Some Vertebrates (and Not So Vertebrates)

To understand vertebrates, we need to first understand chordates. Chordates are the most highly evolved of the deuterostomes. All chordates share at least 4 common features:

(a) the presence of a notochord,
(b) the presence of a pharynx with pouches or slits in their walls,
(c) a dorsal, hollow nerve cord, and
(d) a postanal tail.

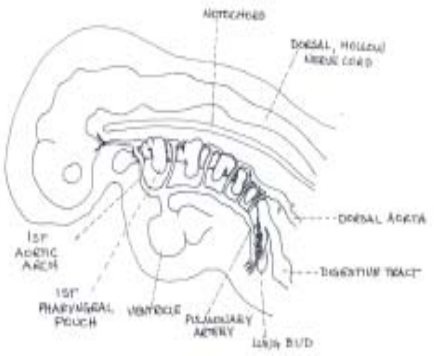

Figure 1. Chordate embryo.

Notochord

At its highest stage of development, the notochord is a flexible, endoskeletal rod of living cells typically located ventral to the central nervous system and dorsal to the digestive system. It is designed for support and serves as an internal skeleton. In vertebrates, the notochord becomes surrounded by cartilagenous or bony rings called vertebrae and is often obliterated.

Pharynx

This is the area in the mouth region that arises from endoderm and forms pharyngeal pouches in the embryo. These pouches may rupture and form external openings called gill slits. They may remain throughout life or close up. The opening starts as an ectodermal groove that often meets the endodermal outpocketing and then ruptures. In aquatic animals, the gill pouches and openings serve as respiratory structures. In animals not aquatic, the pouches often turn into different structures such as the eustachian tube, middle ear cavity, and the palatine tonsils (in mammals). The other pouches form the thymus and parathyroid glands. The number of arches varies from animal to animal.

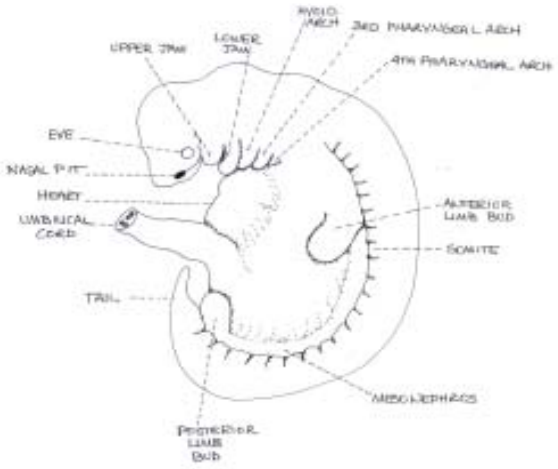

Figure 2. Vertebrate embryo.

Dorsal, Hollow, Central Nervous System

The central nervous system (CNS) in vertebrates is composed of a brain and a spinal cord, both of which contain a central cavity. The CNS arises from the longitudinal neural plate in the dorsal ectoderm, which folds over and forms the hollow tube. Nerves branch off the brain and nerve cord. Ten cranial nerves are found in fish and amphibians and twelve in reptiles, birds, and mammals.

Postanal Tail

This allows for greater motility and a free-swimming existence. It is enhanced later in fishes by fins.

Vertebrae

In the subphylum Vertebrata, the vertebral column serves as an independent axial skeleton which provides more rigidity than the notochord and, at the same time, provides more flexibility. The column is either formed from cartilage, bone, or both.

There are several biological contributions that chordates have provided evolution. These include:

(a) an endoskeleton that evolved from the notochord,
(b) a perforated pharynx,
(c) a predatory habit,
(d) paired appendages, and
(e) neoteny.

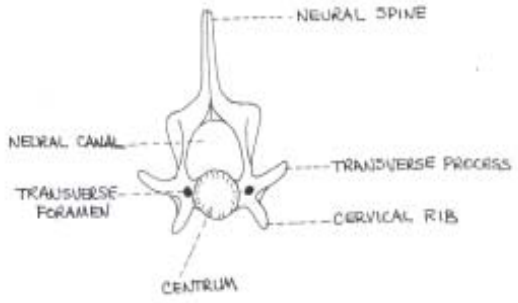

Figure 3. Vertebra.

The endoskeleton allows continuous growth without the need of molting and allows for a greater body size. It also serves as an efficient framework for muscle attachment and, thus, greater mobility. The perforated pharynx allowed the development of internal gills and jaws. The predatory habit led to the highly differentiated brain and paired sense organs. The paired appendages developed into joined limbs for locomotion on land or flight for aereal organisms. The neotenic condition means that there is sexual maturity in the larval body form.

CLASSIFICATION OF CHORDATES

Phylum: Chordata
- Subphylum: Urochordata - tunicates and sea squirts
- Subphylum: Cephalochordata - lancets (amphioxus)
- Subphylum: Vertebrata - bony or cartilagenous vertebrae surrounding spinal chord notochord in all embryonic stages, rarely persists
  - Superclass: Agnatha - jawless fish
    - Class: Myxini - hagfishes
    - Class: Cephalaspidomorphi
  - Superclass: Gnathostomata - with jaws
    - Class: Chondrichthyes - sharks, skates, rays
    - Class: Osteichthyes - bony fishes
    - Class: Amphibia - amphibians
    - Class: Reptilia - snakes and lizards
    - Class: Aves - birds
    - Class: Mammalia - mammals

Subphylum Urochordata (Tail Chordates)

These are invertebrates but they have a notochord, and are the most successful of that group. There are around 2000 species and they are all marine. They are widely distributed in seas from the

shoreline to great depths. The common name is tunicate (or sea squirt), a reflection on the covering or tunic of the animal composed primarily of cellulose. The tunic may be thick or thin, opaque or translucent.

The adult tunicate does not have all the traits of chordates but the larval form does.

The subphylum is divided into three classes:

(a) Ascidiacea (Gr. askiolion = little bag),
(b) Larvacea (L. larva = ghost), and
(c) Thaliacea (Gr. thalia = luxuriance).

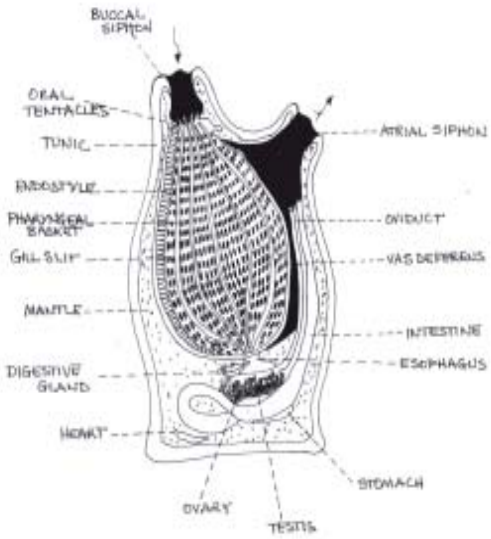

Figure 4. Tunicate or sea squirt.

The Ascidians are the best known and are commonly referred to as sea squirts by their ability to forcefully discharge a stream of water from their excurrent siphon when irritated. Most are sessile and are found attached to rocks, pilings, and even the bottoms of ships. They may be solitary, colonial, or compound. Each solitary form has its own test but compound forms may share tests.

Solitary ascidians are typically spherical or cylindrical in shape and have two projections: the excurrent and incurrent siphons. Water enters the incurrent siphon and passes into a ciliated pharynx, which is minutely subdivided into gill slits. This forms an elaborate basket framework. The gill slits filter the water and the water passes into an atrial cavity and then out through the excurrent siphon.

A glandular groove called endostyle forms a mucous mass that traps any food. Cilia on the gill bars pull the mucous into a sheet, worked into a rope, and then passed into the esophagus and stomach. Wastes are discharged from the anus near the excurrent siphon.

The circulatory system is composed of a ventral heart and two large vessels to either side of the heart. The vessels branch into smaller vessels that feed the pharyngeal basket for gas exchange, the gonads, and digestive structures. A peculiar feature of the heart is its ability to pump blood in one direction and then reverse the direction of pumping. Also, high amounts of the very rare elements vanadium and niobium are found in the blood.

The nervous system is represented by a nerve ganglion and plexus on the dorsal side of the pharynx. Underneath this nerve ganglion is a subneural gland that functions in sampling the water that comes into the pharynx and perhaps some endocrine function in reproduction.

They are typically hermaphroditic with a single ovary and testis. Fertilization is external in sea water.

Of the four chordate characteristics, the adult sea squirt has only the pharyngeal gill slits. The larva, however, has all four. The larva does not feed. It simply swims around for several hours and then fastens itself vertically by an adhesive papillae. It then undergoes retrograde metamorphosis.

☐ Observe the preserved specimen of a tunicate and if available, a live form.

Subphylum Cephalochordata

These are marine, laterally compressed, translucent animals that inhabit the sandy bottoms of coastal waters around the world. They generally don't exceed 7 cm in length. Their common name is lancet, which refers to the knife-shaped body. They were previously given the genus *Amphioxus* but this has been superseded by the name *Branchiostoma*. There are 25 species worldwide with 4 species in North America.

The interesting thing about the subphylum is the lancet exhibits all four chordate characteristics in simple form. Water enters the mouth and passes into a pharynx with gill slits where the food is trapped in mucous secretions. The mucous and food pass into the intestine and eventually into a cecum. The filtered water passes into an atrium and exits via an atripore.

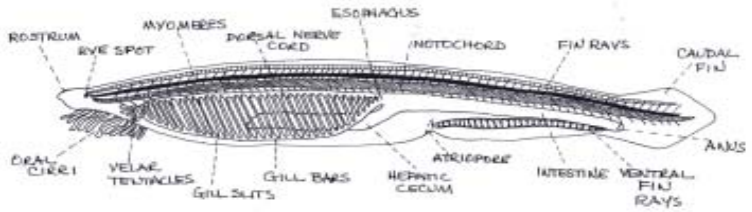

Figure 5. Branchiostoma.

Circulation is via a closed system that is fairly complex although there is no heart. Peristaltic contractions of vessels propel the blood through the system. There are no red blood cells or hemoglobin.There is a hollow nerve cord just above the notochord. Spinal nerves emerge at each myomere. Sense organs are simple, unpaired bipolar receptors located at various places in the body. The brain is a simple vesicle at the anterior end.

Sexes are separate and gametes pass out the atripore and are externally fertilized.

☐ Observe the prepared slide of *Branchiostoma*. Located the notochord, gill slits, atriopore, and nerve chord.

Phylum Chordata

The Fishes

Fishes are the most primitive and oldest of the vertebrate groups, and they are the undisputed masters of the aquatic environment. This supremacy is due to their adaptability. Adaptations include swim bladders that allow them to vary neutral buoyancy, excellent olfactory and visual senses, a lateral line system that detects vibrations in the water, efficient structures for the removal of oxygen from water, highly developed organs for salt and water exchange, and complex behavioral mechanisms.

Fish probably evolved from an unknown free-swimming protochordate ancestor during the Cambrian or Precambrian. These earliest fishes were without jaws (agnathans). Later, it is thought that gill arches moved forward and folded to form jaws in the fishes (gnathostomes). The following is the taxonomic breakdown of fishes:

Phylum Chordata
  Subphylum Vertebrata
    Superclass Agnatha - jawless, cartilagenous skeleton, ventral fins absent, persistent notochord
      Class Myxini - hagfishes
      Class Cephalaspidomorphi - lampreys
    Superclass Gnathostomata - jawed fishes, paired limbs, notochord persistent or replaced by vertebrae
      Class Chondrichthyes - cartilagenous fishes, teeth not fused to jaws, no swim bladder
        Subclass Elasmobranchii - sharks, skates, and rays
        Subclass Holocephali - chimaeras or ghostfish
      Class Ostichthyes - bony fishes, skeleton ossified
        Subclass Crossopterygii - lobed-fined fishes

Subclass Dipneusti - lungfishes
Subclass Actinopterygii - ray-fined fishes
Superclass Agnatha

These members do not have jaws and the bones are not ossified; therefore, the skeleton is cartilagenous. There are no scales and no paired fins. The gill openings are porelike and the body is tubular. The notochord is persistent.

There are two classes: Myxini (or hagfishes) and Cephalaspidomorphi (lampreys).

Subclass Myxini

The hagfishes are entirely marine, and they feed on dead or dying fishes, annelids, molluscs, and crustaceans. Their physiology is considered interesting by those studying fishes, for they are isosmotic to sea water like most marine invertebrates. They have two types of kidneys: pronephric and mesonephric. They also have four sets of hearts in different locations about the body.

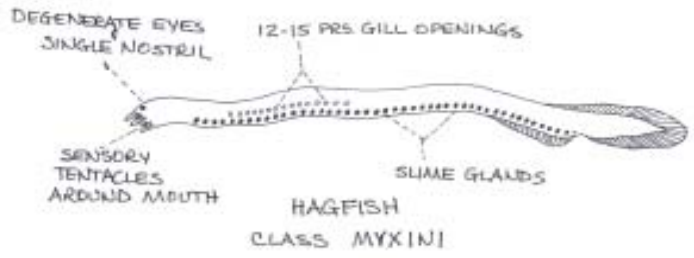

Figure 6. Hagfish.

Hagfishes are well known to sports fishermen when they have to deal with them when they hook them. They produce huge amounts of slime or mucous when disturbed. An average hagfish can produce half a liter of slime in a matter of minutes. This is probably a defense mechanism. The reproductive biology is still unknown. If you want to win a monetary prize, the Copenhagen Academy of Science will award to someone who discovers the reproductive cycle a cash award. Caution! No one has claimed the prize in over 100 years.

☐ Observe the specimen provided. How many gill openings do you see? Why do you think they were given their common name? What are the structures found around the mouth?

Class Cephalaspidomorphi

This class includes the group called lampreys. The marine lamprey is found on both sides of the Atlantic and may reach a length of 1 meter.

☐ Note the oral disk of the animal with the rings of denticles (or teeth). The sucker mouth allows the animal to attach to fish and the teeth rasp their way into the sides of the fish. The adult lampreys are, thus, mainly parasitic.

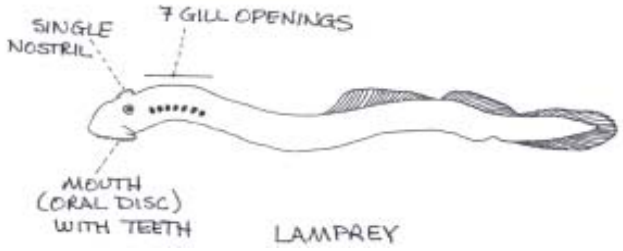

Figure 7. Lamprey.

☐ Also note the gill openings. How many are there? Locate the single nostril on the top of the head. Observe that there are no paired fins present. Marine lampreys are anadromous. This means that they leave the sea where they spend most of their adult life and swim upstream in freshwater to spawn. Males build the nests with help from females by using the oral discs to move stones and using vigorous swimming motions to clear debris. As eggs are shed by the female, the male deposits sperm and fertilizes them. Adults die soon after spawning. The larvae (ammocoetes) are so different from

the parent that biologists for a long time thought they were a different species related to Amphioxus. The larvae will remain in freshwater for 3 to 7 years and then leave as an adult. Large populations of fish in the Great Lakes have been decimated by lampreys.

Class Chondrichthyes (The Cartilagenous Fishes)

These fishes probably arose during the Silurian. Today, there are around 800 extant species. They have been successful largely due to (1) well-developed sense organs, (2) powerful jaws, (3) a swimming musculature, and (4) predaceous habits. The most distinctive feature of the class is the cartilagenous skeleton. Certain areas of the skeleton may be ossified but there is no true bone in the class. This is a little unusual in that the members of this class developed from vertebrates that had bones in their skeletons. Outside of whales, the sharks are the largest living vertebrates.

This class has within it members of the shark family, the skate family, rays, and the lesser known group called ghostfish or chimaeras. Sharks are, of course, the one family that most are familiar. Sharks, skates, and rays belong to the subclass Elasmobranchii and the ghostfish belong to the subclass Holocephali.

Subclass Elasmobranchii

Sharks are one of the most written about groups in the animal kingdom. Indeed, many sharks are dangerous to humans as the great white (*Carcharodon*), the tiger shark (*Galeocerdo*), and the hammerhead (*Sphyrna*). However, many are quite harmless, but all sharks should be treated with caution and respect. The shark that you will study today is the classical animal of zoology and comparative anatomy laboratories: the dogfish or Squalus acanthias. This species rarely exceeds 1 meter in length, whereas the whale shark may exceed 15 meters in length. The characteristic of the dogfish is the dorsal spines associated with the first and second dorsal fins.

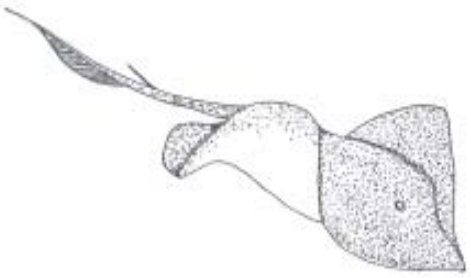

Figure 8. Southern Stingray.

☐ Observe the preserved specimen provided. Try to identify the following external features:

1.rostrum
2.nostril
3.spiracle
4.external gill openings
5.first dorsal fin
6.second dorsal fin
7.pelvic fins
8.caudal fin
9.placoid scales
10.claspers (if male)

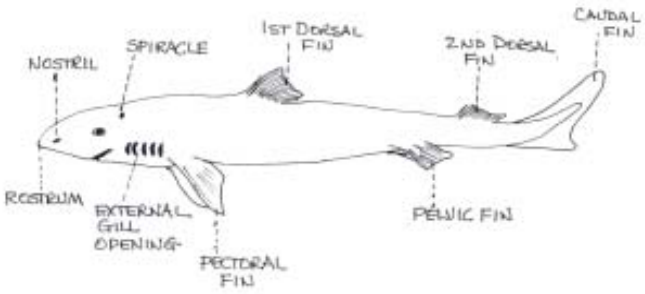

Figure 9. Dogfish.

The spiracle is simply a remnant of the first pharyngeal gill slit. The remainder of the gill openings are openings for true gills. Note that the gill openings are not covered by flaps or opercula. Placoid scales are characteristic of the Elasmobranchs. It is an epidermal outgrowth covered with dentine-like bone as in your teeth. It is covered with enamel and contains blood vessels, nerve endings, and lymph channels just as your teeth do.

☐ Rub your hand along the surface of the shark and feel the sandpapery texture of the scales.

The lateral line of the animal is a device that detects and locates objects in the water. Note the line is seen as a color division more than anything else in the animal.

☐ Also note the heterocercal tail of the animal. In this type tail, the spinal cord goes upward and the fin is unequally lobed. This is considered a primitive type of tail in fishes.

☐ Place the shark with its ventral surface up. Make a shallow incision from the pectoral to the pelvic fins just off center from the midventral line. Next cut through the skin across the first incision the length of the pectoral and pelvic girdles so the body cavity is better exposed. You will need to wash out the body cavity of the animal with cold water.

☐ Be able to identify the following structures:

1. conus arteriosus
2. pericardium
3. atrium
4. ventricle
5. ventral aorta
6. lateral abdominal vein
7. hepatic portal vein
8. pancreas
9. kidney
10. testes (or ovary)
11. liver
12. stomach
13. spleen
14. rectal gland
15. cloaca
16. peritoneum
17. small intestine
18. gall bladder
19. oviducts

Class Osteichthyes

Adaptive radiation is the concept that different species evolve due to the many adaptations that arise to suit them to their environment. The bony fishes, or class Osteichthyes, exhibit the phenomenon to a high extent. There is tremendous diversity in shape and form as well as habitat. You see sea horses, pipe fish, eels, and the fish of tremendous depths that carry their own light sources.

The taxonomy of the bony fishes is as follows:

Class Osteichthyes
- Subclass Crossopterygii - lobe-finned fishes
- Subclass Dipneusti - lungfishes
- Subclass Actinopterygii - ray-finned fishes
  - Superorder Chondrostei - sturgeons and paddlefish
  - Superorder Holostei - bowfins and gars
  - Superorder Teleostei - modern fishes as perch, salmon, eels, trout, etc.

Subclass Actinopterygii

These fishes had their origin in Devonian lakes and streams. They were protected by ganoid scales that were somewhat triangular in appearance. Extant forms include sturgeons, paddlefish, gars,

bowfins, and the modern-day fishes as trout, salmon, perch, bass, etc.

☐ Observe the microscope slide of a ganoid scale. This type of scale would have been found on fossil forms, and it is found today on very primitive forms as sturgeons and paddlefish. It is composed of layers of a silvery enamel called ganoin on the upper surface and by bone on the lower surface. There are three superorders: Chondrostei, Holostei, and Telostei.

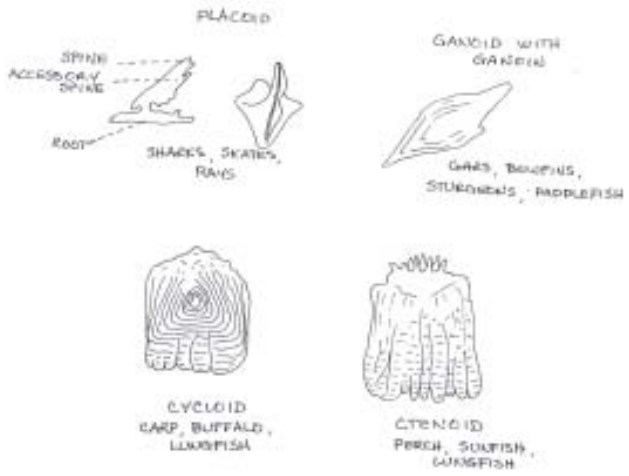

Figure 10. Various types of scales.

☐ Observe the cycloid scale under the microscope. These overlap one another. They are similar to the next type, the ctenoid, and both may be found on the same fish. These scales lay down growth rings and they may be counted to determine the age of the fish. Look for any growth rings that may be present.

☐ Observe a prepared slide of a ctenoid scale. These are more common on perch and sunfish. Note the tooth-like projections from one end of the scale. This i-s the best way to distinguish it from the cycloid scales seen previously. They may also be dated by growth rings.

Superorder Teleostei

This is the third group of modern fishes and the most advanced. The skeleton is primarily ossified. The heavy armor plating of the more primitive species has been replaced by ctenoid and cycloid scales. Some species, as catfish, lack scales entirely. Note that most have the homocercal tail. Lungs have been transformed into a swim bladder for buoyancy. These are the most successful of the fishes.

Perca flavescens (Perch)

Perch are a common freshwater fish found from Kansas to Ohio, and South Carolina northward into Canada. These don't have teeth on the jaws.

☐ Try to find the following external features:

1. caudal fin
2. lateral line
3. first dorsal fin
4. second dorsal fin
5. anal fin
6. pelvic fins
7. nostrils
8. operculum

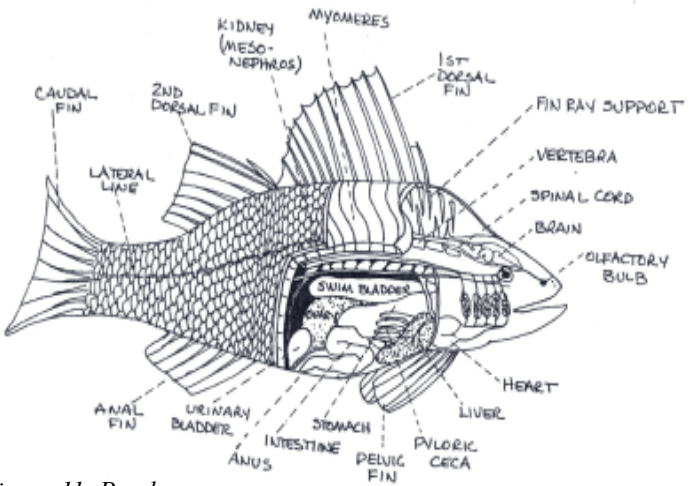

Figure 11. Perch.

☐ To dissect the perch, open up one entire side with a scalpel or scissors by laying the perch on

its side and simply making incisions transversely along the head and tail regions and removing all musculature until you reach the bone. Try to identify the following internal structures.

1. gills
2. heart
3. liver
4. stomach
5. gonad
6. swim bladder
7. intestine

The Amphibians (Class Amphibia)

The members of the class Amphibia (Gk. amphi = both, bios = life) are a product of millions of years of evolution from which there was a gradual movement from the sea to a terrestrial existence. Amphibians today are not totally acclimated to land and most must have moisture in some form for part of their existence. There are over 3,900 species of amphibians in three orders: the salamanders (order Caudata), the frogs and toads (order Anura), and the caecilians (order Gymnophiona).

The salamanders are the least specialized of the three orders and depend the most upon aquatic environments. The frogs and toads are the most successful of the three orders, and the caecilians are tropical, secretive, earthworm-like creatures that are highly specialized. The movement from an aquatic environment to a terrestrial environment required the most dramatic step ever to occur in evolution. Life in the water is safe; it is a uniform environment and thus very stable. Plants had already made the transition and, although amphibians were not the first and only animals to move to land (insects made the transition as well as some molluscs), we study these very closely because they gave rise to the most advanced animals on earth.

Order Caudata

The name of the order refers to the fact that these are tailed amphibians. The order includes the salamanders and the newts. Salamanders are found in temperate and tropical regions of the world. Most are small, rarely exceeding 15 cm in length; however, the Japanese salamander may reach 1.5 meters in length. Salamanders are tetrapods and they are carnivorous.

☐ Observe the preserved specimen of the spotted salamander (*Ambystoma maculatum*) provided. This species is found from south-central Ontario to Nova Scotia southward to Georgia and eastern Texas. It spends most of its life underground, so you seldom find adults. When you find one, it is probably a larval form. How do you think you could tell if it is an adult or larva?

Neoteny

Salamanders typically undergo a metamorphosis where the larval forms have gills and the adults lose the gills and develop lungs. However, some species retain the gills and other larval characteristics in the adult form and are called neonates from the word neoteny (Gr. *neos* = young, *teinen* = to extend). Some of these species are permanently locked into this condition and are reproductive as such. These are obligate neonates. An example is the genus *Necturus* or mud puppy that lives on the bottoms of ponds and lakes. There are five species in eastern North America.

☐ Observe the specimen of *Necturus* provided. Look for the plume”! ike gills and the four toes on both front and hind feet. The tail is strongly compressed. The cloacal opening of the male is lined with tiny projections and bears two fleshy lobes followed by a transverse groove. Is this a male or female?

Order Anura

Frogs and toads are perhaps the most successful of the class, with more than 3,400 species known today. The term Anura means without a tail, which the frog leaves behind in the larval stage. The larval stage is known by most children as tadpoles or pollywogs and are often collected and raised to adulthood by them. Unfortunately, frogs are a poor example of vertebrate anatomy, but they are still used in biology laboratories throughout the world due to their relative abundance. Toads are similar to frogs but are in a separate family, and the term toad is often used with any land-dwelling form.

The largest of the anurans is the West African *Gigantorana goliath* that may be more than 30 cm long from the tip of the nose to the anus and may weigh 3.3 kg (7.5 Ibs.). It often eats rats and ducks. The largest in our area is *Bufo marinus* (Giant Toad) which may reach 23.8 cm in length (9.5 inches). He's found from south Texas and Mexico and was introduced into Florida. It was introduced to control beetles that damage sugar cane but readily took up in back yards where it often will feed from someone's hand. It breeds year-round, and eggs are laid in ditches, canals, streams, and ponds. The parotid glands produce a potent toxin that will burn the eyes and inflame skin. Dogs and cats that eat them often die from the toxin.

☐ Observe the preserved grass frog provided (*Rana pipens*) and try to locate the following internal and external features:

1. external nares

Next, open the mouth and look for:

2. maxillary teeth
3. vomerine teeth
4. internal nares
5. laryngotracheal chamber
6. tympanic membrane (external)
7. eustachian tubes
8. tongue
9. pharynx
19. glottis

☐ Note the life cycle of the frog as presented with eggs, larvae, tadpoles, and adults.

☐ Observe the frog skeleton and try to identify the following:

1.phalanges
2.metacarpals
3.carpals
4.radio-ulna
5.humerus
6.omosternum
7.clavicle
8.coracoid
9.episternum
10.suprscapula
11.glenoid fossa
12.mesosternum

13.xiphisternum
14.transverse process
15.metatarsals
16.astragalus
17.calcaneum
18.tibiofibula
19.femur
20.sacral vertebra
21.urostyle
22.ilium
23.pubis
24.ischium
25.neural spine
26.neural arch
27.centrum

Frog dissection

Place your frog with the ventral surface up. Cut just to the right or left of the midline of the frog from the cloacca upward to the pectoral girdle. Cut across this incision at the pectoral girdle and at the cloacca and spread back the flaps of tissue. Insert a pair of scissors up under the pectoral girdle and snip through this area and spread apart.

☐ Try to identify the following:

1.liver
2.lungs
3.gall bladder
4.kidney
5.stomach
6.intestine
7.pancreas
8.spleen
9.ventricle
10.auricles (or atria)
11.conus arteriosus
12.fat bodies (if female)
13.urinary bladder
14.testes (if male)
15.ovaries (if female)
16.oviduct (if female)

Class Reptilia (L. repto = to creep)

These were the first terrestrial vertebrates. Today, there are some 7,000 species worldwide, with some 300 species in the United States and Canada. They are found in a large variety of aquatic and terrestrial habitats and are considered very successful. The age of reptiles dates from the Jurassic and Cretaceous periods of the Mesozoic era. After that peak, they began a steady decline. There are only four major groups alive today.

Classification of the Reptiles
Order Testudines (Chelonia) - turtles (330 species)
Order Squamata - snakes (2,700 species) and lizards (3,000)
Suborder Sauria - lizards
Suborder Serpentes - snakes
Suborder Amphisbaenia - worm lizards
Order Crocodilia-Crocodilians (25 species)
Order Rhynchocephalia - genus Sphenodon

There are two major features that separate the reptiles from the amphibians: the dry, scaly, glandless skin that resists desiccation, and shelled eggs (amniotic) that are laid on land. The shelled egg represents a great advancement over the eggs of the amphibians. The embryo floats and develops in an aquatic environment provided by the egg. The egg also provides a yolk sac for food. A membrane called the allantois serves as a surface for gas exchange and provides a storage space for nitrogenous wastes. The ammon encloses and protects the embryo in a fluid cushion. The third membrane, the chonon, completely encloses the embryo in the egg and may fuse to the atlantois to form the chorioallantoic membrane that is connected to the circulation system of the embryo.

☐ Observe the model of the egg provided, and identify and give the function of the following:

1.egg shell
2.allantois
3.chorioallantoic membrane
4.airspace
5.yolk
6.ammon
7.egg membrane
8.chorion
9.yolk sac
10.albumen

Order Testudines

This order contains the turtles. Turtles are enclosed in shells composed of the dorsal carapace and the ventral plastron. The shell is actually attached to the ribs of the animal and is formed from two layers: the outer horny layer of keratin and the inner layer of bone.

☐ Observe both the specimen provided and the turtle skeleton and try to identify the individual plates (scutes) that make up the shells. Look first at the dorsal surface or carapace. The small scutes that edge the shell are called marginal scutes. The central row of scutes except for the first scute by the head is called the vertebral scutes. The very first at the head is called the nuchal. The scutes between the vertebral and marginal are called costal scutes.

The plastron is usually divided into two regions by a midline. The first pair of scutes to either side of the midline (from the anterior end) are the gular scutes. Next come the

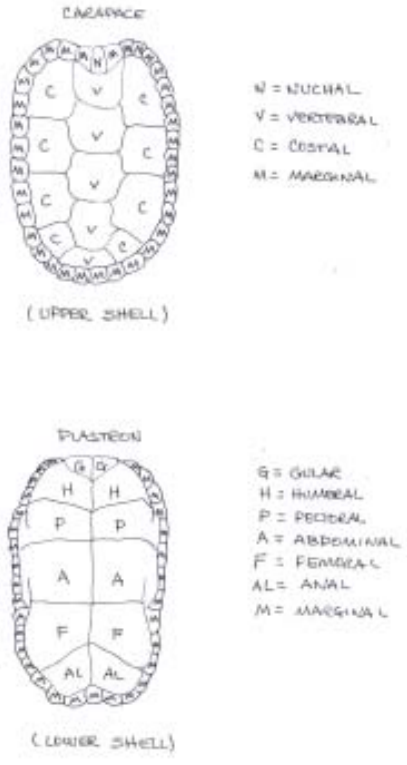

Figure 12. Turtle shell.

humeral, the pectoral, the abdominal, the femoral, and the anal in that order. The shell is protection, but because of it, the turtle cannot expand its chest to breathe. Instead, it uses abdominal and pectoral muscles as a "diaphragm."

☐ Note the horny plates that form the jaw; designed for gripping and chewing food. Also note the claws for digging. Turtles have small brains (rarely exceeding 1% of the body weight), and they have poor hearing but compensate by having a good sense of smell and color perception as good as humans. Fertilization is internal in all turtles. They are oviparous and eggs are layed in the ground, even with aquatic species. Marine turtles are the largest, with some reaching 2 meters in length and 725 kg in weight. Turtles are also the longest lived of vertebrates, some living a century or more.

Order Squamata (Lizards, Snakes, and Worm Lizards)

These comprise 95% of all reptiles, and they are by far the most successful. Lizards and snakes arose during the Creataceous (during the time of the dinosaurs) and are still around today because of their adaptability.

☐ Observe any specimens or models provided.

Class Aves

Birds are the most abundant of the vertebrates outside of the fishes. Some 8,600 species have been described worldwide, and they may literally be found everywhere on the planet. The adaptive radiation exhibited is phenomenal from birds that can dive to depths of greater than 45 meters to the bee hummingbird of Cuba that is the smallest warm-blooded vertebrate at 1.8 grams. There is one distinguishing feature that all birds have and no other animals do—feathers. Even after some 130 million years of evolution, birds have some remarkably similar characteristics inspite of individual variations. They all have forelimbs modified into wings, the hindlimbs are modified for swimming, walking or perching, they have horny beaks, and they all lay eggs. These similarities probably are a result of the birds' ability to fly. Birds have the highest developed organ system of any animals except the mammals and yet this system is highly specialized to allow for flight.

The most ancient form of bird we have discovered is the *Archaeopteryx* (ancient wing), discovered in Bavaria, Germany in 1861. The fossil dated to the Jurassic. It had unmistakable reptilian characteristics and might have been classified as a reptile except for the fact that it had feathers.

Birds are divided into two subclasses: Archaeorinthes (fossil birds as Archaeopteryx) and Neorinthes (modern birds with a few extinct forms included). Those that are in the subclass Neorinthes and are still extant are divided into two broad groups: ratite (flightless birds) and carinate (those that have a keeled sternum for attachment of flight muscles).

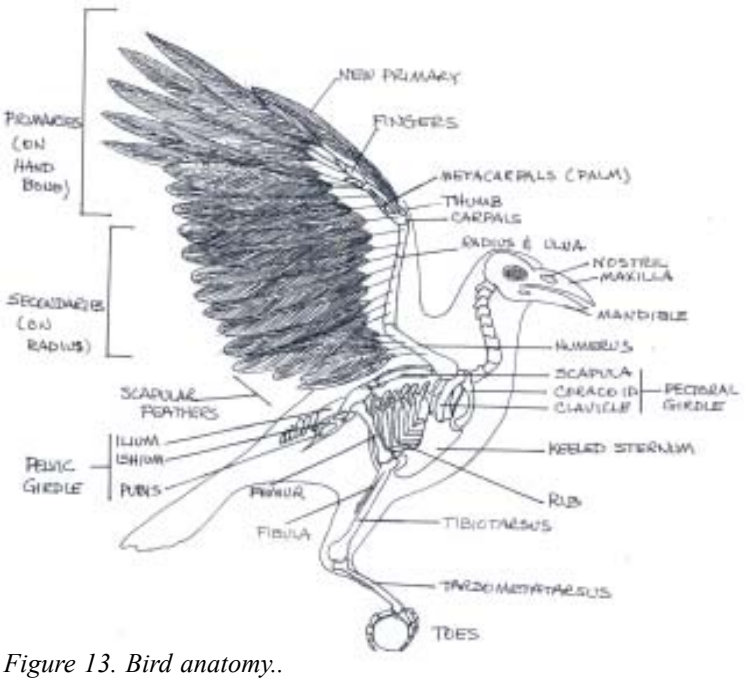

Figure 13. Bird anatomy..

The skeleton shown is that of a

pigeon, a carinate bird.

☐ Note the well-developed sternum. Many of the bones are similar in name to those of human bones.

Feathers

There are four types of feathers in birds: contour or flight feathers, powder-down feathers (help waterproof), filoplumes (no known function), and down (to conserve heat). Powder-down feathers actually disintegrate at the tip and release a talc-like substance for waterproofing.

☐ Observe the feathers provided. What type do you think they are? Look at one under a microscope and try to observe the barb with barbules. What are their functions?

Class Mammalia (Gr. fr mamma = breast)

The Class Mammalia represents the peak of evolution in the animal kingdom. This seems a little strange when one considers the numbers of mammals in comparison with other species. Mammals constitute some 4,000 species in the animal kingdom.

There are some 8,600 species of birds, 21,700 species of fish, and 800,000 species of insects. Despite the lack of numbers, the mammals are the most successful of the animal kingdom with the possible exception of the insects. They represent the largest living animals on Earth - the whales. (The smallest mammal is the Kitti's hognose bat of 1.5 in weight.) Mammals are used by humans as food sources, clothing, beasts of burden, and pets. Mammals probably had their origin with a reptile-like animal in the Mesozoic, before the dinosaurs became extinct. The reptile-like animal with mammalian characteristics was the therapsid. Structural changes found in the therapsid moved it from reptilian characteristics to mammalian. The legs became straighter and held closer to the body. The change in leg structure required greater musclature which necessitated a larger cerebellum, the coordination center for muscles in the brain. There was a separation of air and food passages in the mouth. A strengthened jaw allowed for food to be manipulated and mechanically broken down prior to swallowing. Finally, the great two characteristics of mammals became observed: hair and mammary glands.

STRUCTURAL AND FUNCTIONAL ADAPTATIONS OF MAMMALS

The Integument and Its Derivatives

The presence of hair is a principle characteristic of mammals, but hair is simply a derivative of the integumentary system (the skin). Even though the skin in mammals and other vertebrates are composed of a dermis and an epidermis, the skin is thicker in mammals due to the thicker dermis. Where the body of the mammal is thickly covered with hair, the skin is less thick and in places where there is a great deal of wear (as in the palms of your hand and the soles of your feet) the

outer layers of the epidermis become keratinized. Keratin is a protein found in an alpha helix with water proofing properties.

☐ Observe the model of skin and try to identify the following:

a.epidermis
b.dermis
c.subcutaneous tissue
d.duct of sweat gland
e.sweat gland

f.Pacinian corpuscle
g.arrector pili muscle
h.sebaceous gland
i.Meissner's corpuscle
j.hair root
k.hair foil ide
1.artery
m.vein
n.sweat pore

Hair

Humans, at first glance, are not very hairy creatures. The next time you are at a zoo, look at the gorilla. It's hard to believe, but you match the gorilla hair follicle for hair follice. The difference is that your hair is much finer and that of the gorilla is much coarser. Mammals have two kinds of hair that form the coat (pelage). There is the dense, soft underhair used for insulation and then there is guard hair, a coarse, long hair that protects again wear and tear and to provide coloration. In aquatic animals such as seals and otters, the underhair may grow so dense as to be impossible to wet.

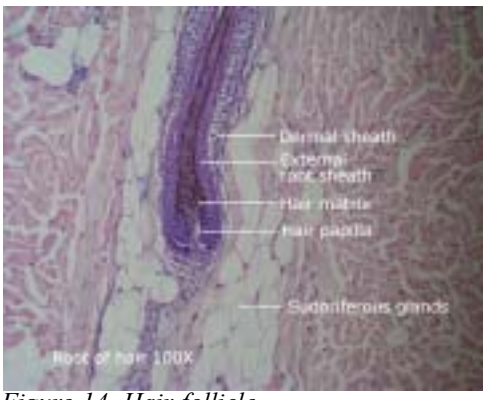

Figure 14. Hair follicle.

☐ Observe the slide of skin provided and observe the hair follicle indicated. Each hair is composed of a shaft and a root. You are seeing mostly root in this section. The shaft is composed of three layers: the medulla or center (not always present in fine hair), the cortex, and the outer layer of cuticle. The root is made up of two layers of epithelial tissue: the external root sheath and the internal root sheath. These are complex layers in their own right. At the base of the hair is the bulb with a papilla composed of connective tissue. It is from the papilla that blood is supplied via capillaries to nourish the hair. The matrix is responsible for growth. Try to identify the epidermis, the dermis, the bulb, the shaft, and the arrector pili muscle attached to the hair. It is the arrector pili that literally causes your hair to stand on end.

After hair reaches a certain length, it stops growing. It often remains in the follicle until new growth starts and then it falls out. Humans continually shed and grow new hair (hence its nothing to get excited about if you see the shower drain getting clogged), but many mammals seasonally shed hair. This process is called molting. Molting may occur once a year as in seals and foxes, twice a year as in most mammals, or even more like the hare which undergoes three. Humans start with fetal hair in the womb called lanugo. Lanugo is usually shed prior to birth except in areas like the eyebrows, eyelids, and scalp. Even these first hairs are shed for coarser hairs called veil us. Coarse hairs that develop during puberty, the hairs of the scalp and the hairs of eyebrows, are referred to as terminal hairs. Scalp hair has a life expectancy of 2-6 years. Eyelashes in humans are shed every 3-5 months. Hair is not found on humans on the palms of the hands, the soles of the feet, the dorsal surface of the distal phalanges, the lips, the nipples, the clitoris, the glans penis (head of the penis), the inner surface of the prepuce (foreskin), the inner surfaces of the labia majora and minor, and finally, the outer surfaces of the labia minor. Straight hairs are oval when cut in cross section, curly hairs are flattened. Because of this, straight hairs are stronger.

Mammalian hair is often modified to serve many purposes. Vibrissae are sensory hairs (you call them whiskers on cats) and detect motion. Porcupines have hair modified into sharp spines. Horns

and Antlers. The term horn indicates that it is composed of a layer of the epidermis called the stratum corneum, a heavily keratinized layer. There are horns that are indeed of this composition, but horns may not be true horns. Horns fall into one of four categories:

1. hair-horns (found in the rhinoceros),
2. antlers (found in the deer family),
3. true horns (found in cattle, sheep, goats, & antelopes - except the pronghorn antelope), and
4. giraffe horns.

The hair horn of a rhinoceros is actually clumped hair stuck together. Hair horns are found in both the male and female rhinoceros and are not shed. Many primitives consider the horn of a rhinoceros an aphrodisiac. Antlers are branches of dermal bone attached to the frontal bone of the skull. These are shed annually. In the beginning stages of formation, the antler is covered with skin called velvet. This wears off and what is left is the bone. Except for caribou and reindeer, only males have antlers. True horns are composed of a core of bone covered by a horny epidermal cap, heavily keratinized. If you remove the epidermal cap, it is hollow. Bovine horns (cattle, sheep, etc.) do not branch as a rule and are never shed.

Generally both sexes have horns, although there are exceptions. In some cases, selective breeding has eliminated horns as in polled cattle. Giraffe horns are simply stunted antlers that remain covered with skin.

Glands

A gland may be composed of a single cell (as in the case of goblet cells in the stomach) or of many cells. Glands secrete substances into ducts or directly into the blood. With this in mind, all glands in the body may be classified as either exocrine or endocrine. Exocrine glands secrete their products into ducts that empty at the surface of the epithelium, either on the skin or into an organ. An example is sweat glands that cool the body. Endocrine glands are ductless and secrete their materials into the blood. The secretions of endocrine glands are always hormones (more about these later). An example of this type of gland is the adrenal glands. Exocrine glands are further broken down into either unicellular or multi cellular glands. Unicellular are, of course, composed of a single cell. The best example of this is the goblet cell found in the epithelial layer of the digestive, respiratory, urinary, and reproductive systems. They generally produce mucus to lubricate the surfaces of these areas.

Figure 15. Goblet cells in intestine.

☐ Observe the section of small intestine provided, and try to find the goblet cells that form an exocrine type of gland. The goblet cells secrete various materials into the lumen of the intestine. Multicellular glands have various forms. If the gland is shaped like a tube or soda straw, it is called a tubular gland. If it is shaped like a flask, it is called an acinar gland. There may even be combinations of the two to form a tubuloacinar gland. To further complicate things, multicellular glands may be either simple or compound. What follows is a description of exocrine glands.

Unicellular - single celled & secretes mucus
Multicellular - composed of numerous cells

Simple - a nonbranched duct

1. Tubular - secretory portion is straight & tubular (crypts of Lieberkuhn in intestines)
2. Branched tubular - secretory portion is branched and tubular (gastric and uterine glands)
3. Coiled tubular - secretory portion is coiled (sweat glands)
4. Acinar - secretory portion is flask-like (seminal vesicle in males)
5. Branched acinar - secretory portion is branched and flask-like (oil glands)

Compound - branched ducts

1. tubular - secretory portion is tubular (Cowper's gland & testes in males, and liver)
2. acinar - secretory portion is flask-like (salivary glands)
3. tubuloacinar - secretory portion is both tubular and flask-like (salivary and pancreas)

Exocrine glands may also be classified as to how the gland releases its secretion. There are three types according to this classification:

1. Holocrine - secretory product from cytoplasm, cell dies and is discharged after cell death
2. Merocrine - produce secretions that form and are discharged from cell without cell death
3. Apocrine - secretory product formed at the outer margin of the cell and this pinches off to form secretion

The sweat gland is a holocrine gland, salivary glands are types of merocrine glands and the mammary gland is an example of an apocrine gland.

☐ Observe the section of ovary. The ovary is an example of an endocrine gland. The glandular part of the ovary includes the corpus luteum and the corpus albicans which secrete hormones. When dealing with the integument (skin), there are four major types of glands that will fall into one of the above classifications (they are exocrine).

1. sweat glands (sudiferous),
2. scent glands,
3. sebaceous glands (oil), and
4. mammary glands.

Sweat Glands

Sweat glands are distributed about the human body everywhere except the beds of nails on the fingers and toes, the margins of the lips, eardrums, and the tips of the penis and clitoris. The greatest number of sudiferous glands are in the skin of the palms and soles where they may reach a density of 3,000 per square inch. You also probably don't need to be told they are found in the forehead and the armpits. Generally, along the axillary region of the body (arms and legs) the sudiferous glands are simple branched tubular type. Elsewhere in the body, they tend to be simple coiled tubular.

Perspiration (sweat) is a complex mixture of water, salts (Nad mostly), urea, uric acid, amino acids, ammonia, sugar, lactic acid, and ascorbic acid. The main function of sweat glands is to regulate body temperature with a secondary function of riding the body of wastes.

Observe the sudoriferous or sweat gland shown in the section of skin provided.

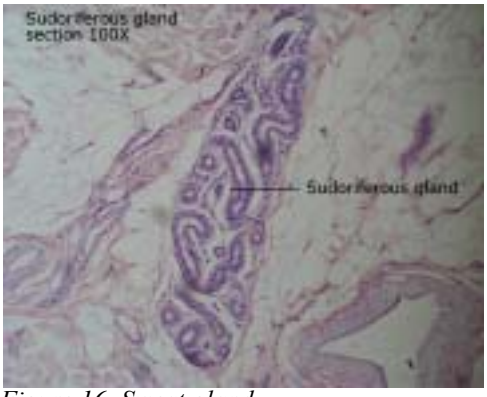

Figure 16. Sweat gland.

Scent Glands

These are found in most mammals but their location and function varies. Some functions include (1) communication with members of the same species, (2) marking of territories, (3) as warnings, and (4) for defense.

Locations also vary widely. In deer, the glands are found in the orbital, metatarsal, and interdigital regions. In the woodchuck, they are-found behind the eyes and on the cheeks. In dogs, beavers, and muskrats, they are found on the preputial area of the penis. Wolves and foxes have them on the bases of their tails, camels along the back of their heads, and skunks, minks, and weasels in the anal region. Humans also have scent glands although western society has taught us to dislike human scents.

☐ Run this experiment at home. Take your forefinger and rub under your nose take your middle finger and rub under your arm pit, and take your ring finger and rub in the groin area. Now smell all three fingers. You should get three different scents. Most scents are musk smelling. Human scents seem to be a sexual stimulate or turn on to the opposite sex and thus can be classified as a phero-mone. Obviously, perfume companies make the most of this information.

Sebaceous Glands

Sebaceous (or oil glands) are simple branched acinar glands and are generally connected by a duct to hair follicles. Size and shape varies depending on the location in the body. They are absent in the palms and soles of the feet but are abundant elsewhere. They are relatively small in the trunk and arms and legs but numerous in the breasts, face, neck, and upper chest. The secretion of sebaceous glands is called sebum. Sebum is a mixture of fats, especially cholesterol, proteins, and inorganic salts. The purpose is to prevent drying of hair and to provide a protective film over the body to prohibit excessive evaporation of water from the skin. Additionally, it keeps the skin supple and pliable.

☐ Observe the sebaceous gland shown in the slide of skin.

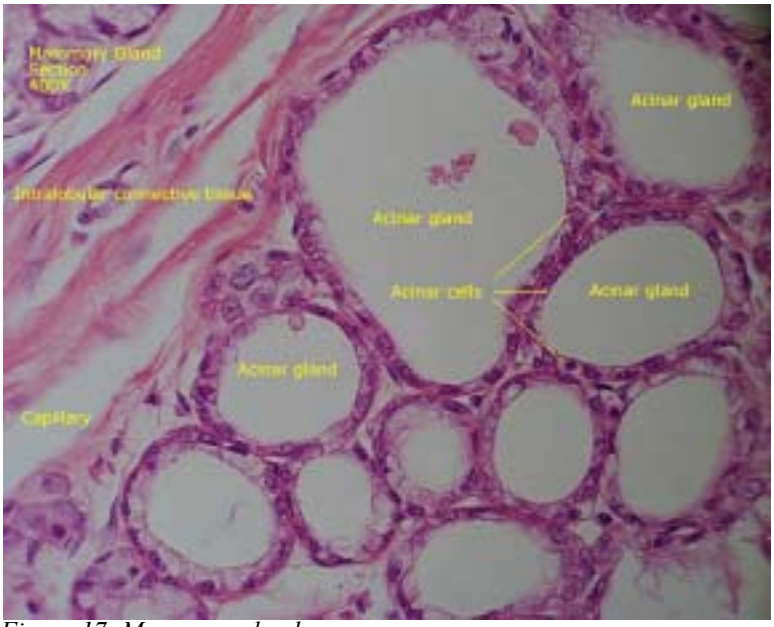

Figure 17. Mammary gland.

Mammary Glands

There is some debate as to the origin of mammary glands. Some scientists feel they are modified apocrine glands and others feel they are actually forms of sebaceous glands. The glands are found over the pectoral is major muscles and are attached by connective tissue. Each gland is composed of 15 to 20 lobes, each separated by adipose (fat) tissue. Adipose tissue determines the size of the breasts but breast size has nothing to do with the amount of milk production. Each lobe is further subdivided into lobules (again with connective tissue) with milk secreting cells (alveoli) embedded within. Suspensory ligaments support the breast. The alveoli are in grape-like clusters and they carry milk via secondary tubules to the mammary ducts. The mammary

ducts enlarge into sinuses called ampullae as they reach the nipple. The ampullae store milk. The ampullae continue forward as lactiferous ducts that end in the nipple. Surrounding the nipple is a pigmented area of skin called the areola that contains modified sebaceous glands. Both males and females have mammary glands. They have their origin as ectodermal cells referred to as milk lines. In the embryo, these milk lines invade the dermis and form the gland itself. In females, fat deposition during puberty causes the breasts to enlarge. The arrangement and number of mammary glands vary from species to species. Humans and apes have a single pair of thoracic nipples (but humans may have extra nipples [supernumerary] - up to 5 pairs). Whales have nipples near the groin, lemurs have them on each shoulder, and nutrias have four on their back.

☐ Observe the mammary gland shown. Try to identify as many parts as possible.

Food and Feeding

Mammals are broadly catergorized as to the food they ingest.

There are four categories:

1. herbivores - feed on plant matter,
2. carnivores - feed on meat,
3. omnivores - feed on either plants and/or animals, and
4. insectivores - feed on insects.

There is some integration of feeding patterns. Some carnivores also eat insects as do some herbivores for example. The one thing that indicates to the scientist the food habit of a mammal is the teeth of that mammal. Animals exhibit diphyodont dentition (two sets of teeth). The first set are the milk teeth or deciduous teeth found in the young and replaced by the permanent teeth of the adult. Additionally, teeth have specialized functions in mammals, unlike the lower vertebrates which have basically the same type of teeth throughout (homodont). This heterodont dentition in mammals is usually divided into four sets of teeth:

1. incisors - used for biting or cutting,
2. canines - used for piercing,
3. premolars - used for shearing and slicing, and
4. molars - used for crushing and grinding.

Incisors have simple crowns and sharp edges. Canines are long and conical in shape. Premolars have compressed crowns with one or two cusps (elevations in the surface) and molars have large, flat surfaces with varying numbers of cusps.

☐ Observe the models provided that show incisors, canines, and molars. The numbers of each type of tooth varies in species. We express the number of each for both the upper and lower jaw as a dental formula. For example, the dental formula for a horse is as follows:

$$\frac{3\text{-}1\text{-}4\text{-}3}{3\text{-}1\text{-}4\text{-}3.}$$ (upper jaw) (lower jaw)

This indicates that both the upper and lower jaws have 3 incisors, 1 canine, 4 premolars, and 3 molars.

Other dental formulas are:

cat $\frac{3\text{-}1\text{-}3\text{-}1}{3\text{-}1\text{-}2\text{-}1}$ human $\frac{2\text{-}1\text{-}2\text{-}3}{2\text{-}1\text{-}2\text{-}3}$ rabbit $\frac{2\text{-}0\text{-}3\text{-}3}{1\text{-}0\text{-}2\text{-}3}$.

☐ Observe the human skull provided and try to observe the human dentition pattern. There is one special problem that herbivores experience. No mammal (or for that matter any other animal) can digest cellulose, the woody material of plants.

Herbivores, instead, have somewhere in their digestive system places where one finds anaerobic bacteria that can break down cellulose. The bacteria break down the majority of the cellulose present and utilize only what they need. The rest is left for the host. For example, herbivores as horses and rabbits have an extension of the gut to form a sack-like structure called a caecum. The caecum houses the anaerobic bacteria. Other rabbits, hares, and some rodents insure exposure of the food to the bacteria by eating the food a second time by ingesting their own feces - the process known as coprophagy. Ruminants have a different method. Cattle, bison, buffalo, goats, antelopes, sheep, deer, and giraffes all have four chambers to their stomach. A cow will eat grass and chew it until it forms into a ball (the bolus). The bolus is swallowed and the food passes through the esophagus to the rumen. The rumen is a large chamber where one finds the anaerobic bacteria. The start of digestion begins here. The food is mechanically and chemically manipulated into small balls called cuds after it passes from the rumen into the reticulum. The reticulum is so named because of the net-like appearance of this chamber. At the cows convenience, the cud is regurgitated to the mouth where it is further masticated (chewed) to mechanically break the food down further. It is then reswallowed and the food goes to the omasum. Salivary enzymes continue the action and then the food is finally passed to the abomasum (the true stomach). The abomasum secretes digestive enzymes and normal digestion takes place here.

Flight and Echolocation

There is only one truly free-flying mammal - the bat. There are mammals; however, that can glide and maneuver with remarkable ability. For example, the flying squirrel cannot actually fly. It glides by utilizing a gliding skin attached to its limbs. Bats are nocturnal insectivores and thus occupy a niche not usually taken by birds. To capture something as small as an insect in total darkness requires some special mechanism. This is echolocation. By emitting high pitched sounds, the object hunted reflects these sound back to the bat who reads them and figures the location of the prey. The sounds emitted begin at a high pitch of around 100,000 cycles per second (Hertz) and then fall to around 30,000 Hertz. The human ear is capable of detecting sounds of only 20,000 Hertz and thus humans cannot detect well this sound. The sounds are emitted as pulses. A pulse is emitted every 5 to 10 microseconds during flight. When searching for prey, pulses are about 10 per second and when prey is found, pulses increase to 200 per second. This still enables the bat to escape pulses coming back too quickly and thus jamming the signal.

☐ Observe the preserved specimen provided. Note the position of the bat at rest. Also look for the phalanges in the skeleton of the bat. Note the skeletal structure is very much like that of ours.

Reproduction.

Mammals, for the most part, have specific times for reproduction. This period is called estrus and it designates the time the female is receptive to the male for reproduction. The time coincides with the most favorable times of the year for rearing young. The estrous cycle of females is divided into four stages:

1. proestrus - ovarian follicles grow,
2. estrus - time of mating,
3. metestrus - no fertilization - repair occurs, and
4. diestrus - uterus becomes small and anemic.

When an animal goes into estrus (heat), she is receptive to the female for reproduction. Some animals have a single estrus during the year and are called monestrous. Examples of monestrous animals are dogs, foxes, and bats. Some animals exhibit a polyestrous cycle. Examples of polyestrous cycles are field mice, squirrels, and many tropical mammals. Humans are somewhat different than lower mammals. We don't usually say the female human is in heat except as colloquialisms. Human females undergo a postovulation period called menstruation where the lining of the uterus is shed. This is the menstrual cycle of females. There are three patterns of reproduction in mammals:

1. egg-laying mammals - the monotremes,
2. pouched mammals - the marsupials, and
3. the placental mammals - the eutherians.

Monotremes (the duck-billed platypus) has but one breeding season a year (monestrus) and normally two eggs are fertilized in the oviduct. As the fertilized egg is passed down the oviduct, glands add albumin and a leathery shell to each egg. Each egg is quite small (about the size of a robin's egg). They are layed in burrows and incubated about 12 days. When the young hatch, they nurse by licking at the milk soaked hairs around the mammary glands (there are no nipples). Marsupials have a somewhat complex gestation and lactation period. One example is the Virginia opossum, Didelphis marsupial is. There is a gestation period of around 13 days where up to 14 young are produced per litter. The young are very tiny at birth (2 grams) and the whole litter can fit easily into a teaspoon. They are blind at birth and virtually helpless, yet they are capable of crawling after birth to the pouch of the mother where her mammary glands are located. They may remain in the pouch up to 2 months. They later emerge and crawl upon the mother's back and often hold onto her tail by clasping hers with their own. There may be 2 litters per year.

☐ Observe the human placenta shown. What is the function of the placenta? Why do animals such as dogs, cats, and some humans eat the placenta after birth? Placental mammals, of which humans are an example, have prolonged gestation where the embryo remains in the mother's uterus and is nourished with food provided by the mother through the placenta. Gestation times vary from placental mammal to placental mammal. Mice have gestation periods of 21 days, rabbits 30 days, cats and dogs 60 days, cattle 280 days and elephants 22 months.

☐ Observe the dissected pregnant cat provided. Note the fetuses in the uterus and the stage of their development.