubates the eggs. Upon hatching, the female hornbill breaks out of the cavity after which, the young birds reseal the nest cavity and remain until ready to fly.

Most passerine birds lay three to six eggs, but clutch size varies from one egg (pigeons and hawks) to twenty eggs (quail). Incubation varies from fourteen days in songbirds to twenty-eight days in ducks and geese. In the majority of bird species the female assumes responsibility for rearing young. In rare instances the male incubates the eggs and raises the young (phalaropes). A few bird species (European cuckoos and American cow birds) are nest parasites laying their eggs in the nests of other birds and allowing the foster parents to incubate and raise their young. The parasitic parents assume no role in rearing their offspring.

Hatching success is surprisingly poor in spite of the elaborate mechanisms employed to conceal and protect their nest and eggs. Predation by snakes, jays, crows, skunks and chipmunks along with the elements substantially reduces survival of eggs and young birds. Mourning doves commonly construct poor nest in inappropriate locations allowing eggs and / or young to fall out of the nest. Good Samaritan rescuers often bring eggs and young birds to the SMC Life Science Department. Hawks and eagles appear to have higher success rates than many other birds.

Birds have evolved two distinct approaches to insure survival of their young. **Precocial** species (i.e. quail, chickens, ducks, and many other water birds) produce young covered in down feathers that are able to run, swim, feed themselves, etc. a very short time after hatching. Precocial species expend a great deal of energy producing many eggs per clutch but provide little in the way of parental care. At the other extreme are the **altricial** species (perching birds, raptors, etc.). These birds expend minimal energy producing a few eggs but their naked, helpless hatchlings require feeding sometimes long after leaving the nest and learning to fly. Altricial chicks require huge amounts of food (more than the chick's body weight per day) and parental care. The energy expenditure is very high in these species. The explanation of this sharp dichotomy between the two different approaches to rearing offspring is as follows: There is only so much energy available to invest in rearing young each breeding season. Therefore precocial species invest most of their energy in the production of many young, but little in their care. On the other hand, altricial species expend a minimal amount of energy in egg production but invest greatly in the raising of a few young. Both approaches produce enough offspring to ensure the survival of that particular species.

Feathers. With the exception of several species of Mesozoic reptiles, birds are the only tetrapods with feathers. Feathers are ideal for a flying vertebrate—nearly weightless, tough and strong. A typical feather is a hollow **quill or calamus** embedded in the integument (skin). The **shaft** bears numerous barbs and is a continuation of the quill. Hundreds of closely set barbs are arranged parallel and spread outward diagonally from both sides of the shaft to form a flat **vane**. Under a microscope each barb bears up to 600 parallel filaments or **barbules** and resembles a miniature feather. The barbules are supplied with minute hooks that cross the barbules of the next barb forming a herringbone pattern of interlocking barbs. Any two barbs are very difficult to separate but readily zip together when a bird primes its feathers.

Feathers are of several different types, each with a specific function. **Flight** or **contour** feathers give the bird its outward form and were described in the previous paragraph. Hidden beneath the contour feathers are soft tufts of **down** feathers. Down feathers are

soft because their barbules lack hooks. Their principle function is to conserve heat. Down feathers are abundant on the breast and abdomen of aquatic birds and on the young of 'game' birds. **Filoplume** feathers are hair like and composed of a weak shaft bearing a tuft of short barbs at their tip. These are the 'hairs' found on a plucked chicken or turkey. The function of filoplume feathers is unknown. The **powder-down** features are found on herons, bitterns, hawks and parrots. As powder-down feathers grow their tips disintegrate into talcum powder-like dust that waterproof other feather-types and produce a metallic luster.

Feathers are epidermal structures that probably evolved from reptilian scales. Scales on the legs and feet of birds are reptilian. Anatomical features of the bird skeleton and soft anatomy also suggest an affinity with reptiles. Furthermore, recent fossil evidence from China and North America support the contention of many zoologists that birds are "glorified reptiles" and in reality members of the class Reptilia.

When growth is complete, feathers, like mammalian hair, are dead structures. Over time a feather becomes worn and is replaced. The molting or shedding of feathers is usually a highly ordered process that proceeds gradually allowing replacements to become functional before the worn feather is lost. Thus the bird can fly while molting. The molting process is so orderly that flight and tail feathers are lost in pairs (one from each side) preserving aerodynamic balance. Exceptions to the above are penguins that molt all at once and ducks and geese that are grounded during their molt. Nearly all birds molt after the nesting season (at the end of summer) and assume a dull 'winter' plumage. Just before breeding season in early spring, birds molt a second time, acquiring a bright "breeding" plumage.

**Figure 1.** Draw a single flight feather 10 cm. long. Label all anatomy.

**Figure 2.** Using a dissection microscope draw a 5 cm. long detailed section of a flight feather shaft showing the interlocking barbs and barbules. Label all anatomy.

Avian taxonomy. Birds are placed in specific orders bases on the structural similarities of their beaks, their feet, and their general body form. Avian orders always end in the suffix **-iformes**, which refers to form or shape. There are approximately twenty-seven extant orders of birds. Class will examine only those orders of birds commonly encountered in Southern California. A number of birds mounted in natural postures, similar to those seen in museum displays, can be seen in lab. Others birds in lab are prepared in unnatural postures and are primarily for ornithological research and not display. **Be extremely careful** with all of these fragile specimens.

### **Order: Gaviiformes**

Loons are diving birds famous for their high-pitched, ghostly call often heard on lakes in Northern Canada. Loons are open-water birds with long, sharp bills, short webbed feet and a tailless, elongated body. Their legs are placed posterior to the center of their body making walking difficult. Small fish and crustaceans, their principle food, are obtained by diving to depths of over 200 feet.

### **Order: Podicipitiformes**

This order includes the grebes. Grebes have sharp bills, webbed feet and a rather elongate, tailless body similar to the loons, however they are smaller and more slender than loons. Like loons, their legs are far back on the body causing difficulty when walking. These birds are famous for constructing floating reed nests, which become waterlogged and sink soon after the chicks are hatched. The chicks then rest on the backs of their mothers before learning to swim. Grebes are diving birds feeding on small fish and crustaceans.

### **Order: Pelecaniformes**

These are all large fish-eating birds known as pelicans, cormorants, frigate birds and boobies. Unlike any other order of birds, this taxon is totipalmate--a web unites all four toes. The **gular** or **throat sac** is large and lacks a covering of feathers. Birds in this group are shallow divers feeding on fish, squid and crustaceans.

### **Order: Ciconiiformes**

Hérons, bitterns, egrets, storks, new world vultures and flamingos are included in this order. These large, wading birds are equipped with long legs, long necks and broad unwebbed feet. They feed in shallow water on frogs, fish and small invertebrates.

### **Order: Anseriformes**

This order includes ducks, geese and swans. These water birds have short legs and webbed feet (only three toes are webbed). Their most obvious characteristic is the broad, dorsoventrally flattened lamellate-bill, the sides of which are fluted for straining small invertebrates and plant material from inedible substances. Many are used by man for food.

### **Order: Falconiformes**

The falconiformes includes hawks, old world vultures, eagles, kites and falcons. Their acute eyesight, sharp, hooked beak and powerful feet equipped with sharp claws (talons) are ideal for a predatory life style. Most are fast fliers that overtake their prey in flight or drop from above on unsuspecting victims.

### **Order: Galliformes**

These are the "hen-like game birds; grouse, chickens, pheasant, quail and turkey. Galliformes are medium sized ground birds with strong beaks and powerful feet used for scratching the ground in search of seeds and other vegetation. They have short, rounded wings suited for quick, powerful take-offs. These birds are hunted by sportsman for food.



**Order: Gruiformes**

Birds in this order include the cranes, rails and coots. They lack webbed feet and spend most of their time in marshes or prairie habitats feeding on both plant and animal matter. A common representative of this order is the American coot, a gray, duck like bird with a slightly down curved bill. Rails are endangered due to the worldwide loss of fresh water marshes.

**Order: Charadriiformes**

This is a diverse group of variable sized birds with pointed wings and good flying skills. Most are associated with shore habitats where they probe the mud and sand for small organisms. As a rule, their toes are not completely webbed. Gulls, sandpipers, killdeer, willets, plovers, avocet and stilts are among the many birds placed in this order. Gulls have webbed feet and long wings and can be found world wide, often in schoolyards, athletic fields, and landfills where their omnivorous tendencies can exploit various resources.

**Order: Columbiformes**

Include in this order are the pigeons, doves and extinct dodos. They have slender bills and four toes of nearly equal length. Most are vegetarians and are common in urban settings (often as pests).

**Order: Strigiformes**

The owls are nocturnal birds of prey equipped with excellent hearing and large eyes surrounded by a disk of feathers. Their very soft feathers (plumage) reduce noise associated with hunting. Owls possess hooked bills and powerful talons (claws) suitable for capturing small mammals, birds and other ground dwelling prey. Prey is eaten whole and the indigestible portions (teeth, hair, feathers, etc) are regurgitated as a ball-like mass or pellet.

**Order: Apodiformes**

This order contains humming birds and swifts. As the ordinal name suggest, these birds have small, weak feet suitable for perching. These birds are capable of fast and acrobatic flight using their powerful, slender, pointed wings. Swifts capture insects in flight and humming birds collect nectar from tubular flowers while hovering like a helicopter.

**Order: Piciformes**

Woodpeckers are climbing birds with strong feet and claws. Each foot has four toes in pairs and each pair points in the opposite direction. The stout, chisel-like bill is

employed as a tool for digging into wood in search of insects. Their stiff tail feathers act as a brace against the tree when the bird “hammers” while searching for insects. Woodpeckers often display colorful plumages featuring red, black, yellow and white. Toucans seen in exotic pet stores are also included in this order.

### **Order: Passeriformes**

These are the perching birds characterized by three forward directed toes and a single rearward directed toe. When perched, the feet automatically tighten their grip in the event that the bird begins to fall rearward. Over one-half of all species of birds and one-third of all extant families of birds are included in this order. Passeriformes are known as “song birds” for their ability to produce charming and beautiful musical sounds. Included in this taxon are the crows, ravens, jays, wrens, mockingbirds, robins, starlings, blackbirds, swallows, orioles, sparrows and numerous others. Their varied feeding habits are reflected in their diverse bill shapes.

### **Study Questions**

1. List the characteristics of birds that are not observed in other vertebrates.
2. List the structural adaptations that enable birds to be the most efficient self-propelled, extant animals.
3. Indicate all extant and extinct groups of animals that have evolved self-powered flight.
4. What groups of birds have lost the power of flight?
5. What portion of the bird’s brain is best developed?
6. In what way(s) is the pectoralis muscle of birds peculiar?
7. How do birds regulate their body temperature without the use of sweat glands?
8. How do passerine birds keep from falling off their perches when sleeping?
9. Other than a food item, what economic importances do birds have?
10. Using only the bill shape and size in Passeriformes, list what each might eat.

### **Figure**

### **Class: Mammalia**

The class Mammalia is named for their mammary glands (L. mamma = breast), which produce milk to nourish their young. Although a relatively small group of 4,800 species compared to 9,900 species of birds and over 25,000 species of fish, mammals are one of the most diverse groups in the animal kingdom. Hair is the most obvious external feature in nearly all species of mammal. Skeletal features found in mammals include two occipital condyles, three auditory ear ossicles, seven cervical vertebrae (except four

genera) and diphyodont dentition (two sets of teeth). Additional soft tissue features include non-nucleated red blood cells, a muscular diaphragm separating the thoracic and abdominal cavities, and a retained left aortic arch. Mammalian eggs develop in utero with a placental attachment (except in marsupials and monotremes) and all groups possess extra embryonic membranes very similar to those found in the reptilian egg. One of the most important factors contributing to the success of mammals is the development of the cerebrum, the region of the brain responsible for intellect and for reason.

Follicles in the dermis produce hair by rapid cell division resulting in growth. A major component of hair is the scleroprotein **keratin**. Two principle types of hair make-up the **pelage**: dense, soft insulating under fur and the longer guard hairs providing protection and color. One important role of pelage is thermoregulation. Wear and tear require hair to be replaced periodically and this process may result changes in pelage color due to changing season or aging. Shedding may occur preceding warmer months or as a seasonal phenomenon. Many arctic mammals assume a white pelage in winter and a darker color in summer.

Many mammals have very distinctive coloration such as spots and strips. These striking color patterns are a form of camouflage or **crypsis** allowing the mammal to blend with its surroundings and thus avoid detection. An excellent example is the zebra. The striped pattern tends to obliterate the contour of the body. However, the zebra is obvious when still, but is a blurred outline when running, making it difficult for predators to single out an individual to capture. In addition, the zebra seems to disappear at dusk when predators are lurking and their detection is more difficult. But in daylight, zebras readily see approaching predators and their color pattern is not a detriment to their survival.

Hair color can also act as a warning. Antelopes and deer expose a white rump patch as a “flag” signaling danger to other members of the herd. Warning or aposomatic coloration, seen in numerous mammals (skunks, badgers, etc.), indicates, “stay away I’m dangerous”.

In many mammals hair assumes numerous specialized functions, for example the ‘whiskers’ or vibrissae on the snout. Crepuscular, nocturnal or burrowing species utilize these special receptors when active. At the base of each vibrissae follicle are nerve endings sensitive to touch. Many mammals have hairs modified as sharp spines for protection (porcupines, hedgehogs and echidnas). Modified hair may form other structures such as the horny covering of hooves in horses and cows, the claws in predators, the fingernails in primates and the horn of the rhinoceros.

More than any other structure, teeth reveal the diet, and thus the niche or life-style, of mammals. Tooth enamel is the hardest tissue in the body and persists long after death. It is often fossilized and when studied may accurately reveal the specific diet of an extinct mammal. This can provide information about the environment occupied by a long dead species.

Mammals have diphyodont dentition consisting of a set of juvenile or milk teeth followed by a set of permanent teeth. The anatomy of mammalian teeth varies according to their specific function. This condition is known as **heterodont** as opposed to the teeth in some other tetrapods with an undifferentiated anatomy (**homodont** dentition). Four tooth types are recognized. **Incisors** with sharp crowns or edges suitable for snipping, gnawing or biting. **Canines** are robust teeth with pointed or rounded tips used for tearing

or piercing. **Premolars** (bicuspid) have crowns with one or two cusps useful for shearing or slicing. **Molars** are often massive, multi-cusped teeth with flat crowns useful for grinding or crushing.

### Figure

Human dentition consists of two incisors, one canine, two premolars and three molars in each half of the upper and lower jaws. The last or third molar in each jaw is called the “wisdom tooth” and in many modern humans this tooth fails to erupt or is entirely absent. When all teeth are present each jaw contains sixteen teeth bring the total number to thirty-two. Mammalian dentition is written in a form recognized by all zoologists. Using man as an example, the formula would be 2-1-2-3 representing the teeth present on each side of the head (16). 2-1-2-3 Man is omnivorous and the teeth are generalized. Carnivores have well-developed canines and sharp-edged posterior dentition . The dental formula of a dog is 3-1-4-2.  
3-1-4-2

Enlarged incisors characterize rodent dentition with enamel on the labial (lip) side only. The lingual (tongue) side, lacking enamel, wears faster thus maintains a sharp edge on the incisors. Rats are capable of gnawing through electrical wiring creating short circuits and sometimes resulting in fires. The dental formula of your beloved lab rat is 1-0-0-3.  
1-0-0-3

Ungulates (hoofed mammals) feed on soft vegetation and leaves using their incisors to clip or snip much like a lawn mower. Many ungulates have lost their upper incisors substituting a pad for the lowers to nip against. Also absent are the upper canine teeth, however the lower canines are only reduced in size. Premolars and molars of these mammals are massive grinding surfaces for “milling” their food. The dental formula for horses is 3-0-3-3 and the formula for the deer is 0-0-3-3. The large gap between the incisors 3-1-3-3 and the premolars is termed a 3-1-3-3 **diastema** (this is where the bit goes in horses).

The elephant’s tusk is a modified upper incisor and is present in both sexes. Male boars have a modified canine forming their tusk. A marine mammal known as the narwhal has a single upper incisor modified as a tusk found only in males. Other teeth are usually absent in this species.

Horns and Antlers. True horns are found in both sexes of sheep, cattle, bison, water buffalo, antelope etc. (i.e. the ruminants). Formed from hollow sheaths of keratinized epidermis (material similar to fingernails) surrounding a core of hollow bone projecting from the skull roof. Horns are neither shed nor branched in all these mammals except pronghorn “antelope”, native to western North America. Curiously, pronghorn shed their branched horns.

Mature antlers are solid bone, branched and found only in males of the deer family (cervidae). Each year antlers form under a highly vascular skin called **velvet**. When growth is completed the velvet dries and is rubbed off by the male. After the breeding season antlers are shed.

Another kind of horn-like structure is found in the rhinoceros. Hair-like horny fibers arise from dermal papillae and are cemented together to form a “horn”. Clearly, the rhinoceros horn is more akin to hair than to true horns.

**Subclass: Prototheria**

**Order: Monotremata**

These are the egg-laying mammals equipped with mammary glands. They retain numerous reptilian characteristics in their skeleton, soft anatomy (they possess a cloaca) and in their reproduction. Included here are the duckbill platypus (**Ornithorhynchus anatinus**) and the echidna (**Tachyglossus**). This order is restricted to Australia, Tasmania, and New Guinea. They bear uncertain affinities to other mammalian orders.

**Subclass: Metatheria.**

**Order: Marsupialia**

These are the pouched mammals and include kangaroos, koalas, wombats, bandicoots and the extinct Tasmania wolf. Opossums are the only extant marsupials residing in the Americas. Today opossums are found in urban settings and are expanding their distribution in North America. Their young are born in a tiny, immature state and crawl from the vaginal area to the pouch where they attach to a nipple and complete embryonic development. Marsupials bear prepubic bones supporting the pouch.

**Subclass: Eutheria**

The remaining orders of mammals are included here. Pregnant females have a special structure in their uterus, the placenta, which provides nourishment for the developing embryo. Adults lack prepubic bones and a pouch.

**Order: Insectivora**

Shrews, hedgehogs and moles are the most primitive placental mammals and are widely distributed throughout most of the world but absent from Australia and New Zealand. They feed on insects and other small invertebrates.

**Order: Chiroptera**

Bats are the only flying mammals. Their wing membrane is supported by the elongated second, third, fourth and fifth digits of the hand. In California, bats are the second most diverse group after rodents. They are crepuscular and nocturnal, therefore go largely unnoticed. Most species are insectivorous however the vampire bats, found in Mexico and South America, feeds on the blood of domestic animals and roosting birds.

**Order: Carnivora**

Dogs, wolves, bears, cats, skunks, weasels as well as many marine mammals are included here. They are intelligent mammals with excellent problem solving ability. Their teeth have evolved for piercing and cutting meat. Although some are habitual omnivores (bears and coyotes), they also hunt.

**Order: Rodentia**

Members of this order are the most diverse, abundant and successful of all mammals. Rodents are the familiar gnawing mammals; mice, rats, beavers, gophers, etc. Their incisors are well developed, however canine teeth are absent. Rodent incisors grow continuously throughout life. Daily gnawing is essential in order to prevent the incisors from growing to the point where opening the mouth is not possible.

**Order: Lagomorpha**

Include here are the rabbits, hares and pikas, often misidentified as rodents. Lagomorphs have two pair of chisel-like incisors in addition to an extra pair of small upper incisors. Rabbits (i.e. cottontails) burrow and have altricial young while hares (i.e. jackrabbits) do not burrow and have precocial young.

**Order: Edentata**

As adults edentates (sloths, anteaters, and armadillos) lack teeth. Many species feed on ants and have well-developed claws for opening anthills and a sticky tongue for catching ants. Most are confined to Central and South America, however armadillos inhabit much of the southern United States, especially Texas. Much of the bodies of armadillos are covered with keratin covered, bony plates with hairs between them.

**Order: Cetacea**

This order includes the mostly marine whales, dolphins and porpoises. Their nostrils or “blowhole” are found near the top of the head. Smaller cetaceans and sperm whales possess teeth, however nine species of larger whales are edentulous and feed on minute organisms strained from sea water by keratinized plates of baleen hanging curtain-like from the roof of their mouths. Hair and skin glands are largely absent. Locomotion is provide by a tail modified into a horizontal fluke. The pectoral limbs are modified as paddle-like flippers and the pelvic limbs are absent (except in extinct species).

**Order: Proboscidea**

Only two species of proboscidiens are living today; the large-eared African elephant and the smaller Southeast Asian or “Indian” elephant. Their upper incisors are modified as massive tusks. Mammoths and mastodons are extinct species found in Europe, Asia,

Africa and North America (three species are known from fossil deposits in the Los Angeles basin and the Channel Islands).

**Order: Primata**

This order includes lemurs, monkeys, apes and man. Most of these large brained mammals are arboreal with limbs adapted for climbing. They have remarkable flexible skeleton and are extremely well coordinated. One species is preoccupied with reproduction.

The last two orders were formerly referred to as “ungulates” or hoofed mammals that walk on the tips of their toes.

**Order: Perissodactyla**

These are the odd-toes mammals known as horses, asses, tapirs and rhinoceroses. Teeth are adapted for chewing plant material. Fossil evidence suggests that horses evolved in North America during the Cenozoic and migrated into Asia three or four million years ago. Sometime during the last 10,000 years horses ceased to exist in North America but were reintroduced in the 1540's by the Spanish (Coronado). Rhinoceroses were also inhabitants of prehistoric North America.

**Order: Artiodactyla**

Deer, elk, camels, swine, antelopes, bison, cows, sheep, etc. are included in this order of even-toes mammals. Usually the tips of the third and fourth toes are retained for locomotion. Their teeth are adapted for the mastication of plant material. Horns and antlers are present in members of the order.

**Figure**

## THE RAT

The rat is an excellent laboratory animal for understanding basic mammalian anatomy. According to the experts, the rat used in lab is the Norway rat, **Rattus norvegicus**, however it is an albino subspecies, **Rattus norvegicus albinus**. The following is a more complete classification:

Phylum Chordata  
Subphylum Vertebrata  
Class Mammalia  
Order Rodentia  
Family Muridae  
Genus **Rattus**  
Species **norvegicus**  
Subspecies **albinus**

The common or black rat, **Rattus rattus**, and the Norway rat are thought to have originated in Southeast Asia and migrated west from China and India to Europe. The common rat reached Northern Europe first and later into Southern Europe, via India and Persia during the 11<sup>th</sup> and 12<sup>th</sup> centuries. This is the rat of the Bubonic plagues and of ‘Pied Piper’ fame. European explorers introduced this rat to eastern North America by 1548.

The Norway rat was carried by shipping from Southeast Asia to China and from there to Siberia and Russia. Overland caravans then carried this species to Europe, reaching England by 1730. By the latter half of the 1700’s these rats were in North America. The Norway rat is larger and stronger than the common rat and displaces it when both are found together. This displacement of the black rat is believed to be a factor responsible for the end of the Bubonic plagues of Europe (Norway rats do not carry the plague). Norway rats prefer basements and lower floors of buildings, whereas black rats prefer attics (hence the name “roof rat”). Where sanitation and modern buildings exist, black rats are rare and Norway rats are common. In many western coastal cities, black rats are found only in city slums.

### **Class: Mammalia**

The class Mammalia has two outstanding characteristics: hair present at some stage of life and mammary glands. Mammary glands produce milk for their offspring. A body temperature held constant (most of the time) and a four-chambered heart are features common to mammals and birds. In mammals the aorta is derived from the left aortic arch while in birds the systemic arterial supply is provided by the right aortic arch.

### **Figure**

External anatomy. The laboratory rats are anesthetized before euthanasia and then preserved. After each lab specimen should be moistened and stored in a plastic bag until



the next lab period. rats have their arterial system injected with red latex for easy identification.

Rinse your specimen thoroughly and dry it with paper towels. Several rinsings each lab period will restore much of the white color to the rat. The hairy coat of mammals is called **pelage**. Long whiskers or **vibrissae** occur just posterior to the nose and above the eyes. Vibrissae allow burrowing or nocturnal animals to maintain contact with objects or surfaces while seeking food. The lateral extension of vibrissae always exceeds the widest part of the body enabling the animal to measure openings, etc. before entering. Nostrils or **nares** are located on snout and can be closed if the rat is submerged. The naked skin of the nose is very sensitive to touch. The mouth is **subterminal** with well-developed lips. A cleft ('hair lip') or groove, called a **philtrum**, exposes the incisors characteristic of this mammalian order. In living rats the eyes bulge out to the sides allowing a nearly 360° visual field while the large pupils provide excellent night vision. A nictitating membrane (or third eyelid) can be seen in the inside corner of each eye. Eyelids are similar to those of other mammals. The large external ears (pinna) are located posterior to the eyes. Notice the ear canal or **external auditory meatus** leading to the eardrum.

The rat has a short neck and a body divided into a **thoracic** region (chest) followed by the **abdominal** region. Rats are **quadrupes** (tetrapods) with four digits and a vestigial first digit. When walking the soles of the feet and heel contact the ground in a locomotor mode known as **plantigrade**. Six pairs of nipples or **teats** can be found on the ventral surface of the body. The well-developed tail of rats has a few scattered hairs distributed between reptile-like epidermal scales

Like most mammals rats have separate urogenital and anal openings. Females have a **urethral** opening ventral to the **vaginal orifice**. At the base of the tail one finds the **anus**. Males possess a **penis** anterior to **scrotal sacs** containing the **testes**. **You are responsible for both sexes so be sure to examine a rat of the opposite sex.**

Skinning the rat. Place the rat on its back in a dissecting tray with the tail toward you. Beginning at the throat make a midline incision posteriorly to just above the anus, be very careful not **cut to deep**. Be careful not to cut through the thin abdominal muscles into the body cavity. Separate the skin from the underlying muscle. Cut around the genitalia on the rat's left side and down to the base of the tail. Now make a lateral incision on the side of each arm and leg to the wrists and ankles. Follow this by making an incision encircling each wrist and ankle. Now remove the skin from the appendages. Lastly, extend the initial incision anteriorly to the mouth and make a cut encircling the mouth. Your fingers are the best tools for separating skin from muscle. The less you cut the better the result. A blunt object such as the end of a scalpel can be helpful when separating skin from the underlying muscle. Work carefully so the muscle will be in good condition. A well-executed skinning requires about one hour. Hints: The only region needing more dissection is the head so leave this area for last. When removing the facial skin cut around the ears and eyes. The skinning process is the same used when skinning bears, deer, cows, etc.

Muscular system. Contracting muscle cells convert the potential energy present in chemical bonds to the kinetic energy of thousands of contracting muscle cells. We will study the superficial **skeletal (striated or voluntary)** muscles, which attach to the

skeleton via **tendons**. Bands can be seen when examining this striated muscle using a light microscope, hence the term “striated”. A sheet of connective tissue called **fascia** covers striated muscles.

The primary function of muscle cells is **contraction**. Muscles are connected to bones by **tendons** and contraction produces movements of the skeleton. The place of attachment of a muscle that moves during contraction is called the **insertion**. Conversely, the point where a muscle attaches that remains fixed in position is termed the **origin**. Muscles that bend joints are identified as **flexors** and those that extend joints are extensors. **Elevators** are muscles that raise appendages while those that lower appendages are **depressors**. Muscles that move bones toward the midline of the body are **adductors** and those that move bones away from the midline are termed **abductors**. Muscles called **rotators** effect rotation of bones. The largest portion of a muscle is called the **belly** and is most often found midway between the origin and the insertion.

The musculature. Carefully dry the surface of the muscles with paper towels and remove all fatty connective tissue. Separate each muscle using a dull probe by working along their natural boundaries then insert the probe under the muscle bundle until it appears on the opposite side. If instructed, **bisect** a given muscle by cutting through the belly at a right angle to the direction of the individual fibers. Make all bisections on the left side of your specimen. To **reflect** a bisected muscle lift up each portion and fold towards its point of attachment. This technique is necessary for identification of attachment points as well as identifying underlying muscles. Below is a list of the superficial muscles that you will be responsible for. Use the figures in this manual as an aid to identification.

### Figure

**Cutaneous maximus.** This muscle is attached to the skin on the lateral and dorsal sides of the body (see figure). It originates under the forelimb and inserts on the underside of the skin. Its action is to move the skin. Cut it free just posterior to the arm than bisect it and reflect the two portions.

**External oblique.** Covering the sides of the abdominal cavity from the ribs to the hips, fibers of this muscle run at right angles to the fibers of the latissimus dorsi. **Do not bisect this muscle.** The external oblique compresses and retains the viscera and act in concert with the rectus abdominis muscle to form a flexible ventrolateral body wall.

**Rectus abdominis.** This muscle is located on the ventral side of the rat from the rib cage to the pelvic girdle and supports the abdominal viscera. **Do not bisect this muscle.**

**Latissimus dorsi.** Lying partially covered dorsally by the spinotrapezius, the latissimus dorsi originates on the thoracic and lumbar vertebrae and inserts on the under side of the upper arm bone (humerus). Its action is to move the arm upward and backward or dorsocaudad. **Bisect and reflect.**

**Spinotrapezius.** This muscle's originates on the thoracic vertebrae and inserts on the spine of the shoulder blade (scapula). It moves the scapula dorsocaudad. Locate the midpoint and bisect this muscle at right angles to its fibers, reflect and expose the underlying portion of the latissimus dorsi.

**Acromiotrapezius.** Representing the central portion of the trapezius group, the acromiotrapezius originate on neck vertebrae and inserts on the scapula. Its action is to move the scapula dorsally. **Do not bisect.**

**Clavotrapezius.** Located anterior to the acromiotrapezius, the clavotrapezius is a narrow, thin band of muscle originating at the top of the neck and inserting on the collar bone (clavicle). When in action this muscle elevates the clavicle. **Do not bisect.**

**Sternomastoideus.** This narrow muscle lies just anterior to the clavotrapezius, originating on the breastbone (manubrium) and inserting under the clavotrapezius on the mastoid process of the skull. The sternomastoideus helps turn the head. **Do not bisect.**

**Masseter.** Located on the posterolateral portion of the head, the well-developed masseter acts to move the lower jaw (mandible) when gnawing and chewing. Its origin is on four regions of the skull and its insertion is on numerous points on the mandible.

**Deltoideus.** This muscle is found along the shoulder posterior to the clavotrapezius, partially covered by the acromiotrapzius. Originating on the clavicle and scapula and inserting on the humerus, this muscle extends, flexes and rotates the humerus.

**Triceps brachii.** Covering the side and back of the upper arm, the triceps brachii originates on the humerus and scapula and inserts on the elbow. The principle action of this muscle is extension of the forearm. **Do not bisect.**

**Biceps brachii.** The biceps brachii is found on the anterior surface of the humerus. It originates on the scapula and inserts on the radius bone of the forearm. Flexion of the forearm is its principle function. **Do not bisect.**

**Biceps femoris.** A large powerful muscle on the lateral side of the thigh the biceps femoris originates on the pelvis and inserts on the lower portion (distal) of the femur and upper (proximal) end of the shin bone (tibia). It abducts the thigh and flexes the calf.

**Bisect this muscle.**

**Gluteus maximus (superficialis).** The gluteus maximus is a wide, thin, triangular sheet covering that part of the hip anterior to the attachment of the biceps femoris and corresponds to the enlarge muscle forming the buttocks in humans. This muscle originates on the pelvic girdle (ilium and sacrum) and inserts via a tendon on the femur (greater trochanter). The anterior border blends indistinguishably with the **tensor fascia lata** anterior to the biceps femoris. **Do not bisect.**

**Gastrocnemius.** Forming the bulk of the calf this muscle originates on the distal end of the femur and inserts on the heel via the **Achilles tendon**. **Bisect and reflect.**

## Figure

Before studying the internal anatomy examine the superficial glands on the ventral and lateral aspect of the neck and head. Located on the anteriolateral aspect of the head is the **lacrimal** or tear gland. This gland provides moisture for cleaning and lubrication of the eye. Examining the ventral surface of the neck locate the **salivary glands**. The largest is the **mandibular gland**. Lying on its anteriolateral surface is the **sublingual gland**. The **parotid gland** is lateral to the mandibular gland. The ducts from these three glands open into the mouth and provide secretions known as saliva. Amylase, an enzyme in saliva, initiates the digestion of carbohydrates.

Internal anatomy. Open the body cavity by making a small incision just below the posterior end of the sternum at the bottom of the rib cage. To avoid damage to the viscera

**do not cut too deeply.** Using scissors, cut through the sternum toward the neck until you reach just beyond the anterior edge of the pectoralis muscle. Reverse direction and cut posteriorly through the body wall along the linea alba to a point just anterior to the genitalia. From this point carefully make bilateral cuts to the vertebral column (see diagram). Return to the chest and cut the **diaphragm** loose from the rib cage while holding the chest open. The diaphragm is the muscular partition separating the chest (pleural) cavity from the abdominal (peritoneal) cavity.

Once you have cut the diaphragm, place your thumbs inside the chest cavity until you touch the vertebral column. Now break all the ribs from bottom to top to allow examination of the internal organs. Next wash out the body cavity with cold water to remove any coagulated blood and excess embalming fluid. Make sure that you agitate the intestines to shake loose any material present. If you did a good job the internal organs will have a nice shiny appearance.

Thoracic cavity. The **heart** is a prominent conical organ centrally located in the thoracic cavity. A thin membrane, the **pericardium** forms a sac (**pericardial cavity**) surrounding the heart preventing it from rubbing against other thoracic organs. Notice that the two **ventricles** appear as a single large, light brown organ with a tough, muscular texture. Two **atria** appear as dark masses, which lie on the anterior surface of the heart. Covering the anterior portion of the heart is the large **thymus gland**. The thymus gland is important for the proper functioning of the lymphatic system. A **lung** lies on either side, immediately lateral and dorsal to the heart. The single-lobed left lung is smaller than the right because the heart is tipped to the left and restricts the available space. On the other hand the right lung is often three lobed. Locate the trachea anterior to the lungs; this tubular structure carries air from the pharynx to the lungs. Look for the **esophagus** dorsal to the trachea. This portion of the **alimentary canal** disappears under the heart and passes through the central portion of the diaphragm to join the stomach.

Abdominal cavity. When handling the abdominal organs be careful not to tear the **mesenteries** binding the various organs together or suspending them from the dorsal body wall. **Be sure you realize that your right is the rats left and vice versa.** The **coelom** is the cavity in which the **viscera** are suspended. Once again note the **parietal peritoneum** and **visceral peritoneum**.

A conspicuous, large brown multi-lobed **liver** lies immediately posterior to the diaphragm. The median lobe of the liver contains a groove or cleft in its central part and the large, left lateral lobe partially covers the stomach. The smaller right lateral lobe is partially hidden from view by the median lobe. A partially divided caudate lobe folds around the esophagus and the stomach. Rats lack a gall bladder. The **stomach** is a curved pear-shaped organ situated on the left side posterior to the diaphragm. A valve, the **cardiac sphincter**, marks the entrance of the esophagus into the stomach and at the opposite end, a **pyloric sphincter** indicates the beginning of the small intestines. The left outer margin of the stomach is termed the **greater curvature** while the inside margin is the **lesser curvature**. A fore stomach is nearest the esophagus, a fundic portion is in the middle and the posterior stomach is the pyloric region. A semicircular, liver-colored **spleen** lies to the left of the lateral lobe of the liver between the greater curvature of the stomach and the left body wall. The spleen stores red blood cells, disposes of old red blood cells and produces certain white blood cells. Suspended in the mesentery between the stomach and the spleen is the flat, lumpy irregular brownish **pancreas**. Do not

confuse it with the yellowish mass of fatty tissue found in the same region. Follow the pancreas to the pyloric end of the stomach to see where pancreatic secretions enter the digestive system. The **small intestine** is a slender tube extending from the stomach to the large intestine. As you follow the small intestine note the blood vessels in the mesentery. The small intestine is divided into **duodenum** beginning at the pyloric sphincter, a central section, the **jejunum** and ending in the posterior **ileum**. A large, sac-like **caecum** marks the beginning of the **large intestine**.

The large intestine or **colon** is the gray-green tube that processes and disposes of fecal matter. It consists of four regions that can be located and identified both by their appearance and by their position. The **caecum** is a large, flattened sac pointed at its posterior end. This blind pouch is situated between the small and the large intestine and is usually located in the lower third of the abdominal cavity. From the caecum the **ascending colon** passes anteriorly up the right side of the body cavity toward the right lateral lobe of the liver. Next the **transverse colon** passes across the body cavity under the liver and stomach and turns posteriorly to become the **descending colon** passing along the left side of the abdominal cavity to join the **rectum**, a short section of the descending colon terminating at the **anus**. Pull the small intestines to the right to view this clearly.

With the intestines moved to the right look for the dark brown, bean-shaped **kidneys**. They are attached to the dorsal body wall and may be partially concealed by fat. Imbedded in the fat anterior to each kidney is a small rounded brown **adrenal gland**. From each kidney a **ureter** passes to the bladder. The ureters are delicate, cream or white colored tubes that are easily broken. Gently moving a kidney may help you find the ureter. The **urinary bladder** is a small, midventral sac located at the bottom of the abdominal cavity. It collects and temporarily stores urine carried from the kidneys by the ureters. The bladder is often collapsed and therefore easily overlooked.

Male and female reproductive systems. The paired **seminal vesicles** are lumpy, brown glands situated on each side of the bladder. Dorsal to the urinary bladder on either side of the penis lie the pea sized, shiny white **prostate glands**. Open a **scrotal sac** and find the **epididymus (head and tail)**, testis and the **vas deferens**. Trace the latter to its union with the penis. In the female the **uterus** is a short gray tube lying dorsal to the urinary bladder and ventral to the rectum. The uterus is divided into two gray-brown, undulating tubes (**uterine horns**) that extend anteriorly against the dorsal body wall toward each kidney. Remove the fat that surrounds the uterine horns for a better view. On the anteriormost termination of the uterine horns lie the **ovaries**; small, lumpy (sometimes pinkish) glands covered in fat. Carefully remove the fatty tissue around one gland. Tiny tubes, the oviducts, are situated between the uterine horns and the ovaries. **To be seen clearly a dissecting scope is needed.**

Protecting your animal from dehydration. After completing the study of the internal organs, moisten the viscera and wrap the skin around the animal and secure with a piece of string. Place your name in pencil on a piece of paper or an I.D. card and place the rat into a plastic sac. Your lab section may have a plastic bucket labeled “Rat City” or a box labeled “Rats” with your instructor’s name on it—place your animals in either of these containers. An excellent study method is to review all the structures you have learned each lab period.

Circulatory system. The circulatory system of the rat is nearly identical to that of man and other placental mammals. Red latex fills the arteries of the rat thus facilitating their study. Time does not permit study of the venous system. By carefully dissecting the rat, it will be possible to locate and identify the major arteries listed below. Occasionally the red latex does not fill an artery. If this has happened, examine another student's specimen to acquaint yourself with that particular artery.

Proceed cautiously to avoid damage to an artery. Always follow a known artery when locating an unknown artery. Do not break arteries or remove organs because they are the keys to identification. As one locates and identifies arteries, carefully remove adipose tissue (fat) and then separate arteries from mesenteries. For clarity you may expose the red latex by removing the arterial walls.

Begin at the heart. Review the anatomy of the heart and identify all parts. The pulmonary circulation is on the right side and pumps blood to the lungs for oxygenation. Oxygenated blood from the lungs is returned to the left side of the heart and then pumped from the left ventricle as the systemic circulation, thus providing oxygen and nutrients to the cells of the body. The large artery carrying oxygenated blood leaves the left ventricle between the atria and is termed the **ascending aorta**. This vessel arches toward the left to form the **left aortic arch**. It turns posteriorly and passes dorsad to the heart to become the **descending aorta**. This straight portion of the aorta travels posteriorly supplying blood to the thoracic and abdominal regions. The descending aorta lies ventral to the vertebral column and is best seen by gently pulling the heart and lungs to the right side. Above the diaphragm the aorta is referred to as the **thoracic aorta**. Posterior to the diaphragm this same vessel is called the **abdominal aorta**. It lies tucked under the vertebral column and produces several branches to the major organs (see below). Near the pelvic girdle the abdominal aorta bifurcates to form two **iliac arteries** carrying blood to the pelvis and posterior appendages. The abdominal aorta cannot be seen unless the viscera are gently moved to the right side of your specimen.

Locate the arteries by beginning with the ascending aorta at the heart. The first artery leaving the ascending aorta is the **inominate artery** leaving as the aorta bends to the left. The short inominate artery bifurcates to form the **right common carotid artery** and the **right subclavian artery** (supplying blood to the right shoulder region). The **left common carotid artery** exits the aortic arch to the left of center (supplying blood to the left side of the neck). **There is no left inominate artery**. Next off the aorta arch is the **left subclavian artery** carrying blood to the left shoulder region. Gently pull the liver, stomach and intestines to your left. The first artery leaving the descending aorta is the **coeliac artery** and it quickly branches to form the **hepatic artery** (liver), the **gastric artery** (stomach) and the **splenic artery** (spleen and pancreas). Posterior to the coeliac artery, the **anterior mesenteric artery** leaves the descending aorta carrying blood to the duodenal portion of the small intestine and the associated mesentery. The very small **adrenal arteries** exit the descending aorta below the anterior mesenteric artery to supply the adrenal glands. A pair of **renal arteries** are the next vessels to leave the descending aorta and travel to each kidney. Just below the renal arteries two small **genital arteries** supply the gonads. Trace these to their respective destinations. Blood to the abdominal wall is provided by a pair of **iliolumbar arteries** leaving the descending aorta posterior to the genital arteries. These vessels pass diagonally across the ventral surface of the dorsal

body wall to reach the root of the thigh. The last vessel exiting the abdominal aorta (descending aorta) is the **posterior mesenteric artery** carrying blood to the lower intestinal tract and the associated mesenteries. The aorta terminates as a pair of **iliac arteries** carrying blood to the hind limbs. These become the rather superficial **femoral arteries** of the thigh. Finally, a third or **caudal artery** exits between the two iliac arteries and supplies blood to the tail.

Urogenital system. The urogenital system includes the primary excretory organs and the reproductive organs. These two systems are considered together because they are either interconnected, as in the male, or are in close proximity, as in the female. The excretory system includes the kidneys, the ureters carrying urine from the kidneys to the bladder for temporary storage, and the urethra, which transports urine to the outside. In males the urethra passes through the penis.

To examine the female more closely, locate the joint between pubic bones and separate it with a scalpel and pry the bones apart. This will expose the **urinary bladder**, the **urethra**, the **vagina** and the **rectum**. Beginning at the external **vagina orifice**, follow the vagina and locate the **uterus**. The uterus bifurcates into two **uterine horns** or **cornu**. Each uterine horn leads to a small tube, the **oviduct** or **fallopian tube** that terminates in a small funnel-like **infundibulum**. Directly above the infundibulum is a small, dark, granular **ovary** clothed in the uterine mesentery. If the rat is immature the ovaries may not be seen. In pregnant specimens the horns of the uterus may resemble “beads on a string”. Each “bead” encloses an embryo, which can be observed by making a longitudinal incision through the uterine wall. Each embryo is surrounded by extra-embryonic membranes and connected to the uterine wall via an umbilical cord. Review the female urinary system at this juncture.

The excretory system of the male consists of the kidney, the ureters, the urinary bladder and the urethra. Except for the urethra’s passage through the penis, the male and female excretory systems are identical. Split the pubic symphysis as described for the female and open the **scrotum** with a scalpel to expose the **testes**. Locate the coiled **epididymis** on the lateral side of each testis. It leads to the **vas deferens**, which passes through an opening in the posterior body wall called the **inguinal canal**. The vas deferens conveys sperm to the urethra and out the penis. At the junction of the paired vas deferens, the ureters and the bladder you will find the two lobate, cream-colored **seminal vesicles**; both of which communicate with the urethra. Partially surrounding the urethra and below the bladder is the **prostate gland**. The urethra passes through the prostate gland and continues to the end of the penis. **Cowper’s gland** lies in the nearby pelvic cavity and, along with the prostate gland and seminal vesicles, produce secretions forming **semen**. The penis points anteriorly and terminates as the **external urogenital orifice**. On each side of the external urogenital orifice is a **preputial gland**. Secretions produced by this gland lubricate the penis during coitus. **REMEMBER: you are responsible for both male and female reproductive systems.**

Nervous system. Vertebrates have evolved the most complex nervous system in the Kingdom Animalia. The vertebrate nervous system is divided into two portions. The brain and spinal cord form the **central nervous system** or **CNS** and the cranial nerves (12 pairs in rats), the spinal nerves (34 pairs in rats), the sense organs, and the autonomic

nervous system form the **peripheral nervous system**. In general nerves are very difficult to locate or preserve, therefore we will only examine the brain.

### Figure

Skin the entire head of the rat and then scrape the top of the cranium with a sharp scalpel until the skull roof is paper-thin. Do not scrape through to the brain. As you scrape, hold the rat tightly by the neck and body. Using the scalpel and stout forceps break and peel away the remaining skull roof to expose the brain.

The large, bisected lobe is the **cerebrum** and each lobe is called a **cerebral hemisphere**. This portion of the brain controls most motor and sensory activities. Anterior to the cerebrum are two small **olfactory lobes** dedicated to the sense of smell or olfaction. Posterior to the cerebrum is the trilobed cerebellum, the location of motor-sensory coordination. Posterior to the cerebellum is the **medulla oblongata**, which resembles a thickened spinal cord. The medulla controls respiration, heart rate, swallowing and gastrointestinal functions. At the junction of the two cerebral hemispheres and the cerebellum lies the small, peaked-shaped **pineal gland**. Unfortunately time does not permit a review of this gland's fascinating evolutionary history. It should be noted that it is sensitive to light received from the retina and helps control the ovarian cycle.