Chordata sm

Objectives:

1. **Identify exterior structures associated with each of the chordates presented.**
2. **Identify interior morphology associated with respiration, reproduction, digestion and absorption, excretion and maintenance of buoyancy as well as chemical balance.**
3. **Using the models presented, compare and contrast the evolution of adaptations of each of the models.**
4. **Distinguish the characteristics that separate chordates from invertebrates previously studied.**

Chordata (Phylum) contains two subphyla of invertebrates and a very large subphylum of vertebrates. Details of the phylogenic relationships of the earliest vertebrates have been lost or have yet to be discovered. Chordates in general share four features at some point in their life cycle. These include:

1. Notochord. The notochord is a stiff rod-like structure that is observed in all chordates at some stage in their lives. It acts as part of the skeletal structure of the developing organism embryologically. In vertebrates it is replaced by vertebrae which form the backbone of the organism.
2. Pharyngeal gill slits are slits leading from the pharynx, the throat cavity, to the exterior.
3. Dorsal hollow nerve cord whose main nerve cord is solid.
4. Muscular, post-anal tail.

Other chordates, vertebrata in general, share the additional structures:

1. Segmented body.
2. Endoskeleton.

Subphylum *Urochordata* includes the sea squirts and their relatives. They are categorized as chordates in that their larval forms have the four shared chordate features, including a notochord and post-anal tail. The adults appear nothing like the vertebrates. Please check your photographic atlas for representatives of this subphylum. The tunicate, or sea squirt, is being researched today for anti-cancer properties.

The subphylum *Cephalochordata* includes lancelets (amphioxus). They appear to be simple fish with extra gill slits and there are only 29 living

genera. Lancelets tend to lie buried in the sand of warmer oceans with only the head protruding. Several rings of tentacles about the mouth filter out large particles and also contain some cells which are sensitive to chemicals and pressure. Food is filtered out by a mucous net secreted in a ventral groove in the pharynx. Mucous containing food is passed from the pharynx into the gut and the water is pushed out through the gill slits. It is commonly believed that the first cephalochordate evolved from a urochodate ancestor through a mutation (or mutations) that resulted in the retention of the juvenial (larval) characteristics of the urochordate in a sexually mature individual. This process (known as paedogenesis) and the retention of these characteristics in subsequent generations (known as paedomorphosis) plays an important role in the evolution of the vertebrates, including our own evolution. Please consult your photographic atlas for structure of the adult lancelet.

The subphylum Vertebrata contains a large and diverse group of animals. Vertebrata are characterized in general by the existence of four traits: increasing cephalization, a neural crest which lies along the margin of the embryonic folds that meet to form the nerve cord, a vertebral column and a closed circulatory system. Vertebrata can be divided into two superclasses: *Agnatha*, (members without jaws) and *Gnathostoma*, which contains 6 classes of jawed vertebrates.

Cephalization is quite pronounced with many of the sensory organs located at the anterior of the organism. All vertebrates have some type of liver, endocrine organs (secreting hormones), and kidneys that are quite different in structure and function from the excretory organs of invertebrates. It is thought that the earliest vertebrates moved via sinusoidal swimming. The original feeding mechanism was probably similar to the filter feeding exhibited by *Amphioxus*. Water containing food probably entered via the mouth, passed over gills and exited through the gill slits. It is thought that gill slits originally functioned in feeding but are used now for respiration and gas exchange.

Vertebrates range in size from tiny fish of less than a gram to whales which weigh in excess of 100,000 kg. The greatest threat to vertebrates is man. About 50,000 species of vertebrates are extant today. This represents less than a tenth of the species that have existed throughout time.

Jawless fish were common and diverse during the Ordovician through the Devonian Period. They are informally known as ostracoderms and were usually small, most being less than 50cm in length. The modern representatives are lamprey (*Cephalospidomorphi*) and hagfish (*Myxini*), long narrow eel-like organisms with sucking mouths. They are scavengers and parasites. Kidneys function in the maintenance of body fluids by controlling the water and salts that leave the body in urine. Vertebrates could not live in fresh water without effective mechanisms in reducing the water that is gained via osmosis.

During the development of jawed fish, part of the gill skeleton moved forward and evolved into jaws. These fish were now able to bite and chew. This ability resulted in rapid radiation of fish. The remaining gill slits were no longer needed for filter feeding and remained as organs for gas exchange. The Devonian is known as the age of fishes when placoderms and acanthodians (the earliest jawed fish) rapidly evolved and radiated in fresh and salt water. These groups declined and had completely disaapeared by the beginning of the Carboniferous period. They were replaced by two classes of jawed fish which may have shared a common ancestor with the placoderms and acanthodians: the cartilaginous fish and the bony fish.

Chondrichthyes, cartilaginous fish, have two pairs of fins: pelvic fins as well as a pair of pectoral fins near the front or anterior of the fish. Unpaired dorsal, anal and caudal fins are also present. Paired fins allow for greater balance and maneuvering ability. Active carnivorous lifestyle is exemplified by the shark and other cartilaginous fish, allowing for them to become larger as well as generally more successful predators.

Shark teeth are enlarged versions of scales. Digestion takes place largely in the stomach and absorption in the intestine. The intestine is short and fat and absorptive area increased by the spiral valve. The liver is large as buoyancy is increased or decreased by the amount of lipid stored therein. Respiration occurs via gill as water is passed over them. Fertilization is internal. Most sharks are ovoviviparous as the developing embryo receives most nourishment from the egg. A few are viviparous where the embryos receive nourishment from the mother's bloodstream. Olfactory organs in their heads allow for increased sensitivity to chemicals while all fish possess lateral line systems which are sensitive to vibrations and sound waves. Eyes are used only after prey has been located with other sensory activity.

Bony fish are represented by about 20,000 species of modern fish. Although originally placed in a single class (*Osteichthyes*), systematists now recognize three distinct classes of bony fish: the ray-finned fish (*Actinopterygii*, which includes nearly all the familiar fish), the lobe-finned fish (*Actinistia*, represented by a single extant genus *Latimeria*, the coelacanth), and the lungfish (*Dipnoi*, containing three genera that live in the Southern Hemisphere). Sources of nutrition are varied and include filter-feeding, eating of insects and other organisms. One of the evolutionary adaptations includes the development of the swim bladder, an outgrowth of the pharynx, which is a gas-filled sac. In some fish the swim bladder acts as an accessory organ of gas-exchange, along with that done over the surface of the gills. A fish can alter its buoyancy by regulating the amount of air in the bladder.

Locomotion is largely controlled by the powerful tail. Pelvic fins are further forward and higher than on the shark. Gill slits are covered by a common operculum. Water enters through the mouth, passes over the gill slits and exits through the gill slits. Reproduction is varied. Generally fertilization is external. Nest building and male brooding is evident in some cases. Fertilization may be internal and young born live. Powerful novel adaptations exist in the areas of defense, camouflage and signaling.

Directions for dissection follow.

Shark Dissection

Squalus acanthias, the spiny dogfish, is a small shark commonly found in the shallow costal waters of the Atlantic and Gulf coasts. Mature sharks are usually 3-4 ft. in length. Many are injected with latex. Obtain a shark and study the external morphology. Your photographic atlas will provide excellent pictures of external and internal morphology.

Locate: broad flat head, trunk and the laterally flattened tail. Scales are placoid and feel like sandpaper due to the tiny spines on each scale. The following structures should be noted:

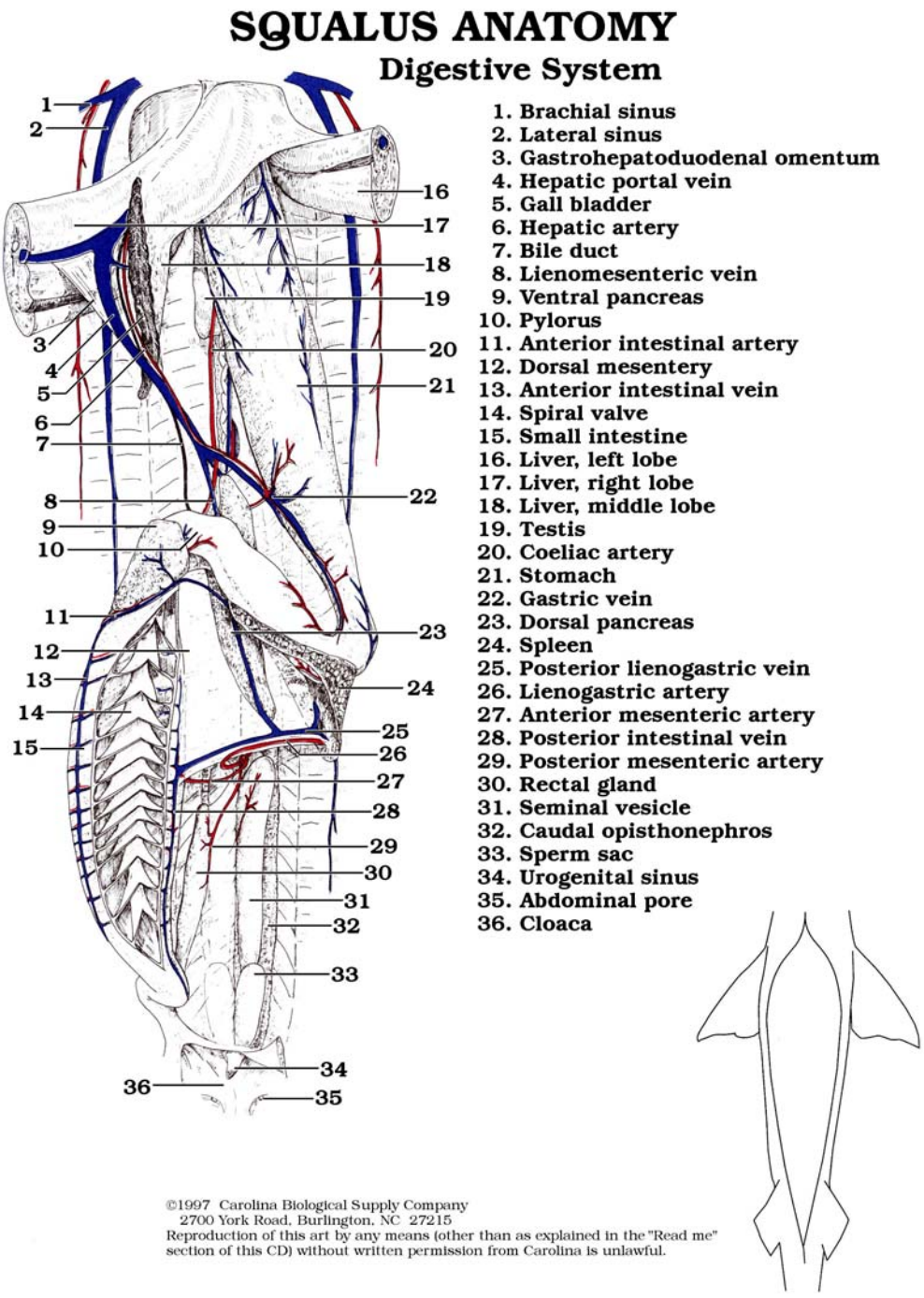
1. pectoral (anterior fins)
2. pelvic fins (posterior fins)
3. claspers (aid in mating)
4. dorsal fins
5. caudal (tail) fin

6. mouth
7. nostrils
8. teeth
9. eyes (with rudimentary lids)
10. spiracles (openings for water intake)
11. external gill slits
12. lateral lines
13. cloaca

In your dissection try to avoid damage to structures that are to be subsequently studied. Do not cut and discard parts until you are certain of their identity. Consult the photographic atlas for pictures and diagrams.

Be conservative in your cutting. Many structures can be separated neatly by teasing them free with a blunt probe. When cutting is necessary make clean incisions with sharp instruments. Always use gloves when handling preserved specimen.

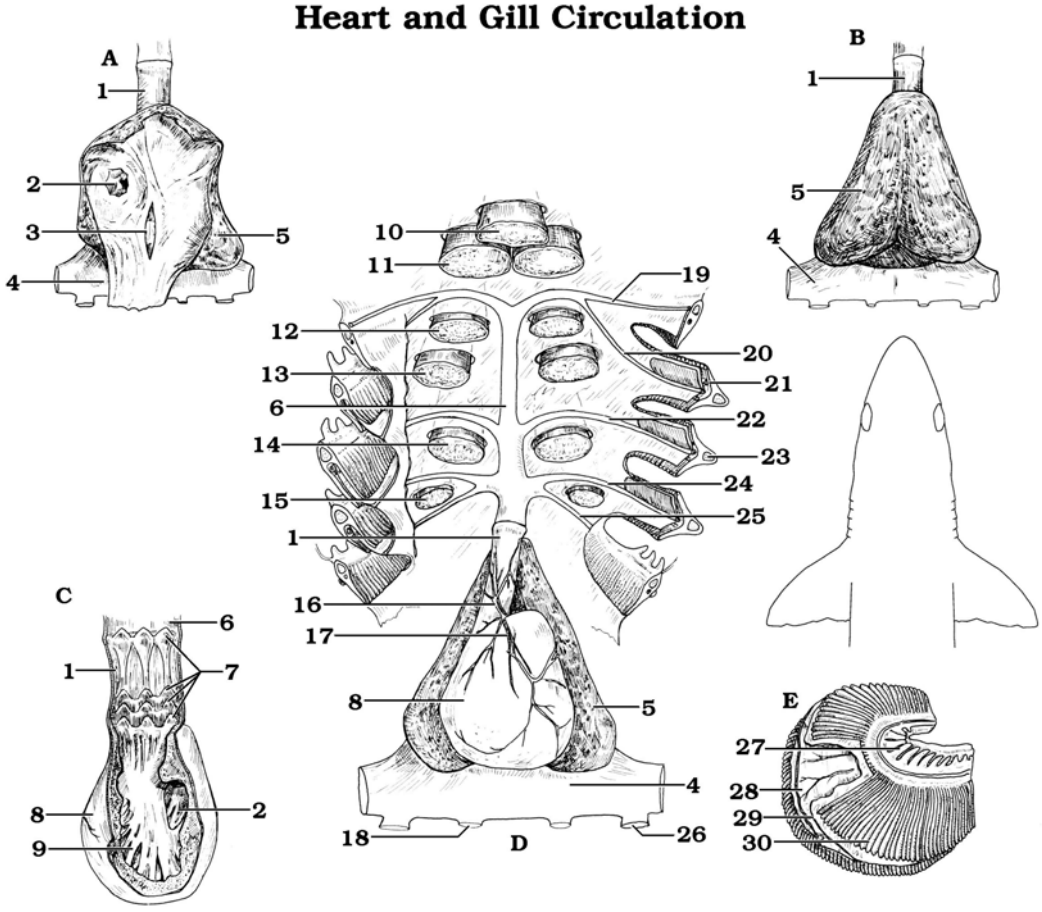
1. Carefully make an incision through the body wall along the midventral line from the pectoral girdle (determined by touching and probing) backwards through the pelvic girdle ending the incision just posterior to the cloaca.
2. Make two transverse two inch incisions through the body wall, one to the rear of the pectoral fins and one anterior to the pelvic fins.
3. Carefully identify the structures and their locations in the shark. The coelom is divided into the pericardial cavity, anterior to the pectoral girdle and the pleuroperitoneal cavity, posterior to the pectoral girdle. The thin partition separating them is the transverse septum.
4. Locate the large esophagus anterior to the stomach. The pylorus sphincter muscle separates the stomach from the small intestine
5. The anterior segment of the small intestine is the duodenum and posterior is the ileum. The bile duct extends from the liver to the duodenum. Within the ileum is the spiral valve which allows for increased absorption.
6. The short and narrow colon connects with the short rectum which is attached the rectal glad which plays a role in balancing salt in the blood.
7. Rectum discharges into the cloaca, a common chamber for products of digestive and urogenital systems.



8. Note: liver, pancreas, thin-walled greenish gallbladder, spleen, ovaries, uterus (enlarged portion of each oviduct.
9. The two-chambered heart consists of a thick-walled ventricle and a thin-walled atrium. Blood enters the atrium and exits through the ventricle.

SQUALUS ANATOMY

Heart and Gill Circulation

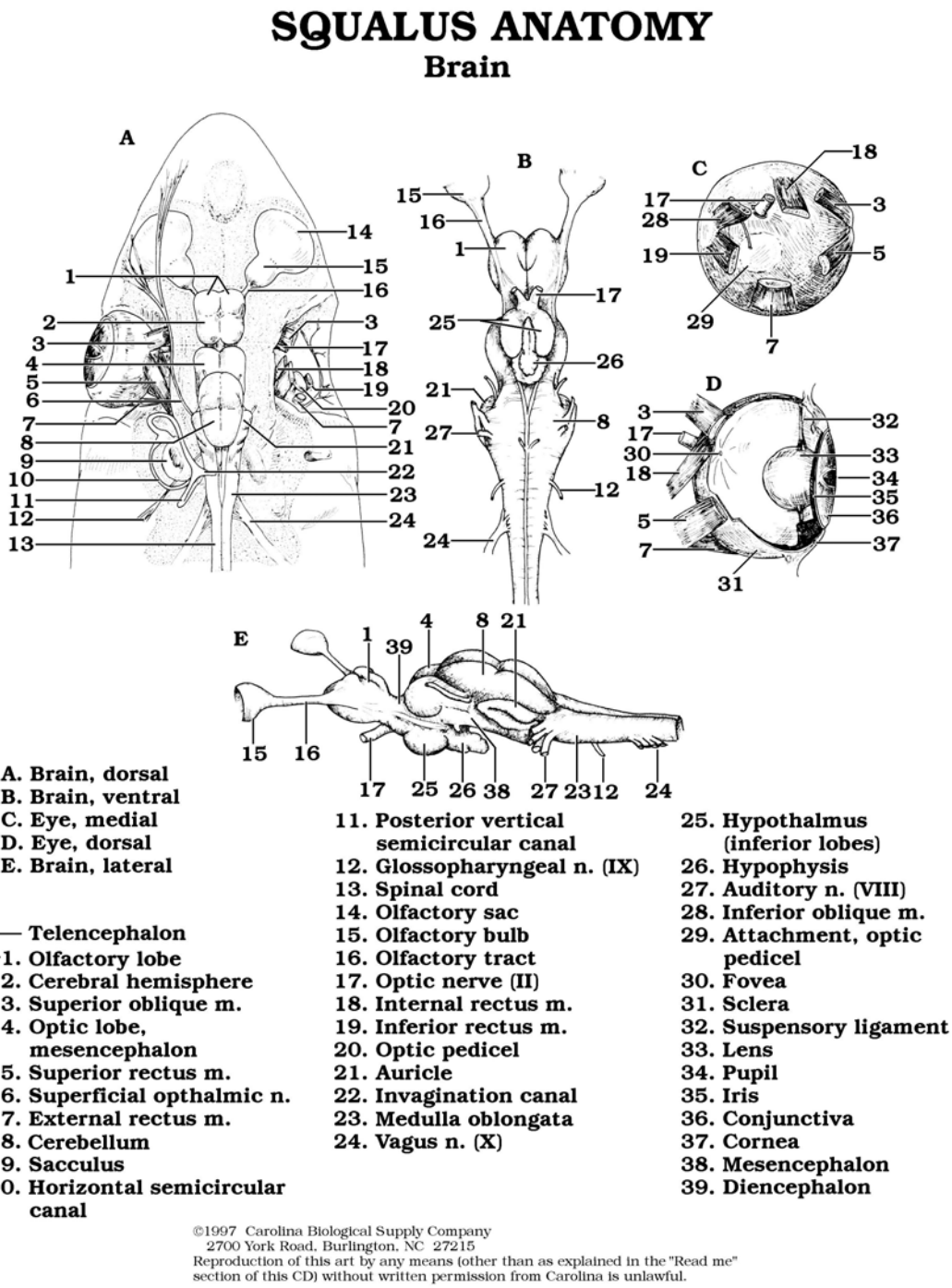


A. Heart, dorsal dissection
B. Heart, dorsal
C. Heart, ventral dissection
D. Heart and branchial circulation
E. Gill, detail

1. Conus arteriosus
2. Atrioventricular opening
3. Sinuatrial valve
4. Sinus venosus
5. Atrium
6. Ventral aorta
7. Semilunar valves
8. Ventricle
9. Tendinous cords
10. Coracomandibular m.
11. Coracohyal m.
12. 1st coracobranchial m.
13. 2nd coracobranchial m.
14. 3rd coracobranchial m.
15. 4th coracobranchial m.
16. Coronary a.
17. Coronary v.
18. Hepatic v.
19. 1st afferent branchial a.
20. 2nd afferent branchial a.
21. Efferent branchial a.
22. 3rd afferent branchial a.
23. Visceral arch
24. 4th afferent branchial a.
25. 5th afferent branchial a.
26. Postcardinal sinus
27. Gill raker
28. Septum
29. Fascia
30. Hemibranch

10. Cut away the lower portion of one of the gills and the cartilaginous bars within the gill arches.
11. The nervous system and sense organs consist of the CNS and the peripheral nervous system. Brains consist of 5 major divisions:

telencephalon, diencepanlon, mesencephalon, metencephalon, mylencephalon.



12. The anteriormost telencephalon is represented by the olfactory sacs connected with the olfactory bulbs. Behind the olfactory bulbs are the cerebral hemisheres

Dissection of Fish

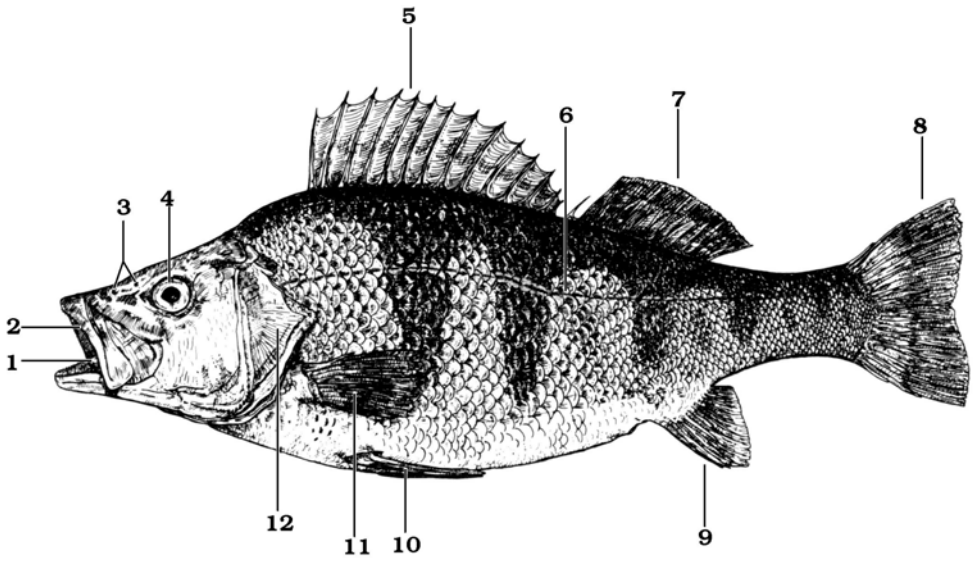
The bony fish, the perch is a model organism. More evolutionary novelties are present in this group of organisms. Many of the adaptations that they exhibit as a group relate to behavior, defense and protective coloration. Please use the photographic atlas to locate external and internal structures. Begin your dissection in a manner comparable to the shark. Using gloves palpate the body until both pectoral and pelvic girdles are located. Carefully make a transverse incision in the body wall on the ventral portion just posterior to the pectoral girdle. Cut carefully, attempting not to damage tissues and organs interior to the incision, backwards to a point lateral to the cloaca (urogenital opening). Just anterior to the pelvic girdle make another transverse incision and pin the sides of the ventral wall to the pan in order to observe the following structures. Once again try to avoid cutting organs that may be needed for study.

Locate:

1. pelvic and pectoral girdles
2. pelvic and pectoral fins
3. anal, caudal, dorsal fins
4. tongue
5. brain
6. gills
7. heart
8. liver
9. spleen
10. stomach
11. intestine
12. gonad
13. anus
14. urinary bladder
15. swim bladder
16. kidney

PERCH ANATOMY

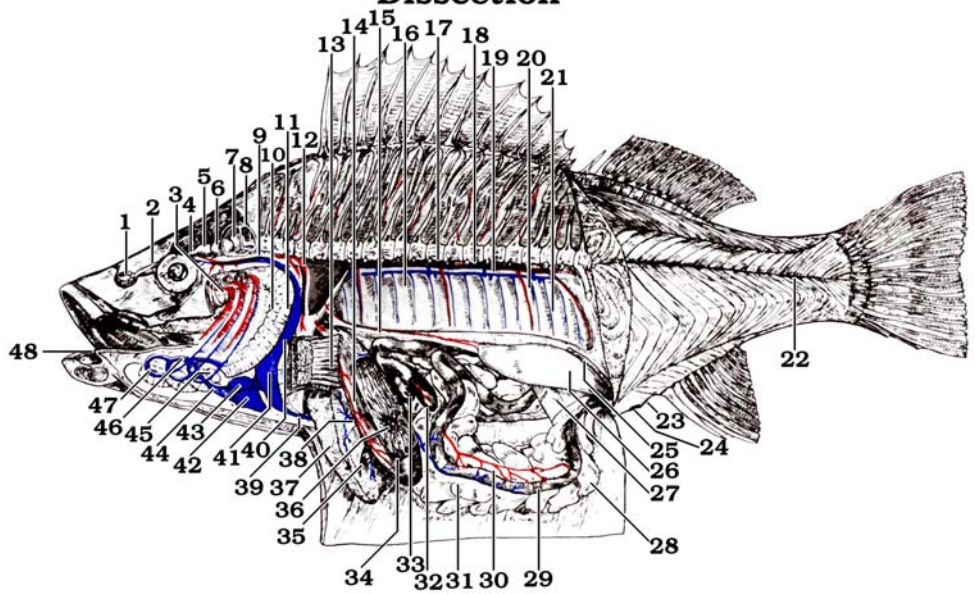
External



1. Tongue
2. Teeth
3. External nares
4. Eye
5. Spiny dorsal fin
6. Lateral line
7. Soft dorsal fin
8. Caudal fin
9. Anal fin
10. Pelvic fin
11. Pectoral fin
12. Operculum

PERCH ANATOMY

Dissection



1. Olfactory basket
2. Olfactory nerve
3. Left efferent branchial ar.
4. Olfactory lobe
5. Cerebrum
6. Optic lobe
7. Cerebellum
8. Internal ear
9. Anterior cardinal vein
10. Gill rakers
11. Gill filaments
12. Left subclavian artery
13. Pectoral fin
14. Gastric artery
15. Gonadal artery
16. Swim bladder
17. Kidney
18. Left posterior cardinal v.
19. Dorsal aorta
20. Segmental artery
21. Segmental vein
22. Lateral line
23. Urogenital pore
24. Anus
25. Urinary bladder
26. Ovary
27. Coelomic mesentery
28. Adipose tissue
29. Large intestine
30. Intestinal artery
31. Intestinal vein
32. Pancreas
33. Pyloric ceca (3)
34. Stomach
35. Gall bladder
36. Pylorus
37. Liver
38. Hepatic portal vein
39. Hepatic vein
40. Ducts of Cuvier
41. Sinus venosus
42. Ventricle
43. Auricle
44. Bulbus arteriosus
45. Ultimobranchial body
46. Ventral aorta
47. Left afferent branchial ar.
48. Tongue

Tetrapod Biology

Amphibians are the oldest class of tetrapods and were the first terrestrial vertebrates. This class probably arose from the lobe-finned fish with lungs. Amphibian fossils date back to the late Devonian, about 365 million years ago. It is likely that the first amphibians were aquatic. The age of amphibians where rapid radiation occurred is the Carboniferous period. The numbers began to decline and by the Mesozoic Era the survivors resembled modern amphibians.

*Urodele*s (salamanders), *Apodans* (caecilians) and *Anurans* are the three extant orders that constitute the class *Amphibia*. We will be concentrating on the frog in this laboratory. Many frogs undergo a complete metamorphosis from being small fish-like aquatic herbivores to terrestrial insect-eating adults. Moist habitats are choice for the amphibian as gas exchange may occur both through the skin and the poorly developed lungs. Fertilization is external and eggs tend to be laid in aquatic habitats. Parental care varies. Many amphibians are recognized by unusual vocalizations.

Frogs are the most commonly studied of the vertebrates. They exhibit numerous adaptations over fish. The skull is flat, broad, and lighter in weight and they have jointed tetrapod limbs rather than fins for locomotion. Adults often develop lungs for gas exchange and a three-chambered heart is formed. The circulatory system has two main parts: the systemic division to supply body organs and the pulmonary division to carry blood to and from the lungs. Special features of the frog include the absence of a tail, the loss of certain skull bones, posterior attachment of the tongue, absence of ribs, no distinct neck and highly developed and powerful hind limbs.

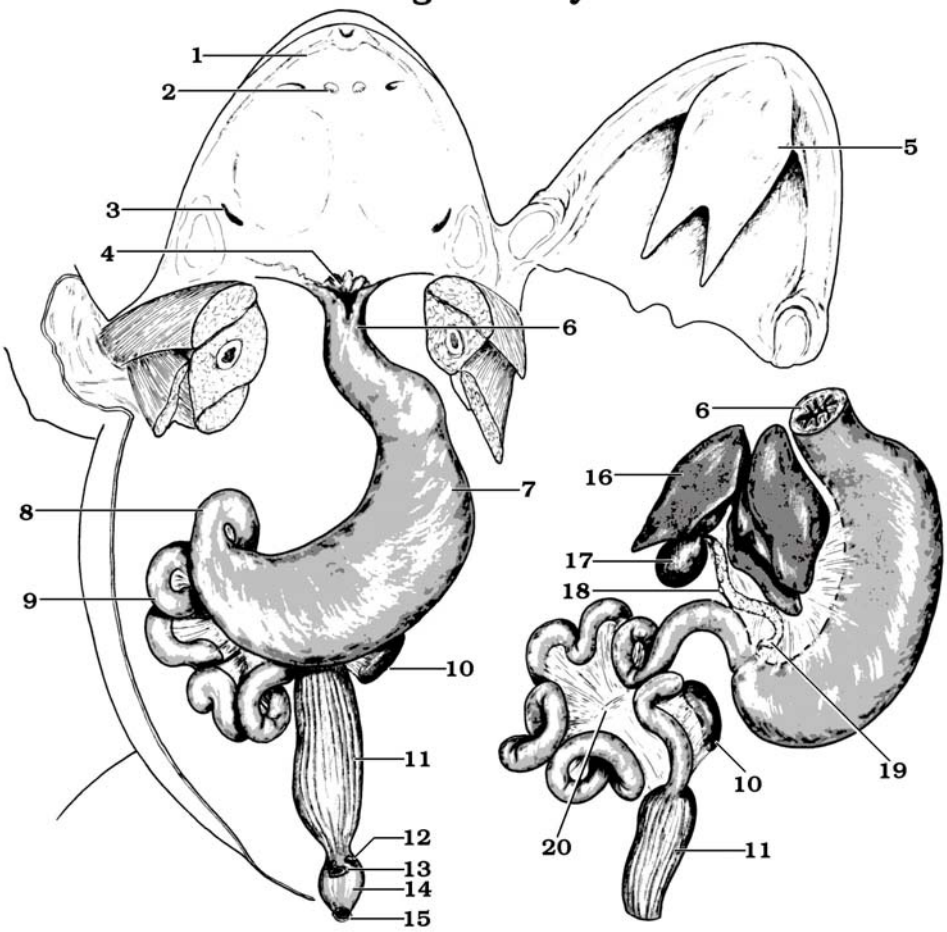
Dissection of the Frog

1. Note the following structures of external anatomy:

    a. eyes
    b. external nares
    c. tympanic membranes
    d. nicitating membrane

2. Place the frog on its back and make a small cut at the corners of the mouth freeing the jaw and oral cavity.

FROG ANATOMY
Digestive System



1. Maxillary teeth
2. Vomerine teeth
3. Eustachian tube opening
4. Esophageal opening
5. Tongue
6. Esophagus
7. Stomach
8. Duodenum
9. Small intestine
10. Spleen
11. Large intestine
12. Ureter opening
13. Bladder opening
14. Cloaca
15. Anus
16. Liver
17. Gall bladder
18. Bile duct
19. Pancreas
20. Omentum

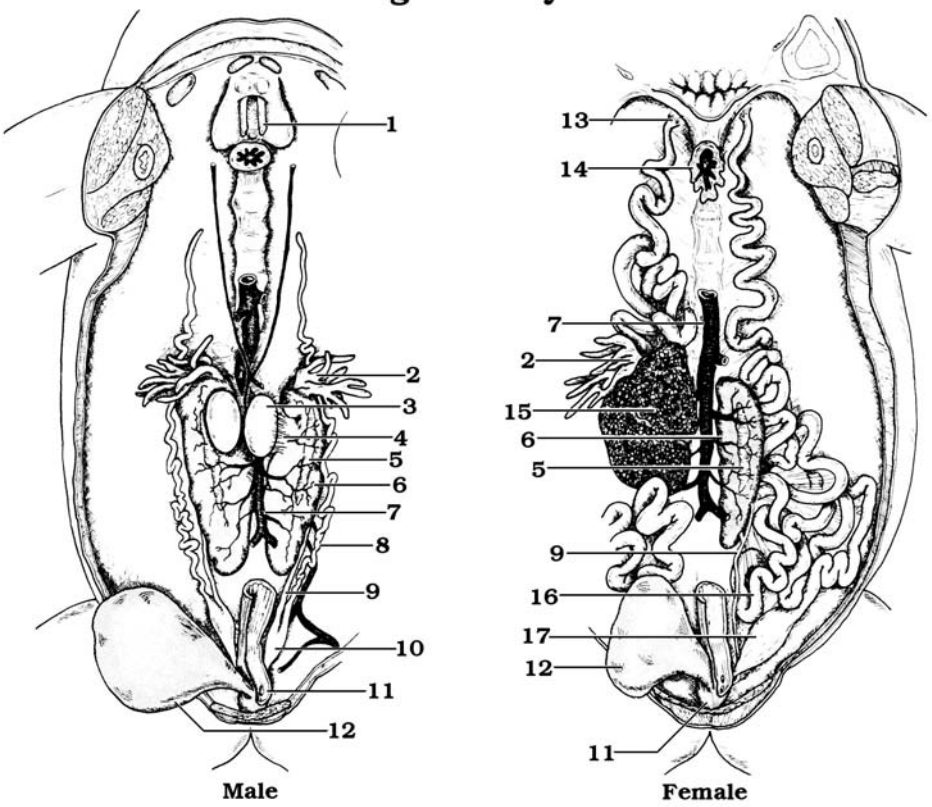
Note the following structures:

a. teeth
b. tongue
c. pharynx
d. glottis
e. bronchi
f. vocal sacs (males) at the posterior corners of the inside of the mouth

4. Lift the skin from the body and make a longitudinal cut slightly to the side of the mid-ventral line and forward from pelvis to tip of lower jaw.
5. Make short transverse cuts at the anterior and posterior ends of this previous cut and pin back the flaps of skin. Examine the muscles.
6. Cut through the bony sternum and up to the posterior end of the lower jaw. Pin the forelimbs back to provide access to the internal organs.

7. Identify:
   a. the 3-lobed liver
   b. gallbladder
   c. bile duct
   d. esophagus, stomach
   e. pancreas
   f. small intestine
   g. large intestine
   h. urinary bladder
   i. cloaca
   j. spleen
   k. mesentary
   l. heart
   m. pericardial cavity,
   n. lungs
   o. urogenital organs
   p. ovaries or testes
   q. fat bodies
   r. kidneys
   s. bladder.

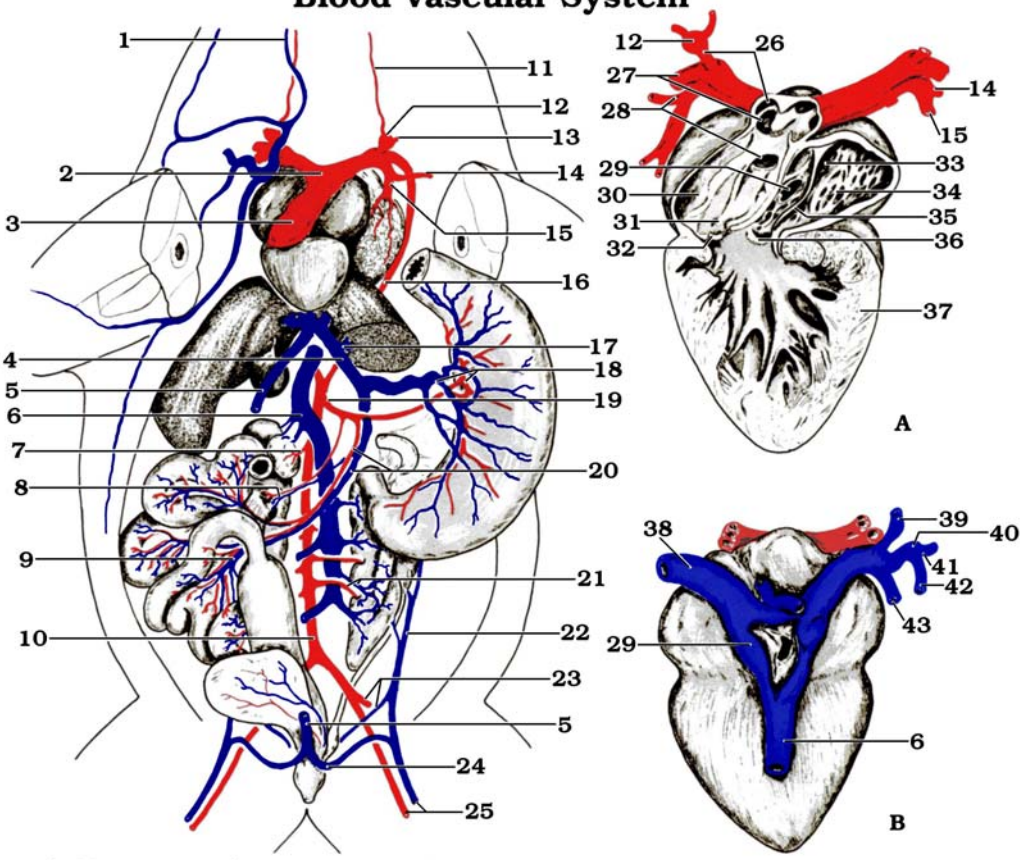
FROG ANATOMY
Urogenital System



1. Glottis
2. Fat body
3. Testis
4. Vasa efferentia
5. Adrenal gland
6. Kidney
7. Post cava
8. Vestigial oviduct
   (not present in bullfrog)
9. Ureter
10. Seminal vesicle
11. Cloaca
12. Bladder
13. Ostium of oviduct
14. Esophagus
15. Ovary
16. Oviduct
17. Ovisac

FROG ANATOMY

Blood Vascular System



A. Heart, ventral
B. Heart, dorsal

1. Lingual v.
2. Truncus arteriosus
3. Bulbus arteriosus
4. Hepatic portal v.
5. Ventral abdominal v.
6. Postcaval v.
7. Genital a. and v.
8. Splenic a. and v.
9. Intestinal a. and v.
10. Dorsal aorta
11. External carotid a.
12. Carotid bulb
13. Internal carotid a.
14. Cutaneous a.
15. Pulmonary a.
16. Aortic arch
17. Hepatic v.
18. Gastric a. and v.
19. Celiacomesenteric a.
20. Mesenteric a. and v.
21. Renal a. and v.
22. Renal portal v.
23. Sciatic a. and v.
24. Pelvic v.
25. Femoral a. and v.
26. Carotid arch
27. Systemic arch
28. Pulmocutaneous arch
29. Sinus venosus
30. Right atrium
31. Spiral valve
32. Semilunar valve
33. Pulmonary v.
34. Left atrium
35. Interatrial septum
36. Atrioventricular valve
37. Ventricle
38. Precaval v.
39. External jugular v.
40. Innominate v.
41. Internal jugular v.
42. Subscapular v.
43. Subclavian v.

Dissection of *Sus scrofa* (Fetal Pig)
Objectives:

1. Identify external structures of *Sus scrofa*.
2. Describe the main structures and function of the digestive system.
3. Describe the structure and function of the pig heart.
4. Describe the respiratory system.
5. Identify main structures of the genital system.
6. Identify and describe the urinary system.
7. Examine the pig brain and locate the dura mater, arachnoid layer, pia mater, cerebellum and cerebrum.

Mammals are classified in an exclusive class as they nurse their young with milk, have hair for insulation purposes and are endothermic or homeothermic. The 4,000 mammals descended from the mammal-like reptile, the therapsid, a small furry creature that scurried about and probably tried to hide from the dominant reptiles including the dinosaurs. The therapsid descended from the synapsid (reference to a skull characterized by two temporal openings located low on the cheeks) line of dinosaurs and arose during the Permian period. Some very important adaptations arose via the therapsid: a larger brain with sensory integration, endothermy and concomitantly, a higher rate of metabolism (hungry little critters) and a number of skeletal changes.

The four groups of teeth (incisors, canines, premolars, molars) may be highly modified depending on the very specialized feeding nature of the animal. The skin of the mammal also is rather specialized with sweat gland (evaporative cooling), sebaceous glands (keeping skin pliable) and scent glands (important in identifying the animal and the territory.) Hair of mammals serves many purposes: mechanical protection, insulation, special coloration as well as water-proofing. The feeding of the young via the mammalian glands of the female allows for increased parental contact and care. There also appears to be a greater investment in the offspring. In general, mammals produce very small litters with respect to their kin *Animalia*.

Herbivores possess specialized microflora in the intestine to process woodier plants, carnivores have specialized adaptations and behaviors to allow them success as predators while omnivores find nutrition in plants and other

animals. Mammals that fly tend to be nocturnal to avoid conflict with birds. Many have specialized structures to assist them in their search for food. Mammals are viviparous with the exception of the Monotremes which are egg-layers. Marsupials tend to be born under-developed and spend much time in their mother's external pouches.

Mammals, since the extinction of the dinosaurs, have radiated and been very successful in exploiting their various niches. The behavior of mammals tends to be complex and fascinating. Some of these include: mating and courtship behaviors, feeding behaviors, behaviors which establish hierarchy, territorial behaviors, and migration behaviors.

The vertebrate that we are examining today is the fetal pig. Most of these are harvested at meat processing plants. The Order is *Arteriodactyla*, even toed hoofed animals. Each toe is generally protected by cornified hooves. The Suborder *Suina* represents swine. Please use your photographic atlas to help find the structures indicated.

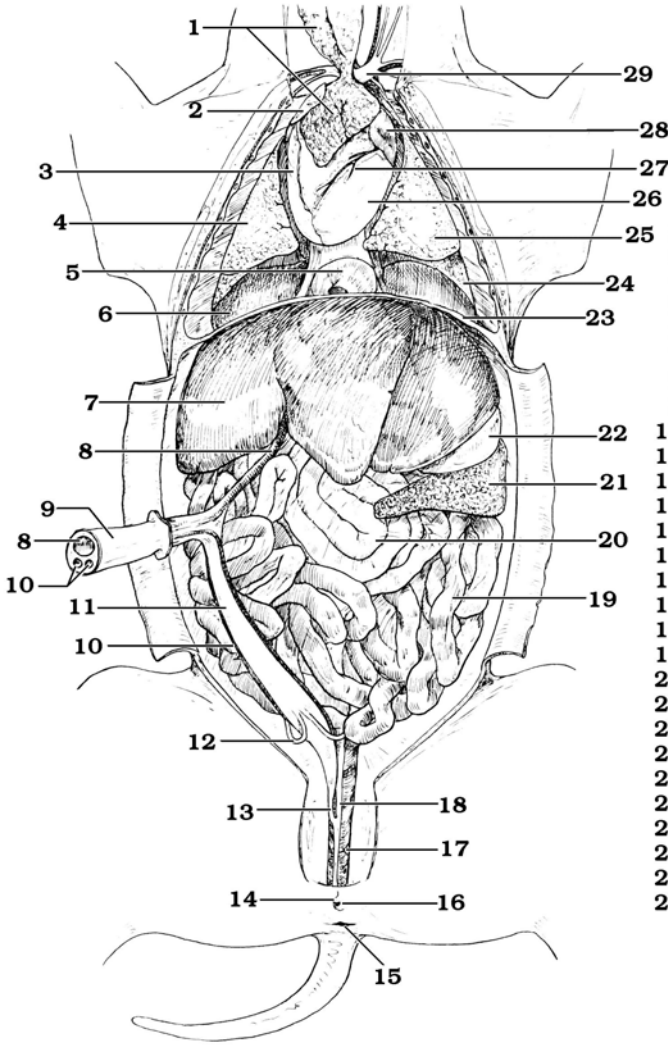
The body is divided into four main section: head (cranial), neck (cervical), trunk (thoracic/abdominal) and tail (caudal). Note the structures indicated in the diagram.

Hold the fetal pig head and force the jaws open to reveal the oral cavity.

Shallowly dissect the ventral side down from a point just below the sternum and cut laterally. Do this on both right and left side. Then cut from just below the sternum to the umbilical cord which we shall cut around to a point even with the hip joint and then again to the side to the hip. Cut from the sternum up to a position just below the line of the front legs and then to the side. Make every attempt to avoid damaging organs for later study. Use the scalpal sparingly and use blunt probes and teasing needles as much as possible. Remember that the organs and tissues are not fully developed and must be handled carefully. We will be focusing on external structures and those organs contained in the thoracic cavity.

FETAL PIG ANATOMY

Dissection



1. Thymus
2. Lung, right apical lobe
3. Pericardium, partly removed
4. Lung, right cardiac lobe
5. Lung, right intermediate lobe
6. Lung, right diaphragmatic lobe
7. Liver
8. Umbilical vein
9. Umbilical cord
10. Umbilical artery
11. Urinary bladder
12. Ureter
13. Urethra
14. Genital papilla
15. Anus
16. External urogenital orifice
17. Rectum
18. Vagina
19. Small intestine
20. Large intestine
21. Spleen
22. Stomach
23. Diaphragm
24. Lung, left diaphragmatic lobe
25. Lung, left cardiac lobe
26. Left ventricle
27. Coronary artery and vein
28. Left atrium
29. Aortic arch

It may be helpful to pin back tissues at this point. Note the following structures:

1. thymus gland
2. pericardium
3. heart
4. lungs
5. trachea
6. esophagus
7. larynx
8. diaphragm
9. liver
10. stomach
11. spleen
12. large intestine
13. small intestine
14. bladder
15. anus
16. kidney
17. pancreas
18. gall bladder

We are not attempting an exhaustive study of the fetal pig today as our interest lies more in comparing and contrasting the morphology of several vertebrates.

A main focus for us is to recognize the increasing complexity of the vertebrates examined. Each organism has special adaptations that have allowed for its success.

In the following table briefly describe the indicated organ systems. Be prepared to compare and contrast them.

	Circulatory System	Digestive System	Respiratory System	Urogenital System
Fish				
Shark				
Frog				
Pig				