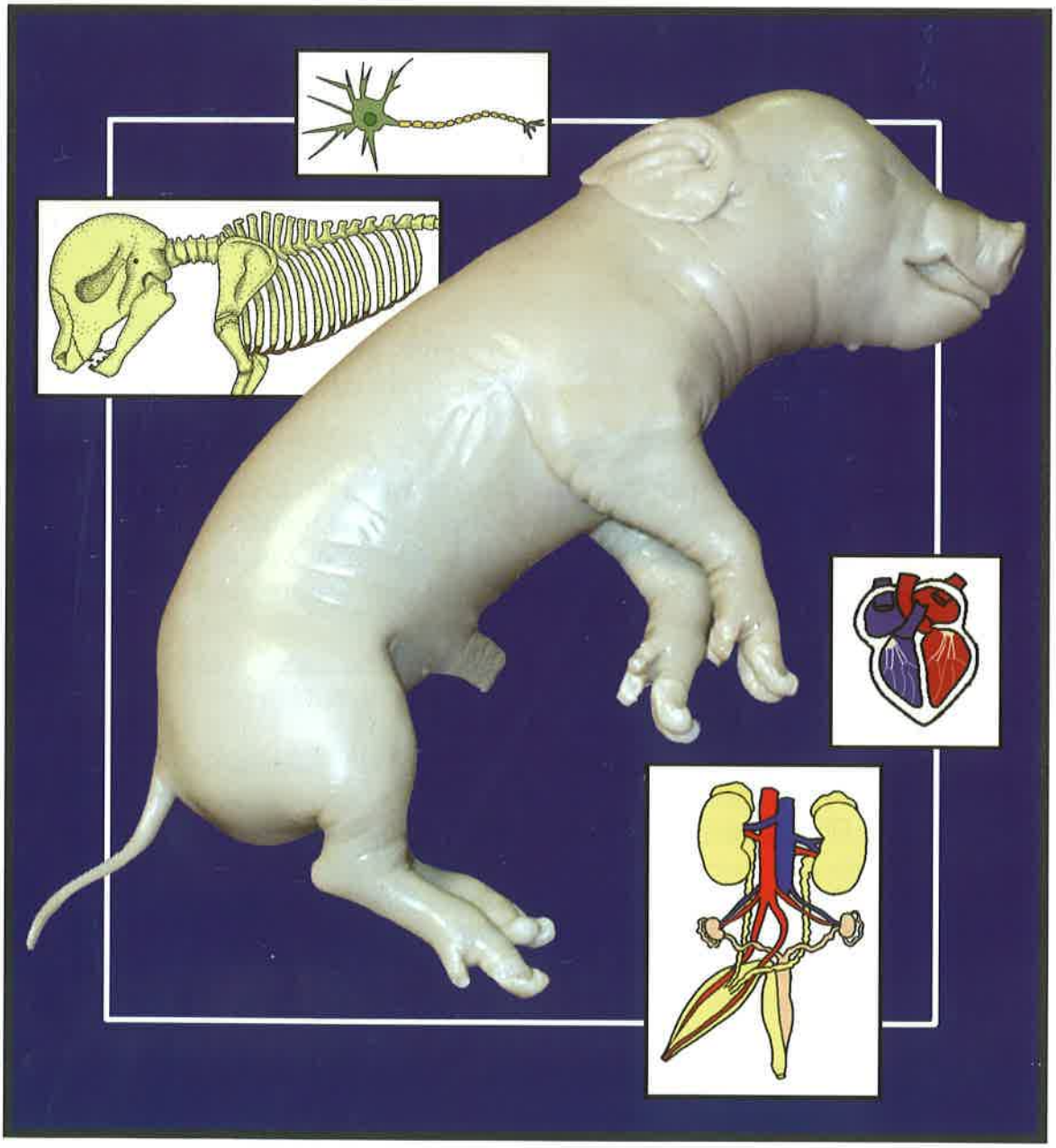
The Taxonomy & Physiology of the

Fetal Pig

A comprehensive, step-by-step dissection guide complete with labeled photographs & illustrations



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How to use this guide:

This guide is intended to introduce the taxonomy and morphology of the fetal pig and to guide the student through its dissection in a step-by-step manner. Dissection instructions are in italics. In general, the photographs may not show all structures because they are too small to be seen, but will show those that are prominent and easily identified. Illustrations are provided that will aid in identification. These figures are designed in a self-quiz manner in which the student may cover up the answers to the numbered structures. Organ systems are summarized throughout the guide. Anatomical and key terms are listed in the back of the guide. Note: The taxonomy in this guide was the most current available as of 2004. Due to discoveries in genetics, taxonomic categories may change in the future.

Fetal Pig Taxonomy

Kingdom: Animalia
Phylum: Chordata
Subphylum: Vertebrata
Superclass: Gnathostomata
Class: Mammalia
Subclass: Theria
Infraclass: Eutheria
Order: Artiodactyla
Family: Suidae
Genus: Sus
Species: scrofa
Full scientific name: Sus scrofa
Common name: domestic pig

figure 1 - Live young pig

Phylum Chordata

The fetal pig is just one of the many animals that belong to Phylum Chordata, which contains some of the most intelligent animals in Kingdom Animalia. Phylum Chordata includes the protochordates (tunicates & lancelets), and the vertebrates (fishes, amphibians, reptiles, birds, and mammals). They inhabit marine, freshwater, and terrestrial environments and are distributed worldwide.

Although there are differences between these animals, all chordates share the following characteristics at some point in development:

1. **Notochord** – Considered a precursor to the modern vertebrate endoskeleton. In most animals, it becomes the cartilage within the vertebrate column.
2. **Dorsal hollow nerve cord** – A fluid filled nerve that transmits impulses and helps form the central nervous system. Most animals retain the nerve cord into adulthood.
3. **Pharyngeal gill slits** – Move water through the pharynx. In many animals, the slits never actually perforate the pharynx but form vestigial pouches.
4. **Post-anal tail** – Generally provides motility in an aqueous environment. In humans, the post-anal tail is a vestigial structure called the coccyx.

All four characteristics are usually only present during the embryonic stage. The embryo of a pig looks almost identical to the embryo of a human. This similarity gives clues to a shared chordate ancestor. One of the few animals that retains all four characteristics during adulthood is the lancelet of Subphylum Cephalochordata.

Subphylum Vertebrata

The animals of Phylum Chordata are currently grouped into the protochordates and the euchordates. The protochordates consist of the two subphyla (shown below) and the euchordates are in Subphylum Vertebrata:

Phylum Chordata

Subphylum Urochordata	Subphylum Cephalochordata	Subphylum Vertebrata
tunicates & sea squirts	lancelet, e.g.: Amphioxus	all vertebrate animals

Typically, the protochordates lack a cranium to protect the brain. They also lack an endoskeleton of vertebrae. In the lancelet, the notochord serves as the endoskeleton. Tunicates lack the classic endoskeleton, but have a tunic or test that provides support. The vertebrates all possess an axial skeleton and a cranium. Vertebrates include lamprey, hagfishes, sharks, rays, fishes, amphibians, reptiles, birds, and mammals.

In addition to the specific four features listed previously, vertebrates also share the following characteristics:

- **Cephalization**
- **Bilateral symmetry**
- **Metamerism**
- Presence of a true **coelom**
- **Endoskeleton**
- **Striated muscles**
- **Integument**
- **Paired limbs**
- **Deuterostome** development
- **Triploblastic** development
- **Organ system** level of organization
- **Closed circulatory system**
- **Complete digestive system**
- **Advanced nervous system**
- **Excretory system** of **kidneys**
- **Endocrine system**

All vertebrates exhibit **bilateral symmetry**, in which the animal can be divided into an equal mirror image, called the sagittal plane. Other anatomical planes are the frontal plane and the transverse plane (figure 2).

figure 2 - Anatomical terms

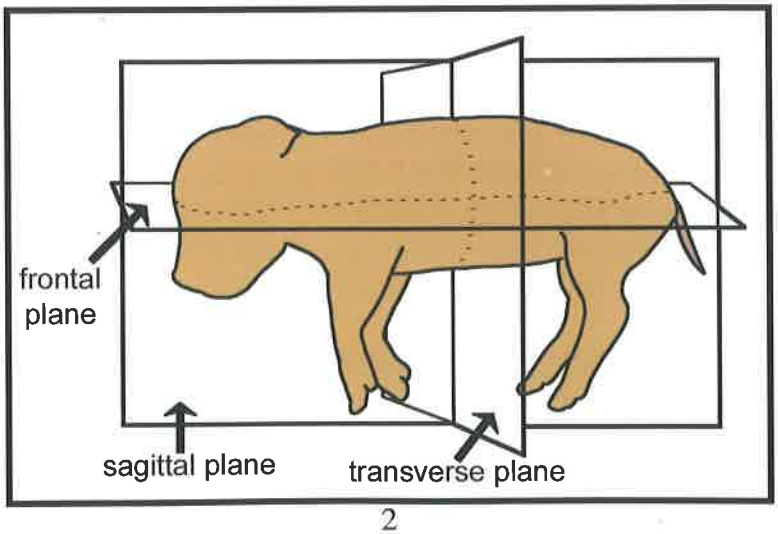
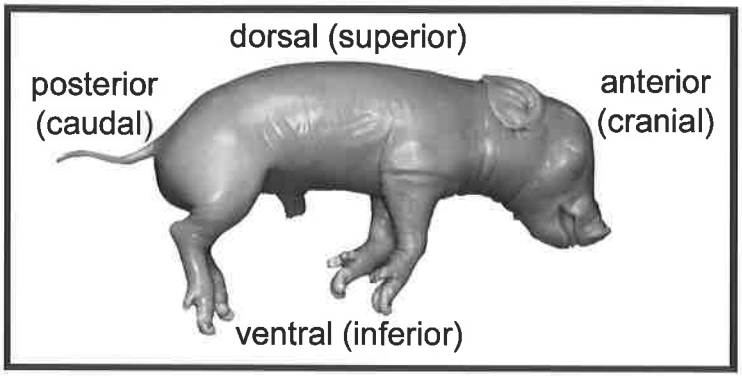


figure 3 - Terms of symmetry



When referring to an animal that is bilateral, you should know the following terms (note: the terms in parantheses are used specifically for animals that are quadrupeds): (figure 3).

- Anterior (cranial) – on or towards the head region
- Posterior (caudal) – on or towards the tail region
- Dorsal (superior) – refers to the upper surface
- Ventral (inferior) – refers to the under surface

Commonly, animals that exhibit bilateral symmetry also show varying degrees of **cephalization**. Cephalization is defined by a gathering of ganglia, or nervous tissue, in the anterior end of the animal. In complex animals, the nervous tissue forms the brain.

Like some other animals from other phyla you may have studied previously, vertebrates share some characteristics in development and organization. They exhibit **metamerism**, which is the repetition of body segments. Metamerism enables the animal to specialize regions of the body for movement and other functions. Chordates are considered **deuterostomes** that undergo **triploblastic** development. They possess a true **coelom**, which is a body cavity that is completely lined with mesoderm tissue. All chordates have an **organ system** level of organization. This means that cells are gathered into tissues, which are then gathered into organs to function in specific ways.

All vertebrates are supported by an **endoskeleton** that is attached to a network of **striated muscles**. The advantage of a living endoskeleton is that it allows for continuous growth and for large body sizes. The world's largest animals are all vertebrates. The body of a vertebrate is protected by **integument** in two layers: the outer epithelium derived from the ectodermal tissue and the inner dermis derived from the mesodermal tissue. This skin covering not only protects but has also been modified by many animals into features such as scales, feathers, claws, and hair.

Vertebrates generally have a **body plan of a head, trunk, and tail**. For many terrestrial animals the **neck** is part of this body plan. They all have **paired limbs**. These limbs may manifest as legs, arms, wings, and fins. In the case of some reptiles such as snakes, the limbs are expressed only as vestigial skeletal structures.

Vertebrates have **closed circulatory systems**. In this type of system, all the blood is enclosed in vessels for transport and is powered by a muscular heart. They have **complete digestive**

systems that consist of an entryway (the mouth) and an exit way (the anus). Having this type of system enables the animal to digest food continuously. Their **advanced nervous systems** make them some of the most intelligent and adaptive animals known. The switch from a rudimentary type of chemosensory system to the complexities of the chordate system probably came about due to a predatory life style. Vertebrates have an **excretory system** of paired **kidneys** that effectively remove wastes. They have an **endocrine system** that facilitates secretions throughout the body.

Superclass Gnathostomata

Superclass Gnathostomata consists of all jawed fishes and other tetrapod vertebrates. Usually paired appendages are also present. This group consists of the following classes:

- Class Chondrichthyes – sharks, skates, rays, and chimaeras.
- Class Actinopterygii – ray-finned bony fishes (formally Class Osteichthyes).
- Class Sarcopterygii – lobe-finned bony fishes (formally Class Osteichthyes).
- Class Amphibia – amphibians: frogs, toads, salamanders, newts, etc.
- Class Reptilia – reptiles: snakes, lizards, crocodiles, alligators, turtles, etc.
- Class Aves – birds (body covered with feathers).
- Class Mammalia – mammals, including humans.

Class Mammalia

Mammals are some of the most diverse animals living today. They can range in size from the tiny shrew that weighs only 0.002 kg, to the largest living animal, the blue whale, which can weigh up to 115,000 kg. Mammals utilize a number of adaptive strategies for survival. Some are efficient predators while others are herbivores that have specialized digestive systems to process plant matter. Mammals are found in virtually every ecosystem around the world. They inhabit terrestrial, arboreal, freshwater, and marine environments. Certain mammals, such as the bat, have the ability of flight. Some are completely nocturnal while others are diurnal. Despite the wide variety of shapes and sizes of mammals, they all share certain characteristics:

- **Hair**
- **Specialized teeth**
- **Muscular diaphragm**
- **Soft palate and secondary bony palate**
- **Axial & appendicular skeleton**
- **Endothermic**
- **Homeothermic**
- **Four chambered heart**
- **Integument of epidermis, dermis, and glands including mammary glands**

All mammals have **hair** in varying degrees. Hair can be used for warmth, protection, camouflage, and to signal distress. When threatened, some animals, such as a dog or cat, will make their hair stand up to give the illusion of greater size. An animal may also bare its teeth when stressed. A mammal's **teeth** are specialized to reflect its diet. Carnivores have prominent canine teeth along with incisors, and molars. Herbivore teeth are used to grind and crush plant matter using high-crowned molars and incisors. Omnivores have heterodont teeth or a combination of different types of teeth. Pigs are considered omnivores.

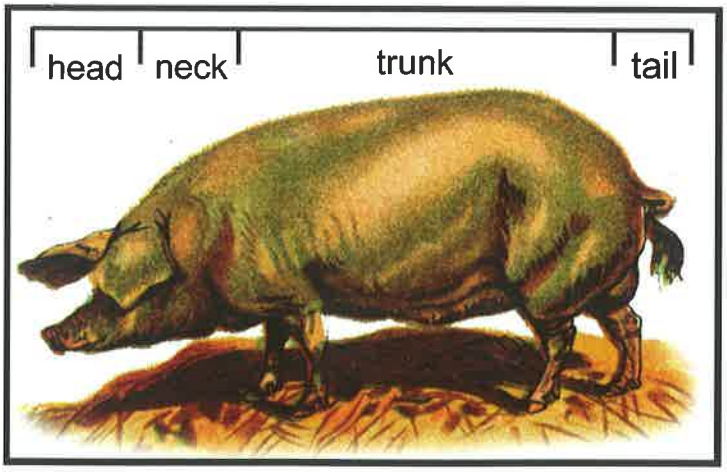
In addition to their specialized teeth, mammal skulls have some other unique characteristics. They have both a **soft palate** and a **secondary bony palate**. The combination of these palates allows the animal to breathe and eat simultaneously. The skull also contains two orbits that house the eyes. The eyes are protected by fleshy eyelids. In predatory animals, the eyes will be oriented toward the front of the head. For prey animals, they are located on the side of the head to allow for wider range of vision to look out for predators. Mammals have a middle ear that consists of three small bones. The ears are generally external and fleshy.

Mammals share the chordate **body plan of the head, neck, trunk, and tail** (figure 4). The skeleton is divided into the **axial** and **appendicular skeleton**. They have an internal adaptation of a **muscular diaphragm** that serves to aid in negative-pressure respiration and divides the thoracic and abdominal cavities. Like other vertebrates, mammals have **integument** of the dermis and epidermis, but they also have several glands derived from the ectodermal tissue. These are: sweat, scent, sebaceous, and mammary glands. The sweat glands serve to cool the body with moisture and aids in homeostasis. The scent glands are used in mate attraction, defense of territory, and intraspecies communication. The sebaceous glands release fatty oils and are usually associated with keeping hair glossy and healthy. The **mammary glands** are used to nourish the young. In some mammals, such as humans, the mammary glands are constantly visible, while in others they are only swollen during pregnancy and nursing. It is a well known fact that mammalian females have mammary glands. However, the males actually have mammary glands but they are largely undeveloped.

All mammals are **endothermic** and **homoeothermic**. It can be easy to confuse these terms. Endothermic refers to the ability to generate heat within the body. This is in contrast to ectotherms (like reptiles) that are reliant on the outside environment for warmth. Homeothermic refers to the ability to maintain a constant internal temperature. In the past, mammals were called "warm-blooded" because they are endothermic. Now, the term endothermic is preferred.

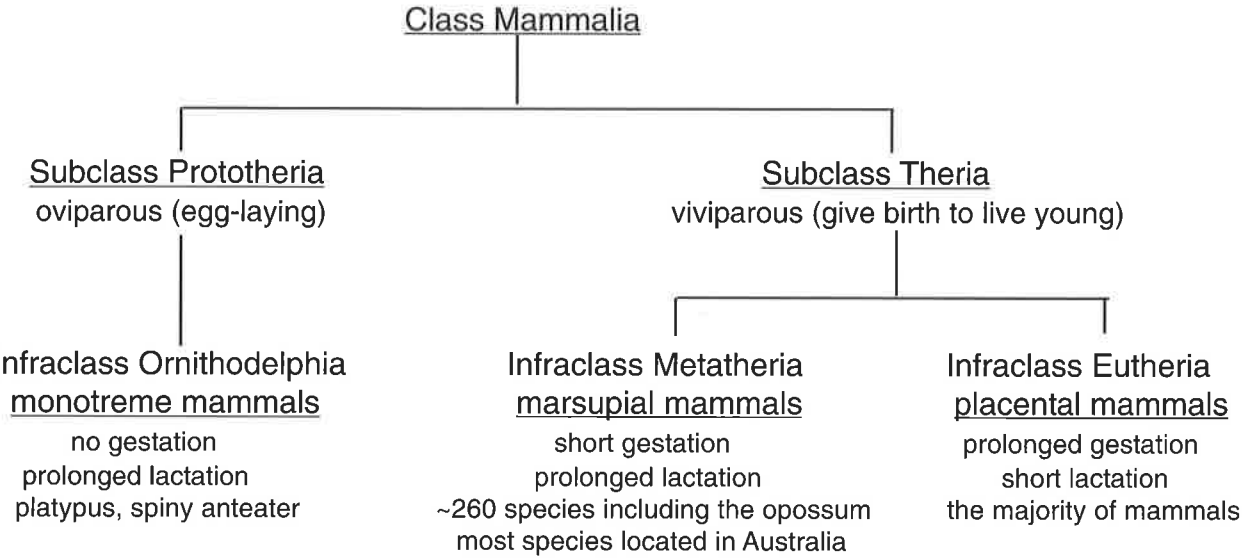
The **four-chambered heart** pumps non-nucleated, biconcave red blood cells throughout a network of arteries, veins, and capillaries to provide oxygen and nutrients to the body. This four-chambered heart allows for the separation of circulation into two separate circuits: the pulmonary circuit and the systemic circuit. You will learn more about this in the "Circulatory System" section of this guide.

figure 4 - Adult pig showing vertebrate body regions



Subclass Theria & Infraclass Eutheria

Class Mammalia is further separated into subdivisions based on the method of reproduction:



Animals in Subclass Theria and Infraclass Eutheria are viviparous and the embryo is nourished in the uterus by a placenta. These mammals have a long gestation period and relatively short lactation period. There is varying period of parental investment when the parents or related adults care for the young. Humans have the longest period of parental investment of all the mammals.

Order Artiodactyla

There are currently ~4500 species of mammals known to exist. They are generally divided into orders based on certain physical features such as the pattern of the teeth and other morphologies. Ungulates are divided according to the number of toes in their hooves. Horses, donkeys, zebras, and rhinoceroses belong to the odd-toed group, Order Perissodactyla. In contrast, the even-toed group of hoofed animals belongs to **Order Artiodactyla**. This order includes the various species of pig, wild boar, camel, deer, antelope, cattle, sheep, goat, and hippopamus. Many of these animals have two toes, but you will observe that your pig has four.

Why study the fetal pig?

In many ways the pig is a typical example of a mammal. It possesses all of the classic mammalian characteristics. In terms of physiology, the pig is almost identical to humans. The major organs are all the same and differ only in small ways. For example, the human liver has four lobes whereas the pig liver has five. Given the fact that pigs are quadrupedal and humans are bipedal, there is an amazing similarity in skeletal and muscle structure. Fetal pigs are small and easy to store. They are obtained from slaughterhouses producing pork. Pregnant

sows are harvested for their meat and the fetal pigs are taken for educational and research purposes. Basically, this is a recycling of biological material that would otherwise go to waste. A single sow can produce a litter of piglets that can number from seven up to eighteen. For these reasons, they are relatively inexpensive and easy to obtain. Fetal pigs have cartilaginous bones that have yet to harden, so they are not difficult to cut into. Most of the internal structures can easily be seen without the aid of a microscope or magnifying glass. Certain features are easier to see in a fetal pig that has gestated for a longer period of time. Later, you will estimate the age of your pig according to its body length.

Because of their similarity to humans, pigs have been used extensively in biomedical research. Pigs are susceptible to some of the same diseases as humans, (e.g. influenza). The primary areas of swine research are with the cardiovascular, urinary, and digestive systems. Since pigs are relatively hairless like humans, they have also been used in dermal research.

External Features – (figures 5, 6, & 7)

Materials:

* Fetal pig
* Dissection pan
* Ruler (cm)
* String
* Protective gloves
* Probe
* Scissors

1. Obtain a fetal pig, dissection tray, gloves and other items listed above.
2. Always wear gloves when handling the specimen.

When you obtain your fetal pig, you may notice a wrinkled appearance in the skin. This is due to the preservation and storage process. Some of the pigs may have pigmented skin.

3. Measure the body of your pig by taking the string from the tip of the snout to the base of the tail along the dorsal side.
4. Mark the length of your string and use your ruler to determine its length.
5. Determine the age of your pig by filling out the chart below and referring to table 1.

Length of your pig:_____ Approximate age of your pig:_____

Table 1 – Determining the age of the fetal pig

age of the fetus (in weeks)	length of the fetus
3	1.1-1.3 cm
7	2.8-3.8 cm
14	22-23 cm
16-17(full term)	~30 cm

6. Continue your observations of the external anatomy. Use figure 5 to assist in the identification of structures.

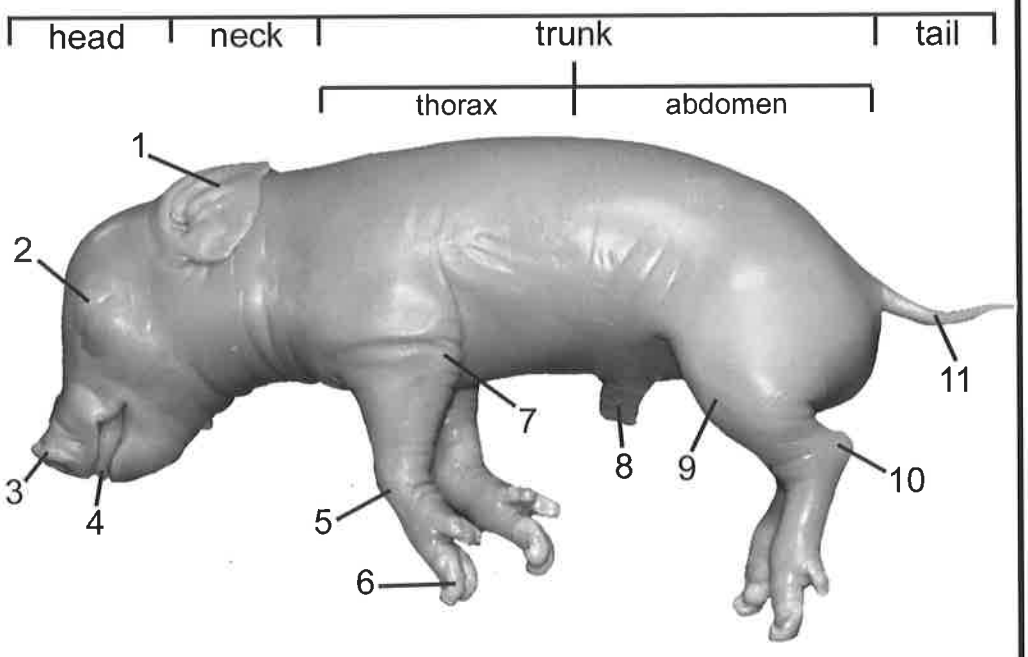
Recall that the typical body plan of a vertebrate is the **head**, **trunk**, and **tail**. The fetal pig is a terrestrial animal, so it also has a **neck** as part of its body plan. The trunk is divided into two parts, the **thorax** and the **abdomen** (figure 3). On the head you will see the fleshy, **external ears** called **pinnae**, the eyes with the upper and lower eyelids, the snout containing the mouth and tongue, and small sensory hairs called **vibrissae**. The pinnae are cartilaginous like human ears. The **snout** is also cartilaginous and contains the nares for the passage of air. The end of the snout is strengthened by a bony region to allow the pig to dig into the soil in search of food. The snout also serves to house many olfactory receptors that give the pig an efficient sense of smell. Pigs have been used to help humans find truffles, a type of mushroom that grows wild in the forest and is considered a delicacy.

Recall that **paired limbs** are one of the typical features of all mammals. When you look at the external anatomy of your pig, you will notice different locations for the **wrists**, **elbows**, **knees**, and **ankles** in comparison to humans. This is because the pig is a quadrupedal animal in contrast to the bipedalism of humans.

7. With your scissors, cut off a small portion of the umbilical to see the structures within. Use figure 6 to assist in identification.

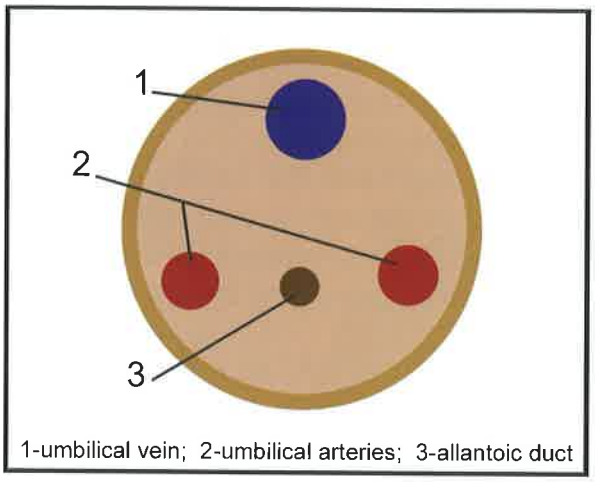
One of the most noticeable features of any fetal mammal from Infraclass Eutheria is the umbilical cord. The fetus grows within the uterus and is nourished by the mother through the placenta. The umbilical cord is how oxygen and nutrients are delivered to the growing fetus.

figure 5 - External anatomy



1-external ears / pinnae; 2-eyelid; 3-snout with nares; 4-tongue; 5-wrist; 6-hoof; 7-elbow; 8-umbilical cord; 9-knee; 10-ankle; 11-tail

figure 6 - Umbilical cord cross-section



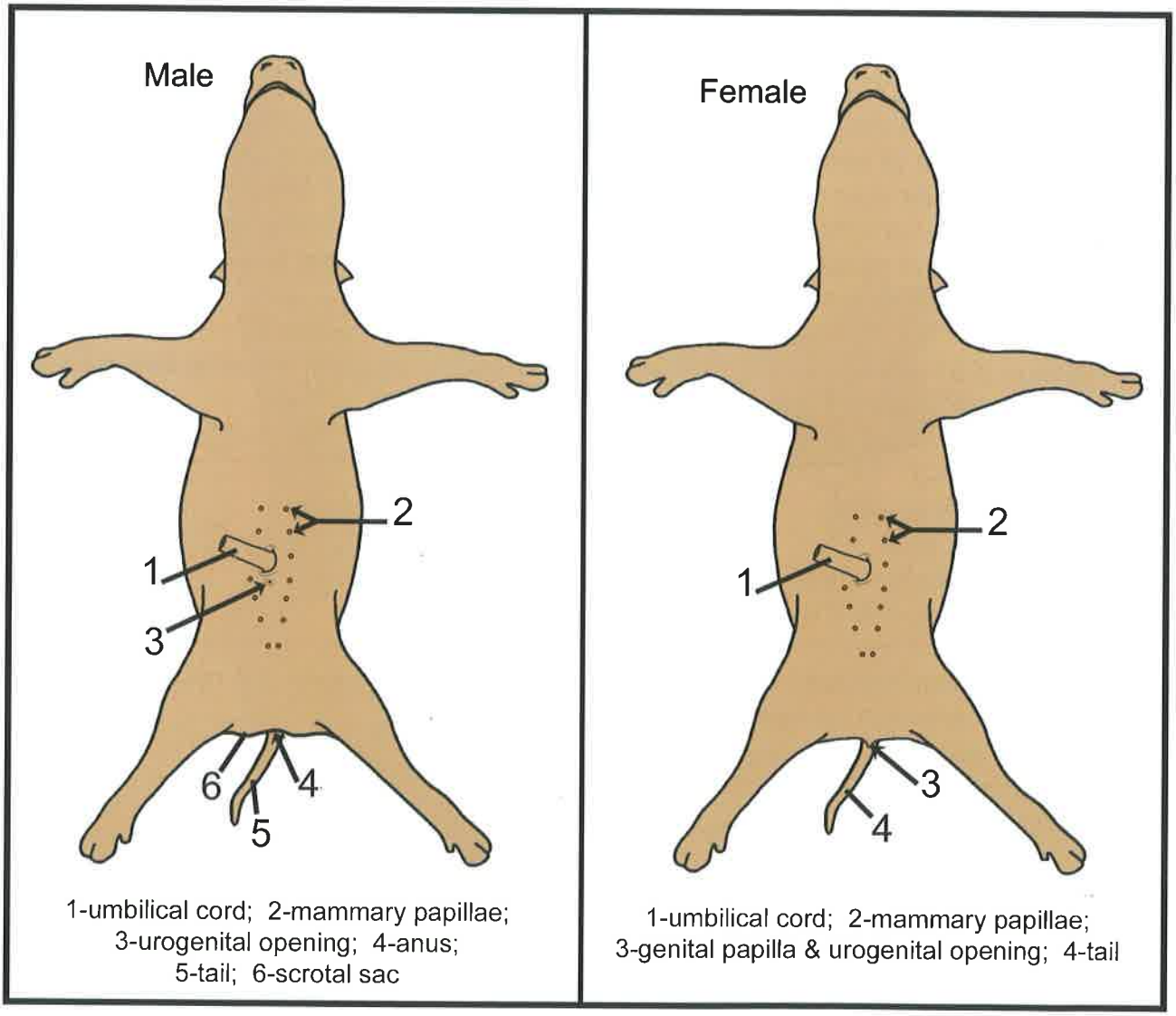
1-umbilical vein; 2-umbilical arteries; 3-allantoic duct

Highly oxygenated blood is transferred to the fetus through the **umbilical vein**. Partially oxygenated blood is removed from the fetus through the **umbilical arteries**. Metabolic wastes are removed through the **allantoic duct** which is connected to the fetus' allantoic bladder.

8. Determine the gender of your pig and observe its structures. Use figure 7 to assist you. Make sure that you observe another student's pig of the opposite gender.
9. Circle the gender of your fetal pig:

male female

figure 7 - Gender differences



1-umbilical cord; 2-mammary papillae; 3-urogenital opening; 4-anus; 5-tail; 6-scrotal sac

1-umbilical cord; 2-mammary papillae; 3-genital papilla & urogenital opening; 4-tail

Some structures will be the same for both males and females. Under the tail, they both have an **anus**. The basic body plan is the same and they both have **mammary papillae**. In females, the mammary papillae will eventually form teats during pregnancy and nursing. The mammary glands produce the milk to feed the young and are located in proximity to the teats. In males, the mammary papillae never develop to serve these functions.

If your pig is male, you will see the **urogenital opening** caudal to the umbilical cord. It serves as a passageway for urine and semen. Depending on the age of your fetal pig, you may or may not see the **scrotal sacs**. In younger fetal pigs, the testes have not yet descended into the scrotal sacs. The penis is not visible, but you can feel it by pressing the skin between the urogenital opening and the scrotal sacs.

If your pig is female, you will see the **genital papillae** under the tail. At the base of this structure is the urogenital opening that serves to release metabolic waste and is the opening to the reproductive system. You will learn more about these structures in the "Reproductive System" section of this guide.

The Skeletal System – figure 8

The skeletal system of a pig is typical for many quadrupedal mammals. You will not be using your fetal pig to study this system. The bones of your fetal pig have not yet hardened, or ossified. At this stage of development, they are primarily composed of cartilage. It can be extremely difficult to remove the flesh off of the bones of a fetal pig. For this reason, it is better to study a specimen of some other small mammal that is an adult. This guide provides a detailed illustration for your use.

Once the animal is born, the bones harden. Typically, a bone contains the shaft, or **diaphysis**, and the extremities, or **epiphyses**. The diaphysis is the interior of the bone where marrow is found. The epiphysis is where growth occurs.

The skeleton of a mammal is described as having two major regions: the **axial skeleton** and the **appendicular skeleton** (table 2):

Table 2 - Axial and appendicular skeleton

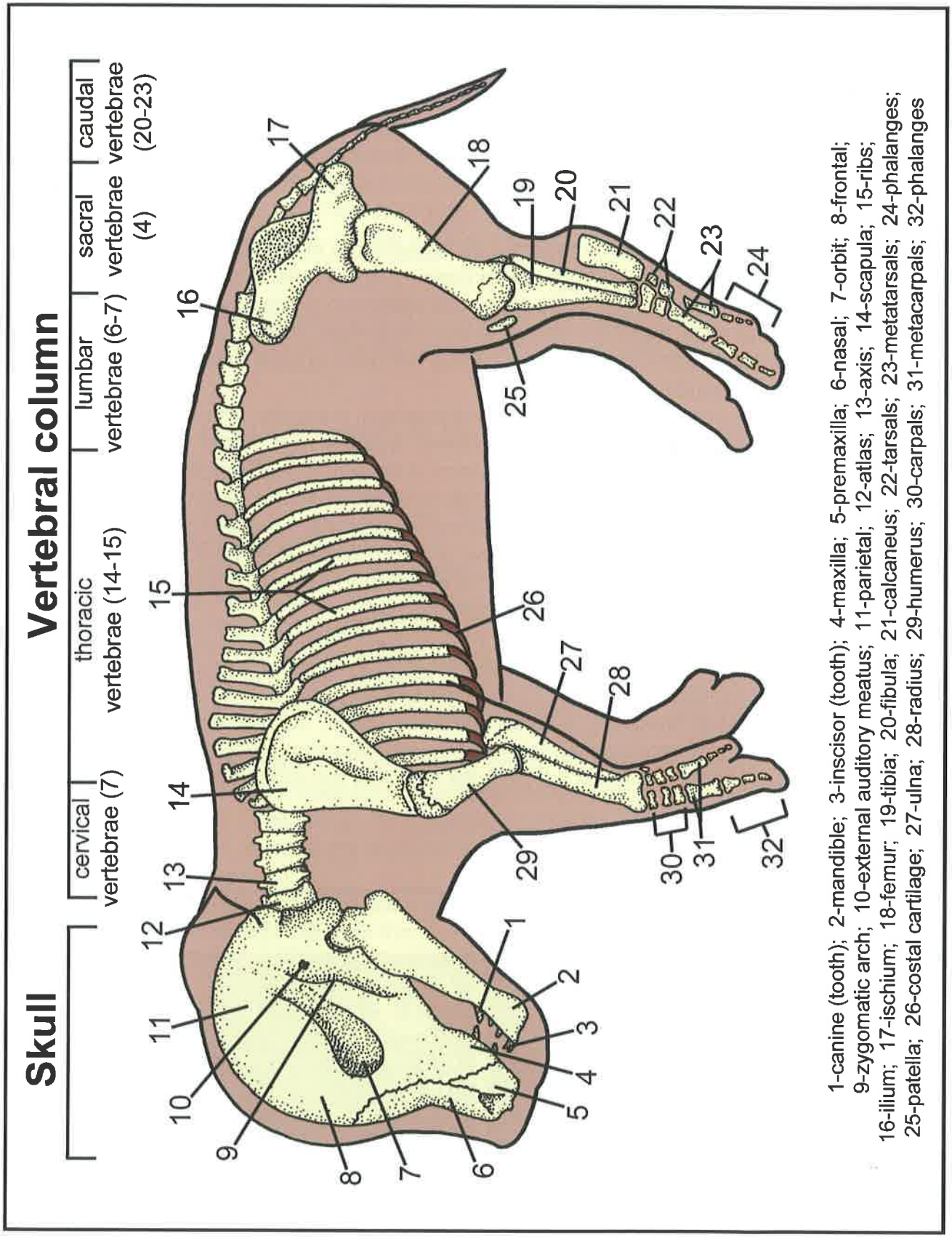
Axial skeleton	Appendicular skeleton
skull	pectoral girdle
vertebral column	pelvic girdle
sternum & ribs	appendages

The vertebral column is divided into the cervical, thoracic, lumbar, sacral, and caudal vertebrae. The number of vertebrae can vary amongst mammals (table 3).

Table 3 - Vertebrate comparisons

Type of vertebrae	Pig	Human
Cervical	7	7
Thoracic	14-15	12
Lumbar	6-7	5
Sacral	4	5
Caudal	20-23	3-5 (coccyx)

figure 8 - The skeletal system



A very important feature of the mammalian endoskeleton is the presence of joints, or **articulations**. They allow for a variety of movements. Several different types of articulations occur:

Synthartrosis – A completely immovable joint. Example: sutures in the skull.
Diarthrosis – A completely movable joint. Example: the knee.
Amphiarthrosis – A joint that has some movement. Example: the vertebrae.

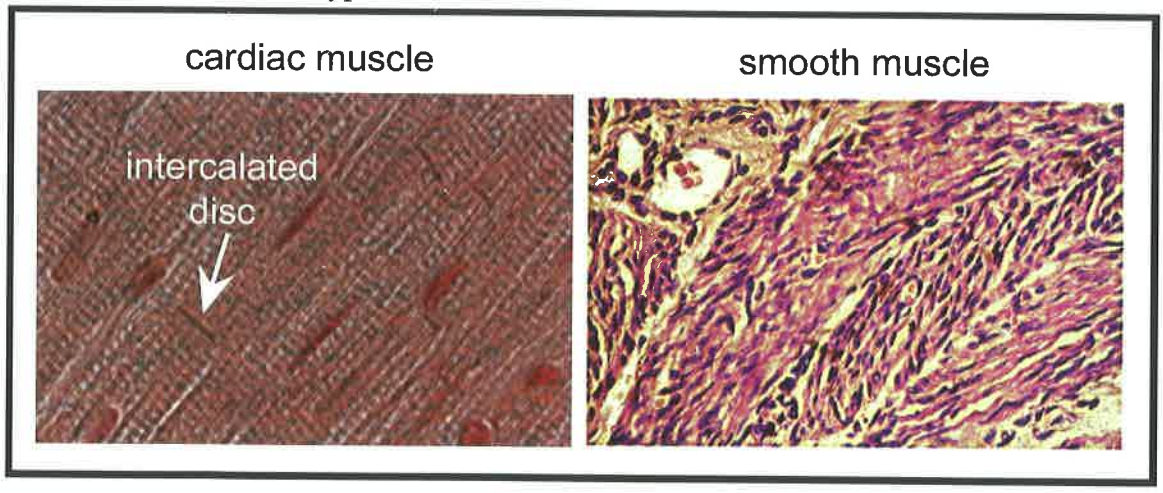
The Muscular System – figures 9 & 10

Fetal pigs have many of the same muscles as humans but in different locations due to the fact that they are quadrupeds. This guide addresses only the most superficial muscles in the lateral view. Your instructor may provide a skinned specimen or may require you to skin your own. When skinning a pig, make an incision in the integument. With your forceps, lift the skin and carefully peel it away from the body by cutting with your scalpel. Usually, late term fetal pigs work best for the study of the muscles.

A muscle is typically composed of three parts: the **origin**, the **belly**, and the **insertion**. The origin is the end of the muscle connected to a fixed, typically rigid part of the skeleton. The belly is the middle part of the muscle. The insertion is the end of the muscle that is connected to a movable portion of the skeleton. The muscle contraction across diarthrotic joints is what causes movement. The insertion of the muscle moves closer to the origin of the muscle. The muscle is connected to the skeleton by a **tendon**, a tough connective tissue. An **aponeurosis**, another type of connective tissue, connects the muscles to its point of attachment. Muscle fibers held together by **fascia**, fibrous connective tissue.

Muscles are divided into three types: smooth muscle, skeletal muscle and cardiac muscle. Smooth muscle is the involuntary muscle responsible for visceral activities such as digestion. Skeletal muscle and cardiac muscle both have a striated appearance. They can be differentiated by the intercalated discs present only in the cardiac muscle. As the name implies, cardiac muscle is the involuntary muscle located in the heart. Skeletal muscle is voluntary and is located throughout the body. Notice the contrast between the striated cardiac muscle tissue and the smooth muscle tissue.

figure 9 - Muscle tissue types



The movement of a muscle is its **action**. There are many different types of actions associated with muscles. Some common actions are listed below:

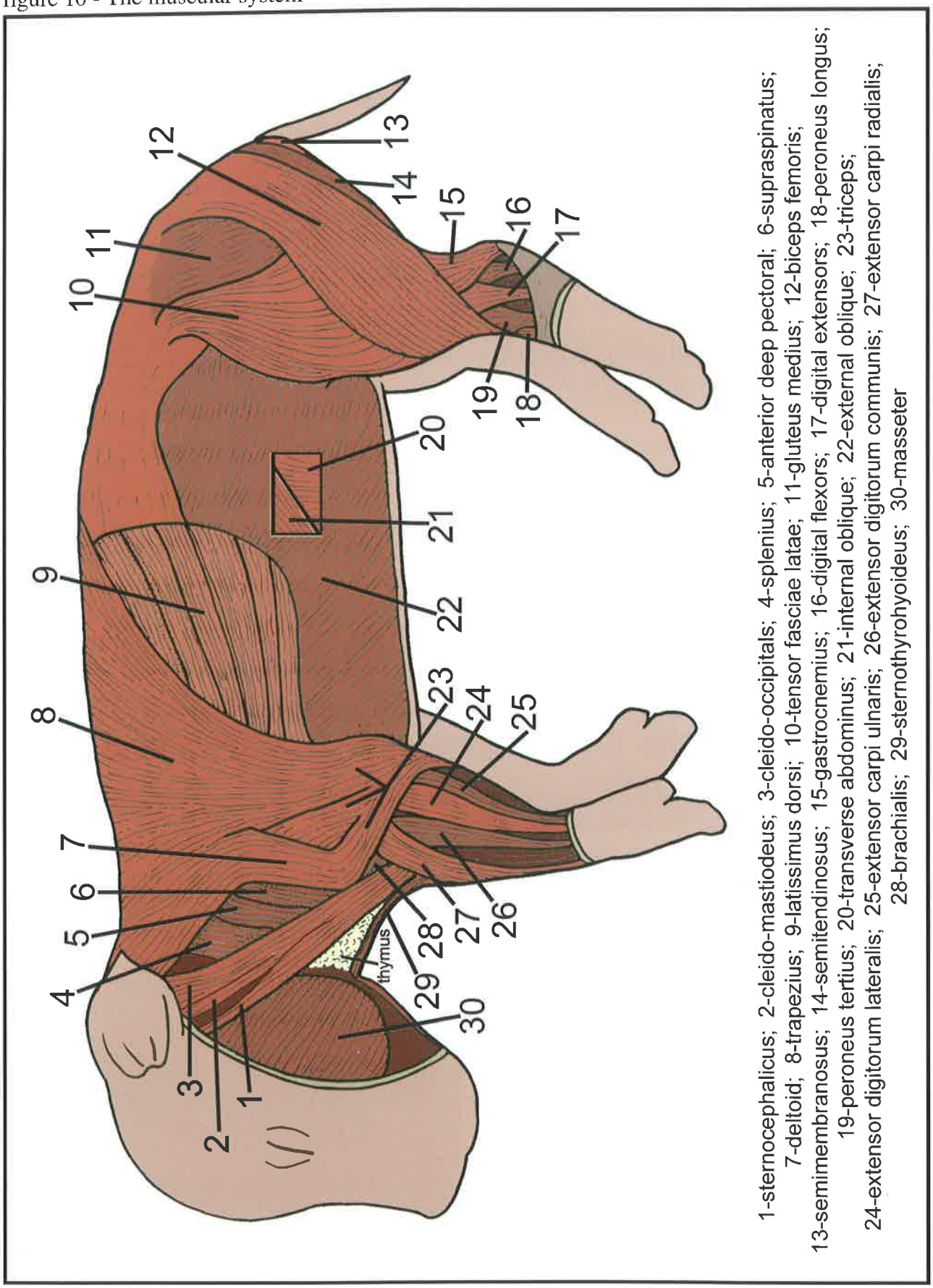
- **Flexion** – Bending a joint so that the angle of that joint decreases. Example: bending your elbow or knee.
- **Extension** – Extending a joint so that the angle of the joint increases. Example: straightening out your arm or leg.
- **Adduction** – Moving the distal part of the bone toward the median axis of the body. (Ad = to) Example: lowering your horizontally raised arms down to the sides of your body.
- **Abduction** – Moving the distal part of the bone away from the median axis of the body. (Ab = from) Example: raising your arms from the sides of your body to a raised horizontal position.

Most muscles are paired and produce actions that are **antagonistic**. That is, they produce opposing effects. For example, the biceps and triceps are considered antagonists.

The following muscles correspond with figure 10 (on the following page). Their origins, insertions, and actions are listed.

1. **Sternocephalicus** – orgin: sternum; insertion: mastoid process of the skull; action: turns and depresses the head.
2. **Cleido-mastiodeus** – origin: lambdoidal ridge of the occipital bone in the skull; insertion: distal end of the humerus; action: flexes the foreleg.
3. **Cleido-occipitals** – origin: lambdoidal ridge of the occipital bone in the skull; insertion: distal end of the humerus; action: flexes the foreleg.
4. **Splenius** – origin: thoracic vertebrae; insertion: occipital and temporal bones of the first few cervical vertebrae; action: moves head from side to side and elevates the head and neck.
5. **Anterior deep pectoral** – origin: anterior end of the scapula; insertion: proximal end of the humerus; action: adducts and retracts the forelimb.
6. **Suprasinatus** – origin: scapula; insertion: humerus; action: extends the scapula.
7. **Deltoid** – origin: spine of the scapula; insertion: proximal end of the humerus; action: flexes the humerus.
8. **Trapezius** – origin: occipital bone of the skull and the spines of the first ten thoracic vertebrae; insertion: spine of the scapula; action: elevates the shoulders.
9. **Latissimus dorsi** – origin: thoracic and lumbar vertebrae; insertion: humerus; action: draws the humerus upward and backward, also flexes the shoulder.
10. **Tensor fasciae latae** – origin: ilium; insertion: patella and tibia; action: extends leg.
11. **Gluteus medius** – origin: longissimus dorsi muscle, ilium, sacroiliac and sacrosciatic ligaments; insertion: proximal end of the femur; action: abducts the thigh.
12. **Biceps femoris** – origin: ischium, sacrum; insertion: patella, thigh; action: abducts and extends the hind leg.
13. **Semimenbranosus** – origin: ischium; insertion: distal end of the femur and the proximal end of the tibia; action: extends hip and flexes the hip joint.
14. **Semitendinosus** – origin: first and second caudal vertebrae, ischium; insertion: proximal end of the tibia and calcaneus; action: extends hip, flexes knee joint.

figure 10 - The muscular system



1-sternocephalicus; 2-cleido-mastiodeus; 3-cleido-occipitals; 4-splenius; 5-anterior deep pectoral; 6-supraspinatus; 7-deltoid; 8-trapezius; 9-latissimus dorsi; 10-tensor fasciae latae; 11-gluteus medius; 12-biceps femoris; 13-semimembranosus; 14-semitendinosus; 15-gastrocnemius; 16-digital flexors; 17-digital extensors; 18-peroneus longus; 19-peroneus tertius; 20-transverse abdominus; 21-internal oblique; 22-external oblique; 23-triceps; 24-extensor digitorum lateralis; 25-extensor carpi ulnaris; 26-extensor digitorum communis; 27-extensor carpi radialis; 28-brachialis; 29-sternothyrohyoideus; 30-masseter

15. **Gastrocnemius** – origin: distal end of the femur; insertion: by the Achilles tendon to the calcaneus; action: extends the foot.
16. **Digital flexors** – origin: proximal ends of the tibia and fibula; insertion: the digits; action: flexes the digits.
17. **Digital extensors** – origin: proximal ends of the tibia and fibula; insertion: metatarsals; action: extends the digits
18. **Peroneus longus** – origin: proximal ends of the tibia and fibula; insertion: metatarsals; action: flexes the ankle.
19. **Peroneus tertius** – origin: distal end of the femur; insertion: third metatarsal; action: flexes the foot.
20. **Transverse abdominus** – origin: lateral surface of the last 9-10 ribs, lumbodorsal fascia; insertion: linea alba, ilium, femoral fascia; action: constricts abdomen, arches the back.
21. **Internal oblique** – origin: lateral surface of the last 9-10 ribs, lumbodorsal fascia; insertion: linea alba, ilium, femoral fascia; action: constricts abdomen, arches the back.
22. **External oblique** – origin: lateral surface of the last 9-10 ribs, lumbodorsal fascia; insertion: linea alba, ilium, femoral fascia; action: constricts abdomen, arches the back.
23. **Triceps** – origin: proximal end of the humerus; insertion: on the olecranon surfaces of the ulna; action: extends the forelimb. The triceps are divided into three regions: the long head (towards the back of the arm), the medial head (the middle triceps), and the lateral head (towards the front of the arm).
24. **Extensor digitorum lateralis** – origin: distal end of the humerus; insertion: through ligaments in the digits; action: extension of the digits.
25. **Extensor carpi ulnaris** – origin: distal end of the humerus; insertion: through a long tendon into the fifth metacarpal; action: extends the wrist.
26. **Extensor digitorum communis** – origin: distal end of the humerus; insertion: through ligaments in the digits; action: extension of the digits.
27. **Extensor carpi radialis** – origin: distal end of the humerus; insertion: distal end of the radius; action: rotation of the front foot.
28. **Brachialis** – origin: proximal region of the humerus; insertion: distal end of the radius and ulna; action: flexes the elbow.
29. **Sternohyoideus** – origin: anterior end of the sternum; insertion: hyoid bone; action: used in swallowing, retracts and depresses the hyoid.
30. **Masseter** – origin: zygomatic arch of the skull; insertion: mandible; action: closes the mouth and elevates the jaw.

Entering the Body Cavity – (figures 11 & 12)

Materials:

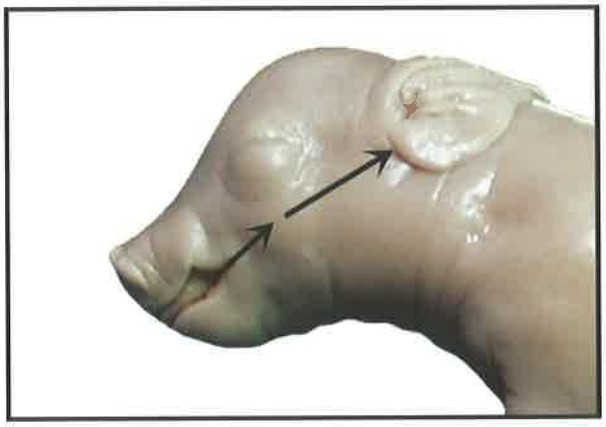
* Fetal pig	* Dissection tray	* Protective gloves	* Scalpel	* Forceps
* Blunt probe	* Sharp probe	* Scissors	* Plastic bag	* Tag

Note: When handling your fetal pig, always wear protective gloves. Make sure you have completed your external observations before proceeding.

1. Begin by entering the mouth. Use your scalpel to cut from the corner of the mouth to the ear (figure 11). You will need to cut through the cartilaginous jaw all the way to the ear.

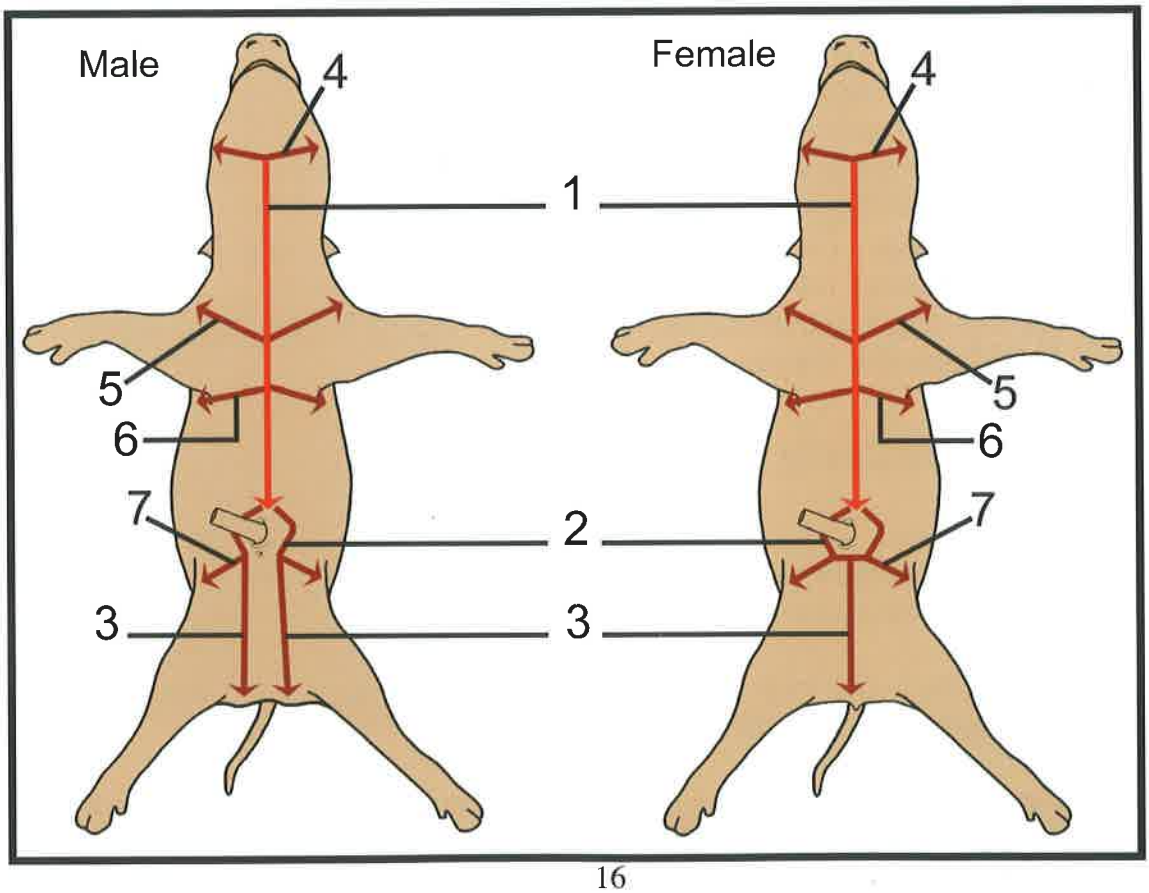
2. Make sure to cut deep enough so that you can pry the mouth open far enough to see down the throat (figure 11).

figure 11 - Entering the mouth region



3. Depending on the gender of your pig, you will make incisions according to the graphic in the figure shown below. Cuts are numbered in order.
4. When initially cutting into the body, carefully score the epidermis. Repeat scoring, not cutting too deep, until you begin to see the organs below. Try not to cut into the liver or any other organs. Initially use your scalpel, then lift up on the body wall and cut up with your scissors.
5. You will need to use your scalpel to cut through the sternum on the chest. Once again, do not cut too deep. A gentle sawing motion may be necessary. The sternum is still primarily composed of cartilage and should separate with minimal effort.
6. As you go through your dissection, try not to remove any organs until absolutely necessary. Your dissection will make more sense if you can keep it relatively intact.
7. As you open the body, you will see the **umbilical vein** holding the umbilical cord to the liver. Take a piece of string and tie it to the umbilical vein near the liver and ~0.5 cm towards the umbilical cord. With your scissors, cut the umbilical vein. You will use these strings to orient yourself while studying the circulatory system.

figure 12 - Entering the body cavity



8. Carefully use your scalpel to cut the **diaphragm** along the body wall. Try to keep it intact.
9. Now that you have the body cavity open, rinse it in a water bucket (or follow the procedures of your lab). Fetal pigs are preserved in formaldehyde or formalyn, so you need to rinse away any trace amounts. Change your gloves at least once during the dissection.
10. Pull apart the ribs and sides of the body. It may be necessary to cut the ribs with your scissors along cuts #5 and #6 (figure 12).
11. Secure your pig to your dissecting tray by either using strings tied at the wrists and ankles or by using T-pins. If using T-pins, push them through each wrist and ankle. For both techniques, you will need to secure down the body wall with T-pins. Always follow the procedures suggested by your lab.
12. Using your forceps, scissors, and scalpel, examine and remove the internal protective membranes, following the text in "The Body Cavity and its Membranes".

Note: Clean-up is part of lab! Your instructor should provide you with plastic bags and tags to store your pig. A good dissection can take some time, so it is necessary to store your pig until your next lab. Clean your dissecting tools and tray. Properly dispose of excess biological tissues and organs. Make sure to wipe down your station with paper towels and disinfectant spray. Always wash your hands after lab.

The Body Cavity and its Membranes

The body cavity, called the **coelom**, is divided into two regions: the **thoracic cavity** and the **abdominal cavity**. They are divided by the muscular **diaphragm** located just above the liver. The thoracic cavity is above the liver and the abdominal cavity is below it. As you cut into the body you will notice several membranes lining the body wall and various organs. They support the internal organs within the coelom. The body wall consists of the **integument** (skin), the **transverse abdominus muscle**, the **external** and **internal oblique muscles**, and the **parietal peritoneum**. The parietal peritoneum (pariet = "wall") is a layer of epithelial tissue that lines the body wall. The tissue covering the internal organs is the **visceral peritoneum** (visceral = "internal organs"). A double layer of peritoneum is referred to as mesentery. The protective membranes lining the lungs are called **pleura**. Like the peritoneum of the body cavity, pleura (pleura = "side") consists of the inner **visceral peritoneum** lining the lungs and the outer **parietal pleura**. The membranes covering the heart are the inner **visceral pericardium** directly surrounding the heart and the outer **parietal pericardium**.

The Head & Neck Regions – figures 13, 14, 15, & 16

Once you have properly cut the mouth open, you should see the **hard and soft palates**. The hard palate contains distinct ridges that the soft palate lacks. The hard and soft palates work together to allow for simultaneous breathing and swallowing by separating the oral cavity from the air passages. Further into the mouth, the **epiglottis** covers an opening called the **glottis** that leads to the **trachea**. The epiglottis helps direct food down the **esophagus** and air into the **trachea**. During respiration, the epiglottis moves forward to prevent the passage of food or liquid down the trachea. While eating, the epiglottis covers the trachea (figure 13).

Now take a look at the structures in the neck (figure 14). You may need to remove two strands of muscles called the sternohyoid muscles (shown in figure 10). The **larynx**, sometimes referred to as the "voice box", lies between the epiglottis and the trachea. It is composed of cartilage. Below the larynx you will see a dark brown oval structure called the **thyroid gland**. It is an endocrine gland that regulates metabolism and produces hormones for growth and development. On either side of the larynx and thyroid you will see the **thymus**, a prominent structure in fetal animals that diminishes as the animal matures. It functions in immune responses, containing lymphocytes and T-cells. The thymus is also located just above the heart (figures 15 & 16). It is a diffuse structure that lies on both sides of the trachea.

figure 13 - Breathing and swallowing

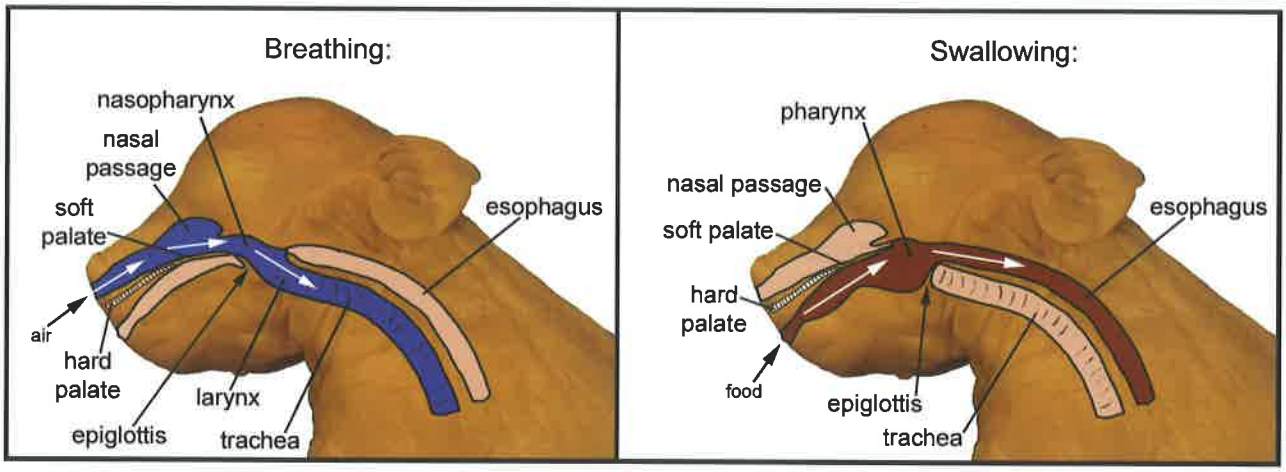


figure 14 - The oral cavity and throat

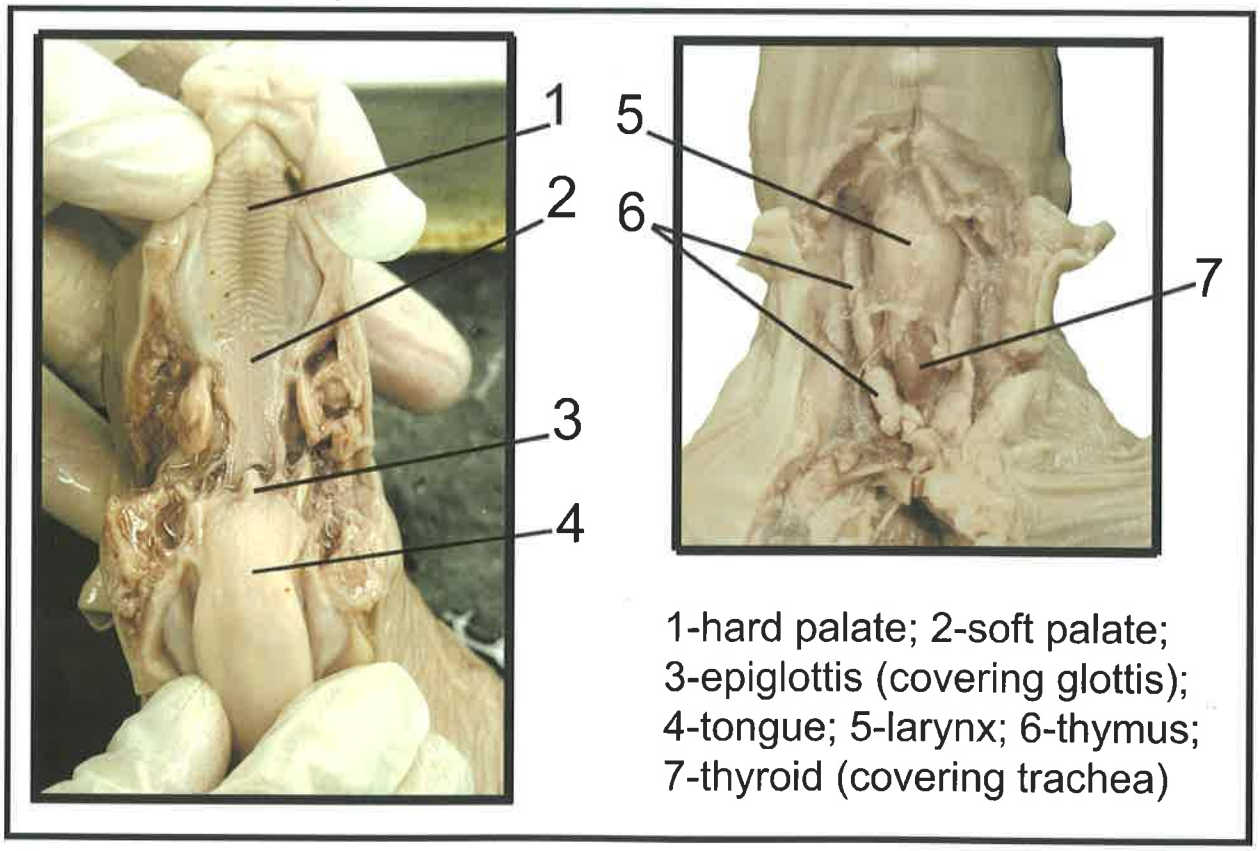
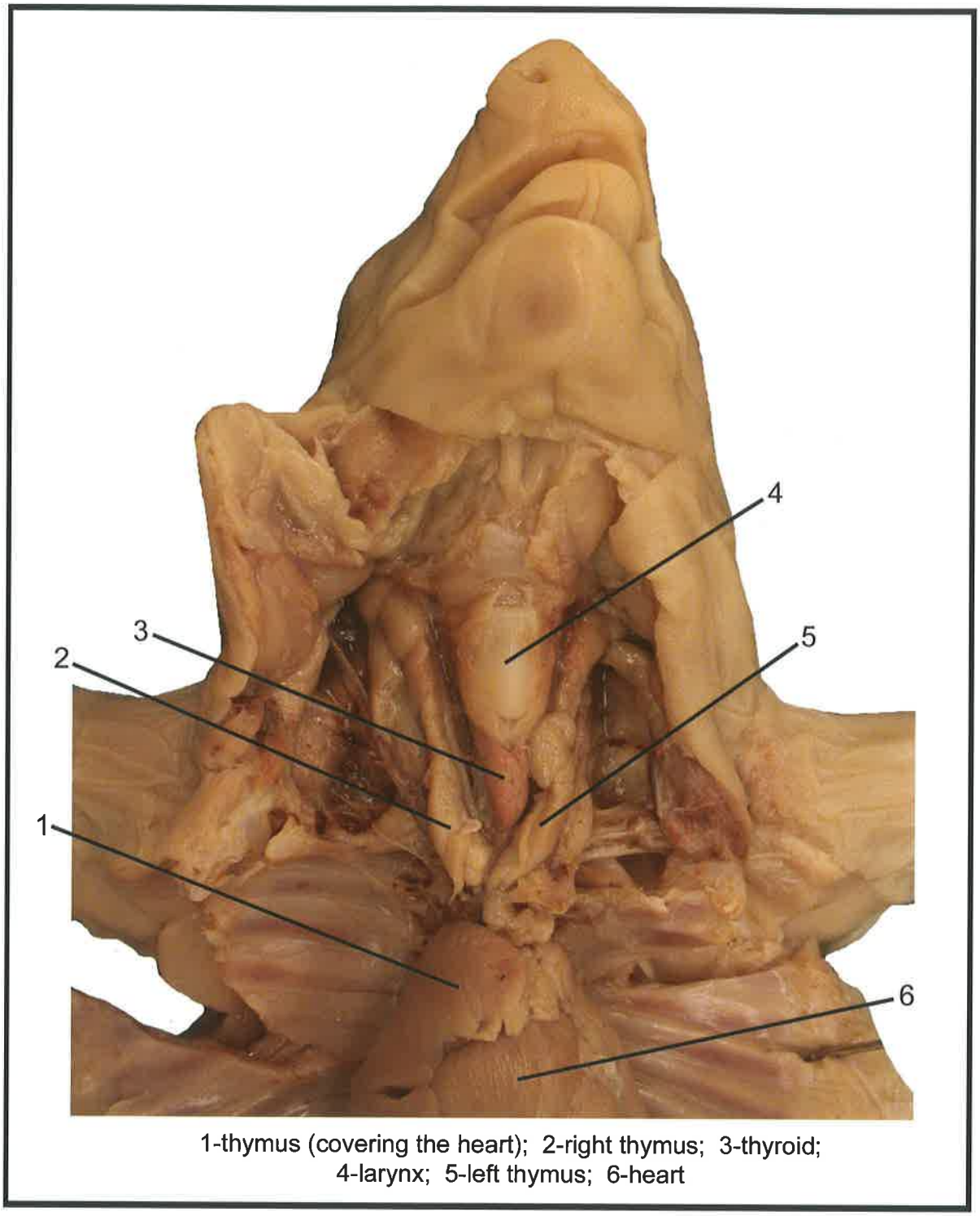


figure 15 - Close-up of the thymus



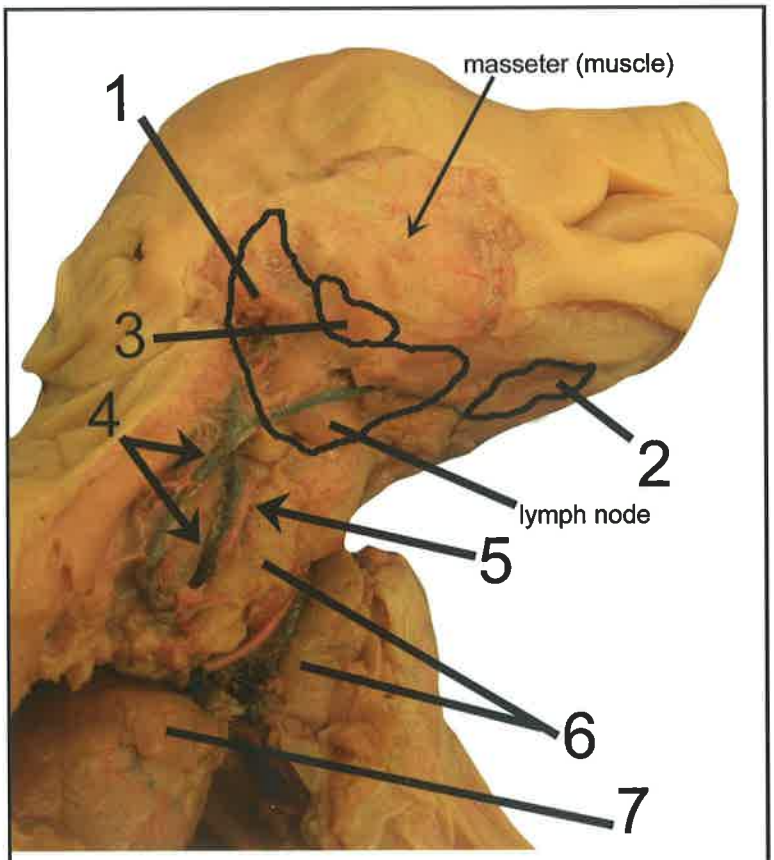
1-thymus (covering the heart); 2-right thymus; 3-thyroid;
4-larynx; 5-left thymus; 6-heart

Recall that the trachea lies ventral to the esophagus (figure 13). You will need to remove the thyroid in order to see the **trachea**, which is commonly referred to as the "windpipe" due to its respiratory function. The trachea has a ribbed appearance and is composed of cartilage. To see the **esophagus**, carefully push aside the trachea using your blunt probe. The esophagus is the link between the pharynx and the stomach. It has a shiny and muscular appearance.

The Salivary Glands - figure 16

The salivary glands are the first step in the process of the chemical digestion of food. The chewing action of the teeth, responsible for the mechanical break down, increase the surface area of the food. This allows for more efficient chemical action. The salivary glands produce an enzyme, salivary amylase, that breaks down starch. The salivary glands have a textured appearance and can be diffuse. You may also see some of the lymph nodes, which have a shiny appearance, the masseter muscle in the cheek, and some of the arteries and veins in this region. In order to see these structures, you will need to carefully remove the skin. Make an incision and pull up the skin using your forceps. Slip your scissors under the skin and cut along the cheek and neck as in figure 16.

figure 16 - The salivary glands and related structures



1-parotid gland; 2-sublingual gland; 3-submaxillary gland; 4-internal & external jugular veins 5-carotid artery; 6-thymus; 7-thymus covering the heart

Salivary glands:

1. **Parotid gland** – This salivary gland is the largest and most diffuse of the salivary glands. It is triangular in an L-shape and has a lumpy appearance. The muscles around it will appear striated and fibrous.

2. **Sublingual gland** – This long, thin salivary gland lies in the region of the mandible, under the jaw. You will need to remove some of the surface muscles to see this gland. (sub = under; lingua = tongue)

3. **Submaxillary gland** – This salivary gland sits within the angle of the parotid gland. It is also sometimes called the mandibular gland, due to its proximity to the manible. You may have difficulty differentiating the submaxillary gland from the parotid gland . (sub = under; maxilla = jaw)

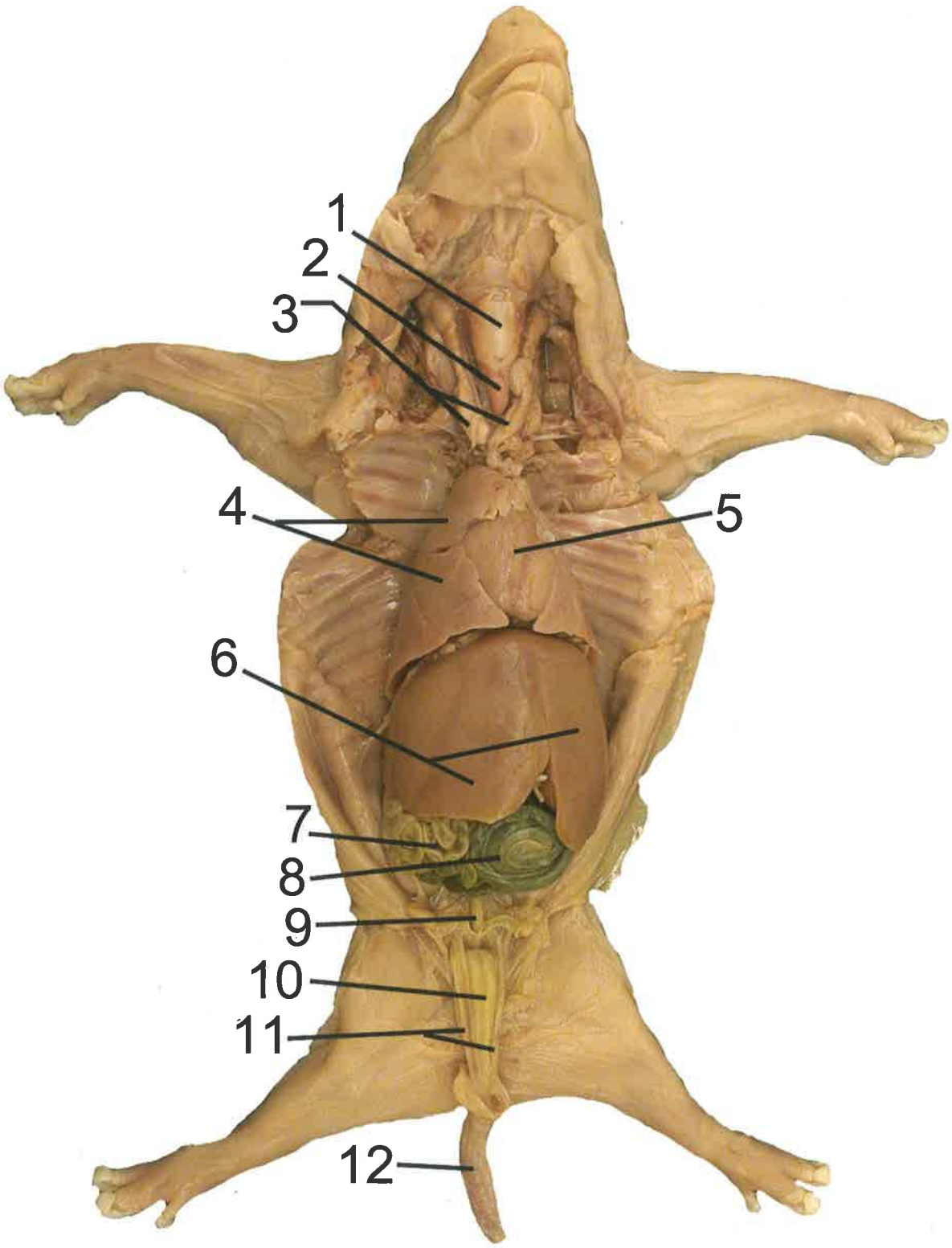
note: Some of the salivary glands in the photograph have been removed to show deeper structures. The black lines indicate their regions.

The Thoracic & Abdominal Cavities – figures 17, 18, 19, & 20

The following structures and functions correspond with figure 18 (on page 22).

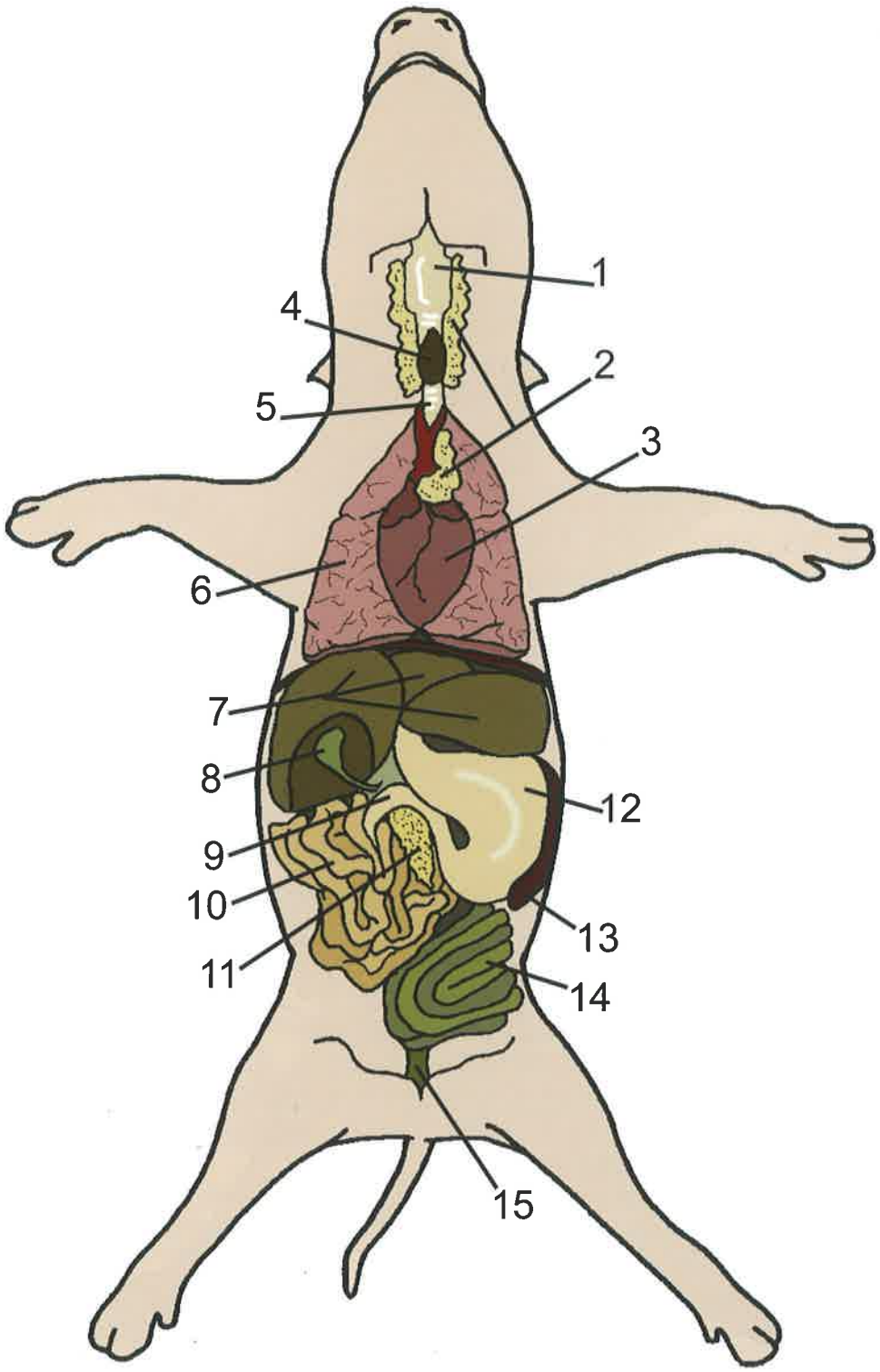
1. **Larynx** – Commonly called the "voice box" due to its function in producing vocalizations. The larynx contains the vocal cords (to see the vocal cords you may cut open the larynx with your scalpel). It is the connection between the nasopharynx and the trachea and

figure 17 - The surface structures of the body cavity



1-larynx; 2-thyroid; 3-thymus; 4-lobes of the lung;
5-heart; 6-lobes of the liver; 7-small intestine;
8-large intestine / colon; 9-rectum; 10-bladder;
11-umbilical arteries; 12-umbilical cord

figure 18 - Illustration of the internal organs of the thoracic and abdominal cavities



1-larynx; 2-thymus; 3-heart; 4-thyroid; 5-trachea; 6-right lung;
7-lobes of the liver; 8-gall bladder; 9-duodenum; 10-small intestine;
11-pancreas; 12-stomach; 13-spleen; 14-large intestine; 15-rectum

Note: The liver is reduced to show some of the other organs in this illustration.

provides a passageway for air (figure 10). The larynx is composed of four cartilages: the thyroid cartilage (along the ventral and lateral walls), the cricoid cartilage (ring-shaped on the dorsal side), the arytenoids (under the epiglottis), and the epiglottis (covers the glottis).

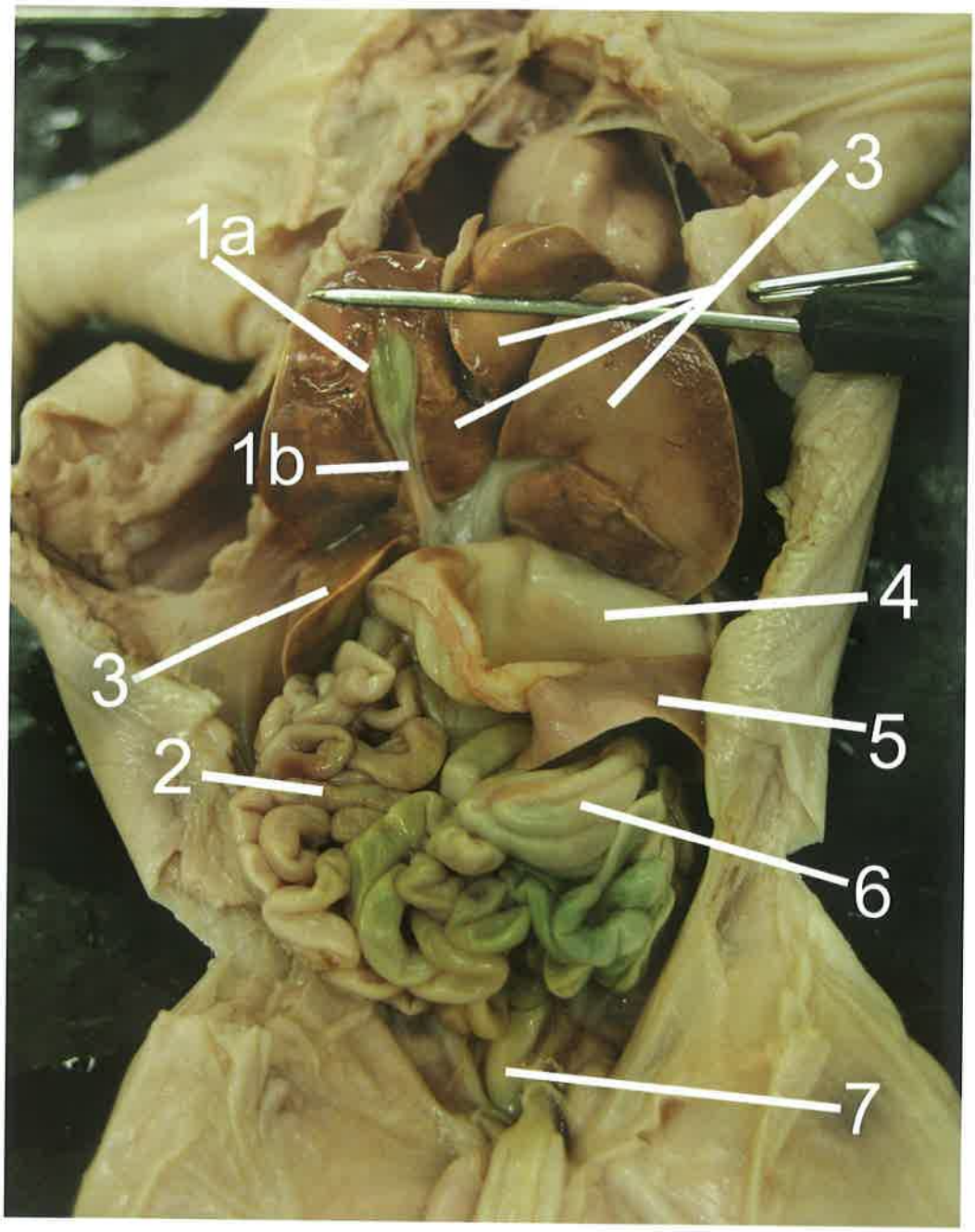
2. **Thymus** – This gland is lumpy and has a light cream color. The thymus functions as part of the lymphatic system and contains lymphocytes such as T-cells. It plays a role in immunological responses.
3. **Heart** – The four-chambered heart pumps blood throughout the body. In a non-fetal animal the heart receives highly oxygenated blood from the lungs and delivers deoxygenated blood back to the lungs once it has circulated throughout the body. Read "The Circulatory System" to learn more about how the heart works.
4. **Thyroid** – The thyroid is a dark brown or red oval structure that is located in proximity to the trachea and the lateral thymus in the throat. It is responsible for regulating metabolism and plays a role in growth and development. The thyroid is part of the endocrine system and produces the hormones thyroxin and triiodothyronine.
5. **Trachea** – The tube is the passageway for air that leads to the lungs. The trachea lies ventral to the esophagus (figure13). It is composed of cartilage and is ribbed in appearance (in contrast to the esophagus that is smooth).
6. **Lungs** – The lungs have a spongy texture and appearance. The lungs function in respiration to add oxygen and remove carbon dioxide from the body. You will notice many lobes of the lungs. How many lobes does your fetal pig have?

   Number of lobes in right lung: _____

   Number of lobes in left lung: _____
   (Humans have five lobes: three in the right lung and two in the left lung). To learn more about the lungs and related structures, read "The Respiratory System" section of this guide.
7. **Liver** – The liver is the most prominent organ of the body cavity. You will notice many lobes of the liver. Recall that the human liver has four lobes. How many lobes do you see? Use your blunt probe to carefully move aside the intestine to see all the lobes.

   Number of liver lobes: _____
   The liver has many functions. It metabolizes carbohydrates and fats. It produces bile and bile salts that emulsify fats in the duodenum. Bile is an alkaline solution of bile salts, bile pigments, cholesterol, and other components secreted by the liver. It is stored in the gallbladder and delivered to the duodenum through the bile duct. In the duodenum, bile functions in the emulsification, digestion, and absorption of fats. The liver also stores and regulates glycogen, iron, copper, and vitamins A, B12, D, E, and K. It produces plasma proteins and enzymes. The liver contains epithelial cells called hepatocytes that contain enzymes that detoxify poisons and toxins such as alcohol.
8. **Gallbladder** – The gallbladder stores and concentrates bile secreted by the liver and delivers it to the duodenum through the **common bile duct**. The gallbladder is a round "pea-green" structure on the under surface of the right lobe of the liver.
9. **Duodenum** – The duodenum is the first portion of the small intestine that continues the digestive process. It receives bile from the common bile duct and is the site of the emulsification, digestion, and absorption of fats. The duodenum also receives pancreatic enzymes such as pancreatic amylase and tyrpsin.

figure 19 - The abdominal cavity showing the gall bladder



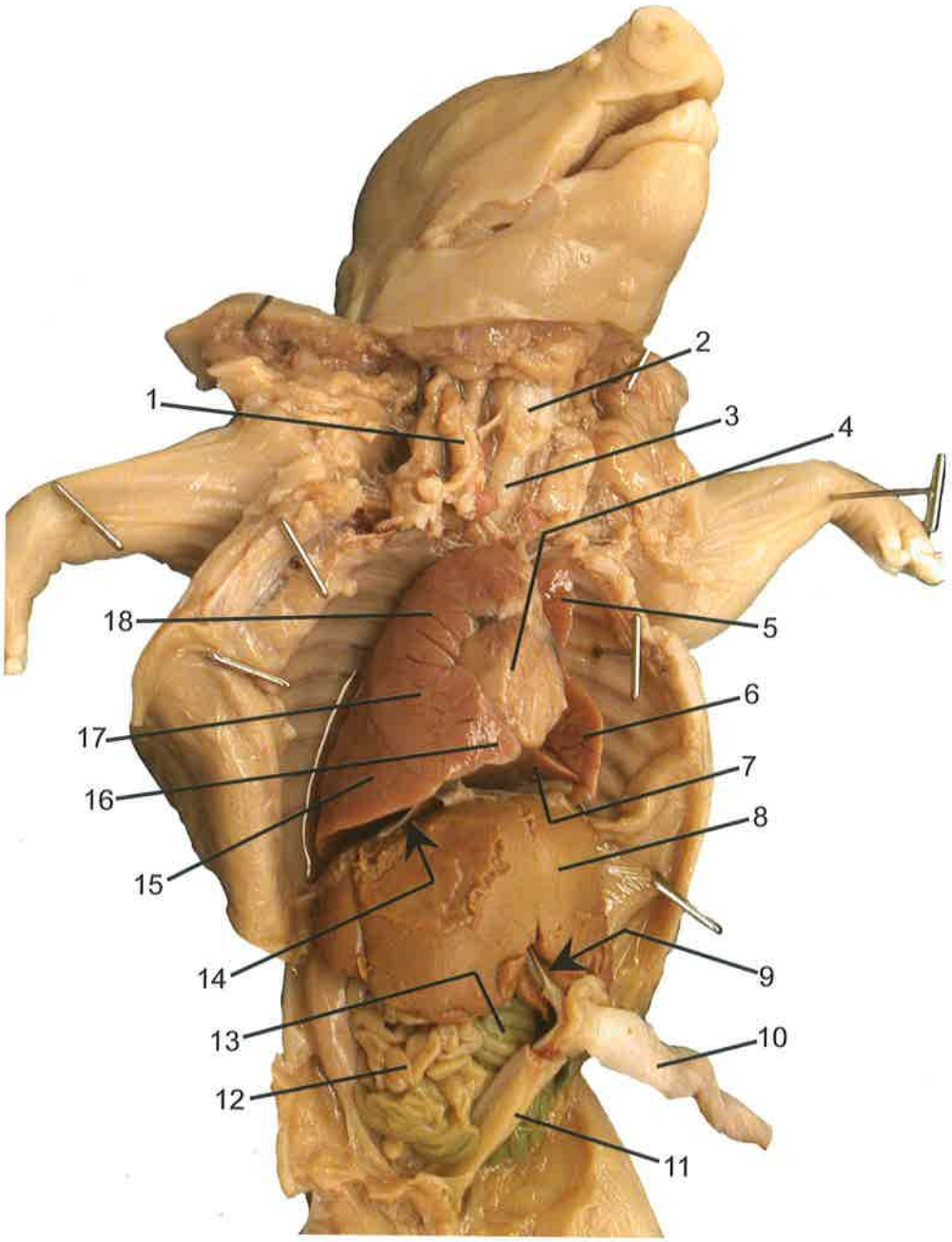
1a-gallbladder; 1b-common bile duct; 2-small intestine; 3-lobes in the liver; 4-stomach; 5-spleen; 6-colon (large intestine); 7-rectum

10. Small intestine – The small intestine consists of three parts: the **duodenum** (the first portion), the **jejunum** (the middle portion), and the **ileum** (the final portion). The jejunum makes up over half of the small intestine. In the fetal pig the jejunum is indistinguishable from the ileum. The jejunum and ileum absorb nutrients and digest chyme. Chyme is the

partially digested food that passes from the stomach to the duodenum. The **ileocecal valve** marks the end of the small intestine and the beginning of the large intestine. This valve regulates the passage of material. The length of the human small intestine is ~20 feet. In order to compare the human intestine and fetal pig intestine, cut away the small intestine and measure it. Convert your measurement into feet for a direct comparison.
Length of the small intestine: _____
In order to see the interior of the small intestine, cut open a portion of it and place it on a slide or view a prepared slide under a microscope. You will see **villi**, small finger-like projections that increase the surface area of the inner wall of the small intestine for more efficient absorption. The villi give the interior of the small intestine a velvety texture.

11. **Pancreas** – The pancreas is the major digestive gland of the digestive system in vertebrates. It is located beneath the small intestine. You may need to push aside the small intestine to see it. This structure is cream in color and lumpy in texture. The pancreas has dual functions in the exocrine and endocrine systems. The exocrine function is to secrete pancreatic (digestive) juices into the duodenum through the pancreatic duct. This duct is too small to be easily seen in the fetal pig. Pancreatic juice is a combination of water, electrolytes, and enzymes. These enzymes can break down sugars, starches, lipids, and proteins. The endocrine function is to produce insulin, glucagon, and other hormones that are important in the regulation of sugar levels and the metabolism of fats and carbohydrates.
12. **Stomach** – The stomach is divided into three regions: the **cardiac** end, the **fundus**, and the **pyloric** end. The cardiac region is attached to the esophagus in the anterior end of the stomach. The **cardiac sphincter** regulates the passage of food from the esophagus to the stomach. The fundus makes up the body of the stomach. The pyloric region leads to the duodenum and is the posterior end of the stomach. The **pyloric sphincter** regulates the passage of food from the stomach to the duodenum. If you open the stomach you will see a green substance called **meconium**. This is not chyme since a fetal animal does not eat food, but receives its nutrients from the mother through the umbilical cord. Meconium is a combination of old epithelial cells, mucus, and amniotic fluid. It is stained green from bile coming into contact with the mucus. Within the stomach you will see ridges, called **rugae**, which increase the surface area of the stomach wall.
13. **Spleen** – The spleen is a dark brown flap to the left of the stomach. It is part of the retriculoendothelial system, which is the system of macrophage cells. Macrophage cells engulf and digest foreign cells and dead cells. The spleen's cells phagocytize old red blood cells, platelets, and bacteria. It removes the iron and other useful components before breaking down blood cells. The spleen also serves an immune function by initiating responses by the T-cells and B-cells. It is the site of the largest concentration of lymphatic tissue in the body.
14. **Large intestine** – The large intestine consists of the coiled **colon** and the straight **rectum**. The entrance to the colon is marked by the **ileocecal valve**. The large intestine digests bacteria, reabsorbs water, and forms feces from chyme.
15. **Rectum** – The rectum is the straight portion of the large intestine. It is responsible for the formation and transportation of feces to the **anus**.
16. **Esophagus** (not pictured) – The esophagus delivers food from the mouth to the stomach. It lies dorsal to the trachea (figure 10). Unlike the trachea, it is smooth and muscular in appearance. The **cardiac sphincter** marks the end of the esophagus and regulates the passage of food.

figure 20 - The body cavity showing the umbilical vein intact



1-thymus; 2-larynx; 3-trachea; 4-heart; 5-left apical lobe; 6-left cardiac lobe; 7-left diaphragmatic lobe; 8-liver; 9-umbilical vein; 10-umbilical cord; 11-allantoic bladder; 12-small intestine; 13-large intestine; 14-diaphragm; 15-right diaphragmatic lobe; 16-intermediate lobe; 17-right cardiac lobe; 18-right apical lobe

The Digestive System

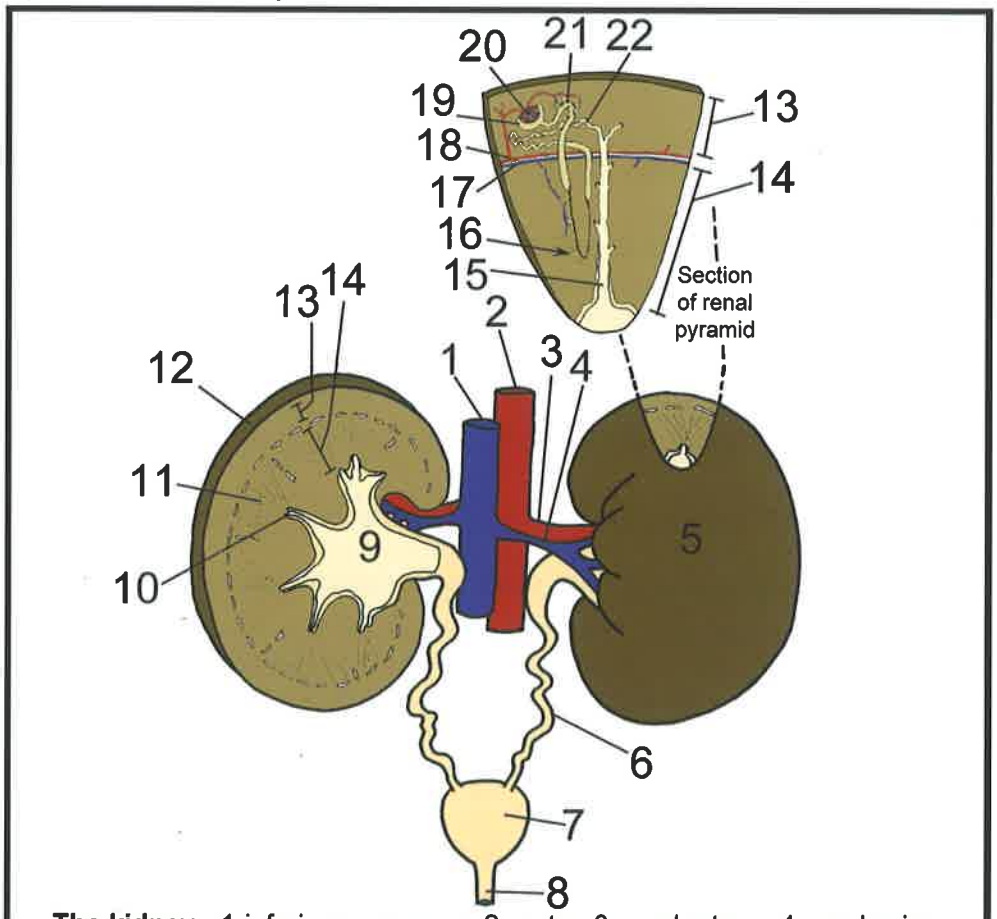
The digestive system consists of the **alimentary canal**, which runs from the mouth to the anus. It processes food into energy. Food enters the mouth and the chewing action of the teeth mechanically breaks it down. The salivary glands chemically break down the food through enzymatic action. It moves through the **pharynx**, through the **esophagus**, and into the **stomach**. Within the stomach, the food is mixed with acidic gastric juices and is further

broken down. From there it passes into the **duodenum** (the first portion of the small intestine), through the **jejunum** (the second portion of the small intestine), through the **ileum** (the final portion of the small intestine), through the **large intestine** (the coiled portion is called the colon), and out through the **rectum** and **anus**. Several digestive glands are associated with this process: the **liver**, the **gallbladder**, and the **pancreas**.

The Urogenital System - figures 21, 22, 23, 24, 25, & 26

The urogenital system consisting of the excretory system and the reproductive system, differs between the male and female. The excretory system removes liquid nitrogenous waste from the body in the form of urine. The reproductive system produces young.
Note: To see the structures of the urogenital system you will need to remove the liver, stomach, small and large intestine, and spleen. Take care not to remove any of the arteries and veins. In order to see the reproductive structures you will need to cut through the pelvic girdle and spread it apart. Take care not to cut through any of the organs. Some of the reproductive organs may be difficult to find. Have some patience and proceed through your dissection in a methodical manner.

figure 21 - The kidney and related structures



The kidney: 1-inferior vena cava; 2-aorta; 3-renal artery; 4-renal vein; 5-kidney; 6-ureter; 7-urinary bladder; 8-urethra; 9-renal pelvis; 10-calyx; 11-renal pyramid; 12-renal capsule; 13-renal cortex; 14-renal medulla; **The nephron:** 15-collecting duct; 16-loop of Henle; 17-vein; 18-artery; 19-Bowman's capsule; 20-glomerulus; 21-proximal convolluted tubule; 22-distal convoluted tubule

The Urinary System - figure 21 (on previous page)

The most noticable organs in the urogenital system are the **kidneys**, bean shaped organs in the lumbar region of the body cavity. They are covered by a membrane called **peritoneum**. With your forceps and scissors or scalpel, carefully remove the peritoneum. There may also be fat tissue covering the kidney that will need to be removed. The kidneys are pocketed between the muscle wall and the viscera. You will see the **renal artery** and **renal vein** leading to each kidney. The renal arteries and veins transport blood to and from the kidneys. The kidneys function in the excretion of hydrophilic substances such as ions, water, urea and other nitrogenous wastes. They play a role in homeostasis by regulating the volume and composition of blood. On top of the kidneys are the adrenal glands, which produce hormones that aid the body during stressful situations.

The kidneys are composed of several parts: the renal cortex, the renal medulla, and the renal pelvis. The **renal cortex** is the outer layer of the kidney and contains the cortical nephrons and renal corpuscles. The **renal medulla** contains the **renal pyramids**, triangular and striated structures that contain tubules and blood vessels, various blood vessels, and **calyces**. The calyces lead to the **renal pelvis**, the expanded portion of the **ureter**. The ureter leads to the **urinary bladder**. In the fetal pig the urinary is called the **allantoic bladder** that lies between the **umbilical arteries**. In the fetal pig the allantoic bladder leads to the allantoic duct into the umbilical cord (figure 4). In non-fetal animals, the urinary bladder leads to the **urethra**, which then leads to the external environment through the **urogenital opening**.

The Male Genital System – figures 22, 23, & 24

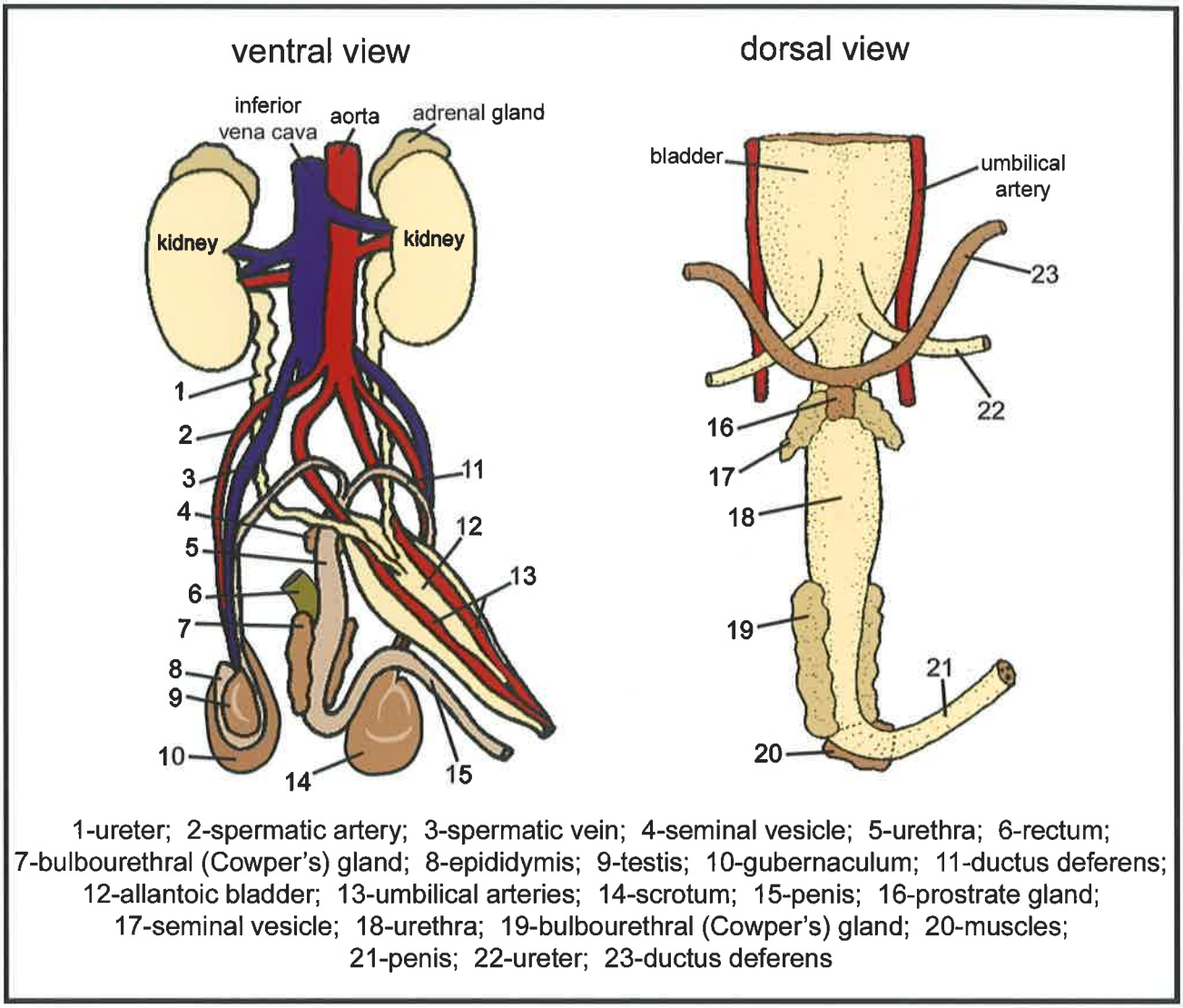
Depending on the age of your fetal pig, the testes may not be descended into the scrotal sac. If your pig is young, many reproductive organs may be underdeveloped and difficult to find. Have some patience and proceed through your dissection in a methodical manner.

Note: In order to see the reproductive structures you will need to cut through the pelvic girdle and spread it apart. Take care not to cut through any of the organs.

The following structures correspond to figure 22 and include some structures not part of the urogenital system.

1. **Ureter** – The ureter is an extension of the renal pelvis that transports urine to the urinary (or allantoic) bladder.
2. **Spermatic artery** – The spermatic artery delivers blood to the male reproductive organs.
3. **Spermatic vein** – The spermatic vein transports blood from the male reproductive organs.
4. **Seminal vesicle** – The seminal vesicles are a pair of glands that lie on the dorsal side of the urethra. They secrete and produce 60% of the volume of semen in the form of fructose, which stimulates mature sperm into activity.
5. **Urethra** – In a non-fetal animal, the urethra transports urine from the urinary bladder to the urogenital opening.
6. **Rectum** - The rectum is the straight portion of the large intestine. It is responsible for the formation and transportation of feces to the anus.
7. **Bulbourethral (Cowper's) glands** – The bulbourethral glands, sometimes called the Cowper's glands, are small oval glands that are located at the intersection between the urethra and the penis on either side of the prostate gland. They produce seminal fluids that are highly viscous and alkaline. The seminal fluid provides a swimming medium for sperm. It also functions to protect the sperm by neutralizing the acids in the vagina.

figure 22 - The male urogenital system



1-ureter; 2-spermatic artery; 3-spermatic vein; 4-seminal vesicle; 5-urethra; 6-rectum; 7-bulbourethral (Cowper's) gland; 8-epididymis; 9-testis; 10-gubernaculum; 11-ductus deferens; 12-allantoic bladder; 13-umbilical arteries; 14-scrotum; 15-penis; 16-prostrate gland; 17-seminal vesicle; 18-urethra; 19-bulbourethral (Cowper's) gland; 20-muscles; 21-penis; 22-ureter; 23-ductus deferens

8. Epididymis – The epididymis coils around the testes and functions to store sperm and allow it to mature.

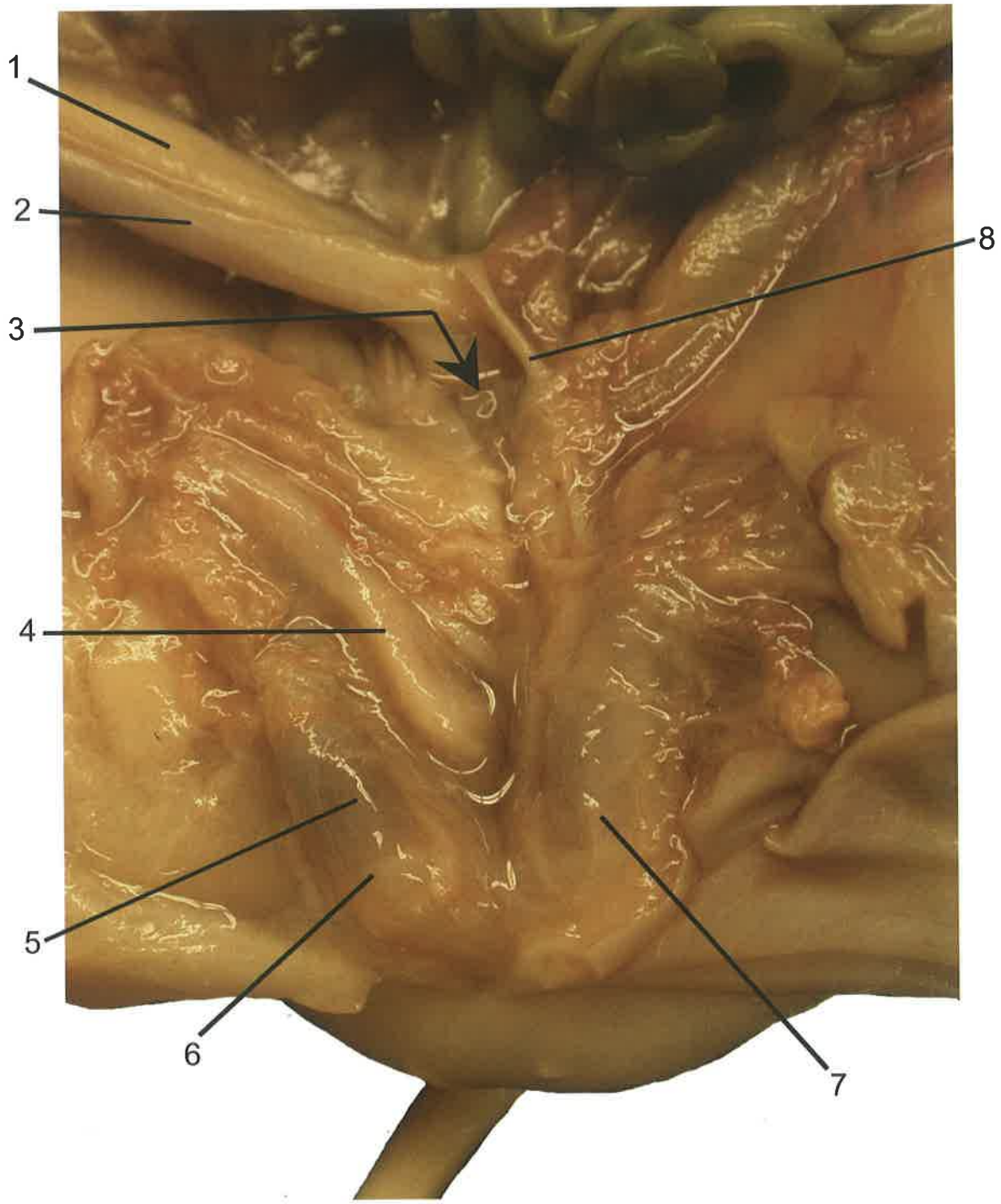
9. Testis – In a young pig, the testes can be mistaken for the ovaries of the female due to their bean shape and location high in the abdominal cavity. As the fetal pig matures, the testes descend into the scrotal sacs. In older fetal pigs, the scrotal sac must be removed to view the testis. The testis is the site of spermatogenesis and production of the hormone testosterone.

10. Gubernaculum – The gubernaculum is a fibrous cord that attaches the testis to the epididymis.

11. Ductus deferens – The ductus deferens is sometimes called the vas deferens. This tube transports sperm from the epididymis to the urethra.

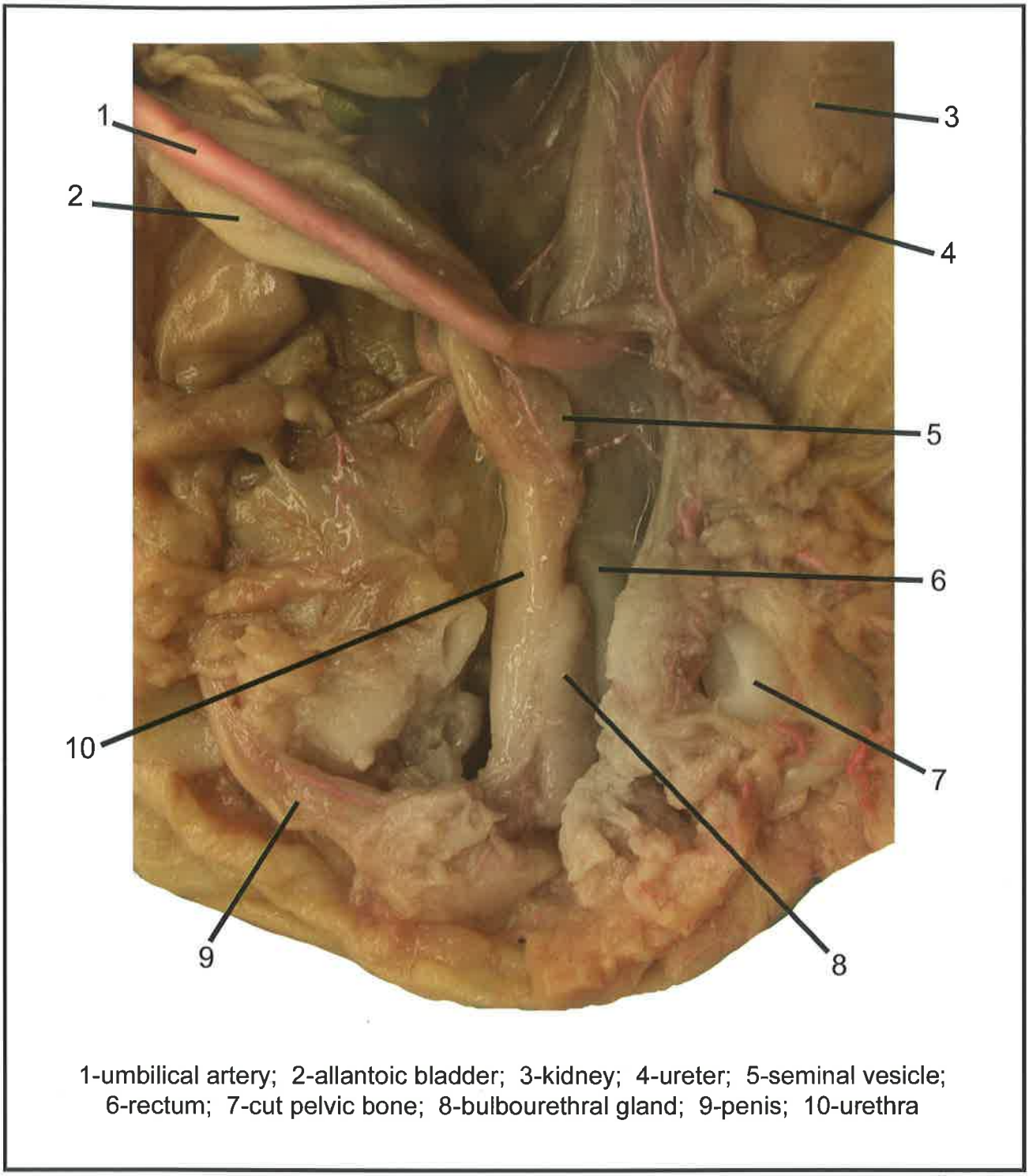
12. Allantoic bladder – In fetal mammals the urinary bladder is called the allantoic bladder. Waste is transferred from the fetus to the mother via the allantoic duct through the umbilical cord (cross-section shown in figure 6 on page 9).

figure 23 - The male urogenital system (shallow view)



1-allantoic bladder; 2-umbilical artery; 3-down to the urethra; 4-penis;
5-testis (descended inside the scrotum); 6-right scrotum;
7-left scrotum; 8-inguinal canal

figure 24 - The male urogenital system (deeper view)



1-umbilical artery; 2-allantoic bladder; 3-kidney; 4-ureter; 5-seminal vesicle; 6-rectum; 7-cut pelvic bone; 8-bulbourethral gland; 9-penis; 10-urethra

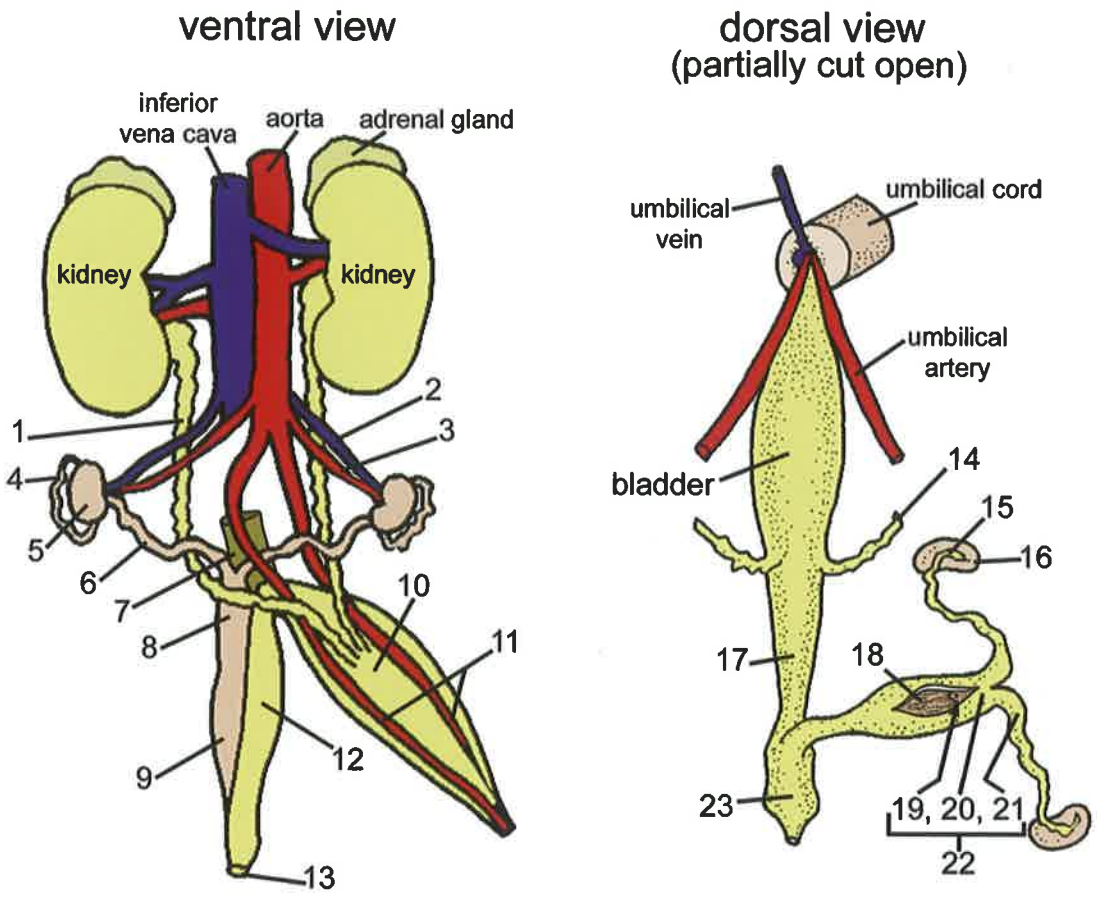
13. **Umbilical arteries** – The umbilical arteries deliver partially oxygenated blood from the fetus to the mother. You will learn more about fetal circulation in "The Circulatory System" section of this guide.
14. **Scrotum** – The scrotum is also referred to as the scrotal sac. This sac houses the testis, epididymis, and the gubernaculum. As the fetal pig matures, these structures descend into the scrotum along the **inguinal canal**. In the adult animal, the scrotum is outside the body to maintain a temperature ~3° below the body temperature. Sperm survival depends on this lower temperature.
15. **Penis** – The penis extends from the urethra. In adult animals, it is the passageway for both sperm and urine to the external environment.
16. **Prostrate gland** – The prostrate gland is a small, hard structure at the junction between the bladder and the urethra. It produces seminal secretions that provide 33% of the volume of semen. This fluid contributes to sperm motility and helps protect the sperm from the acidic environment of the vagina in the female.

The Female Genital System – figures 25 & 26

Note: In order to see the reproductive structures you will need to cut through the pelvic girdle and spread it apart. Take care not to cut through any of the organs.
The following structures correspond to figure 25 and include some structures not part of the urogenital system.

1. **Ureter** – The ureter is an extension of the renal pelvis that transports urine to the urinary (or allantoic) bladder.
2. **Ovarian artery** – The ovarian artery delivers blood to the female reproductive organs.
3. **Ovarian vein** – The ovarian vein transports blood from the female reproductive organs.
4. **Oviduct** – The oviduct is also called the fallopian tube. It transports eggs from the ovary to the uterine horn. This is also the site of fertilization.
5. **Ovary** - The ovary is the site of oogenesis and production of the hormones progesterone and estrogen.
6. **Uterine horn** – The arms of the "Y" that connect the uterus with the oviducts. It is in the uterine horn that the fetus develops.
7. **Rectum** – The rectum is the straight portion of the large intestine. It is responsible for the formation and transportation of feces to the anus.
8. **Uterus** – The uterus is the site of menstruation in mature animals. It is where the fertilized eggs implant and grow from the embryo stage to the fetal stage of development. In a pregnant female the uterus is often called a womb.
   The uterus is composed of three parts: the **uterine horn**, the **uterine body**, and the **cervix**, a small constriction between the uterus and the vagina (see #19, 20, & 21 in figure 25).
9. **Vagina** – The vagina receives the penis during copulation.
10. **Allantoic bladder** – In fetal mammals the urinary bladder is called the allantoic bladder. Waste is transferred from the fetus to the mother through the allantoic duct through the umbilical cord (figure 6).

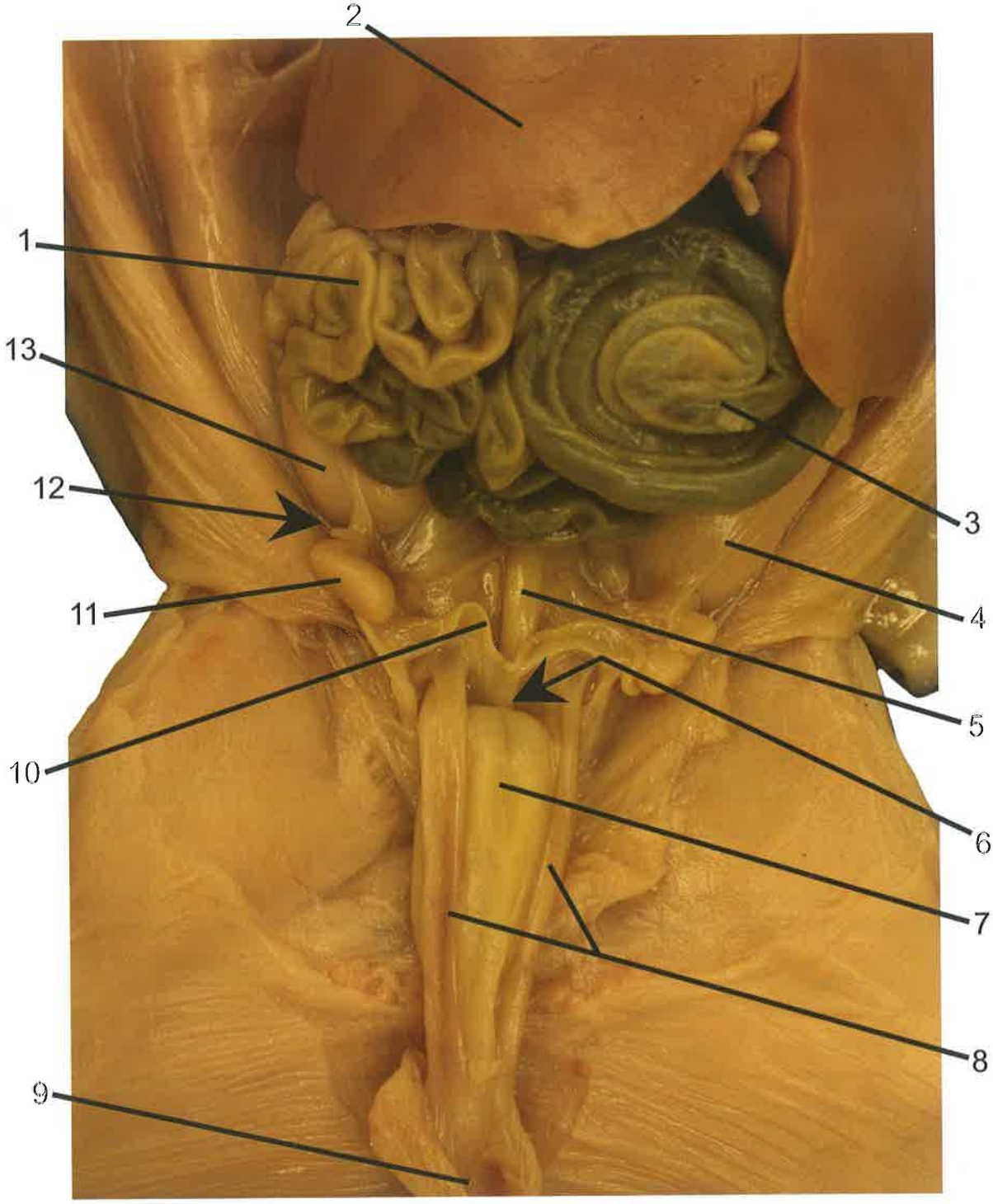
figure 25 - The female urogenital system



1-ureter; 2-ovarian vein; 3-ovarian artery; 4-oviduct; 5-ovary; 6-uterine horn; 7-rectum; 8-uterus; 9-vagina; 10-allantioc bladder; 11-umbilical arteries; 12-urethra; 13-urogenital opening (leads to the external urogenital papilla); 14-ureter; 15-oviduct; 16-ovary; 17-urethra; 18-vagina (interior); 19-cervix; 20-uterine body; 21-uterine horn; 22-uterus; 23-urogenital sinus

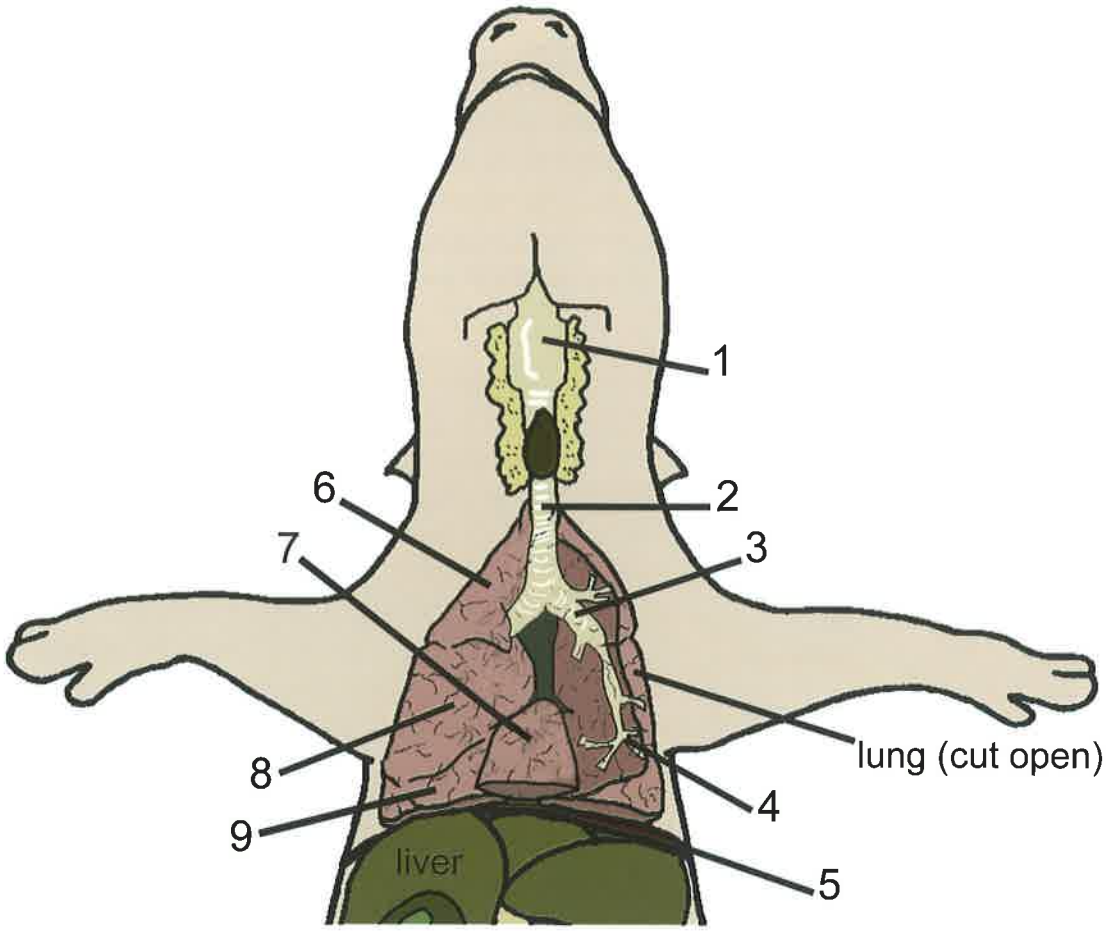
11. **Umbilical arteries** – The umbilical arteries deliver partially oxygenated blood from the fetus to the mother. You will learn more about fetal circulation in "The Circulatory System" section of this guide.
12. **Urethra** – In a non-fetal animal, the urethra transports urine from the urinary bladder to the urogenital opening.
13. **Urogenital opening** – The urogenital opening connects the urethra to external genital papilla.

figure 26 - The female urogenital system



1-small intestine; 2-liver; 3-large intestine; 4-left kidney; 5-rectum; 6-down to the body of the uterus; 7-allantoic bladder; 8-umbilical arteries; 9-umbilical cord; 10-uterine horn; 11-ovary; 12-oviduct; 13-right kidney

figure 27 - The respiratory system



1-larynx; 2-trachea; 3-bronchus; 4-bronchiole; 5-diaphragm; 6-right apical lobe; 7-intermediate lobe; 8-right cardiac lobe; 9-right diaphragmatic lobe

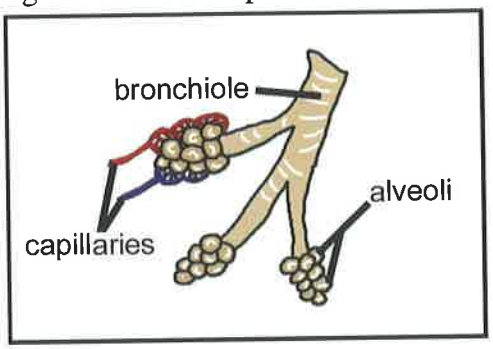
The Respiratory System – figures 27 & 28

The respiratory system is responsible for the inspiration of air and gas exchange in the body. Air is inhaled through either the **mouth** or the **external nares** into the **nasopharynx**. It passes through the **larynx**, passes through the **trachea** and into the **lungs**.

The lungs are the major organ of the respiratory system in air-breathing vertebrates. They are enclosed in the **pleural cavity** by the **visceral** and **parietal peritoneum** and consist of several lobes. In humans there are three lobes in the right lung and two in the left lung. Your fetal pig has seven lobes. The right lung contains the **right apical lobe**, the **right cardiac lobe**, the **right diaphragmatic lobe**, and the **intermediate lobe**. The left lung contains the **left apical lobe** (sometimes called the cranial lobe), the **left cardiac lobe**, and the **left diaphragmatic lobe**. The apical lobe lies cranial to the middle cardiac lobe. The diaphragmatic lobe is most caudal, lying just above the diaphragm. The intermediate lobe lies in between the right and left cardiac lobes, but is still considered part of the right lung system.

Once in the lungs, the air goes through a series of channels that progressively get smaller. The trachea divides into the **bronchii**, which then divide into smaller **bronchioles**. The bronchioles empty into small air cells called **alveoli**. They converge with a network of **capillaries**

figure 28 - Close-up of a bronchiole

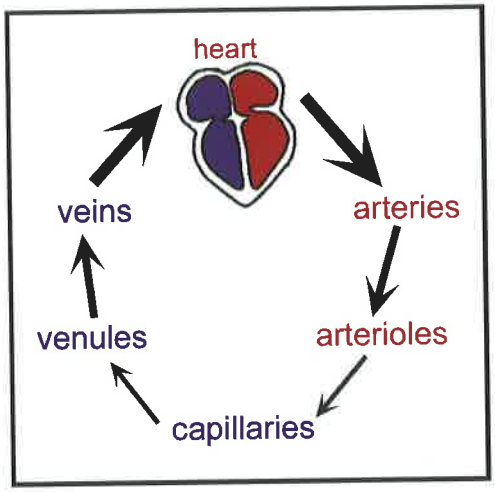


that deliver oxygen via the blood to the rest of the circulatory system and return waste carbon dioxide to be exhaled.

In mammals, the process of breathing is done through **negative pressure breathing**. Air is pulled down into the lungs through the contraction of the **diaphragm** and results in inhalation. When the diaphragm relaxes and moves up, the lungs are restored to their smaller volume, which results in exhalation.

The Circulatory System – figures 29 - 36

figure 29 - General circulatory plan



When studying the circulatory system, it is better to work with injected fetal pigs. Arteries are injected with red latex, and veins are injected with blue latex. The heart is located in the pericardial cavity and is covered by the parietal and visceral peritoneum. You will need to carefully remove the peritoneum by pulling it up with your forceps and cutting it away with your scalpel. When viewing the circulatory system, remove the major organs in the abdominal cavity. Study the venous system first, since many veins lie on top of the arteries. You may not be able to identify all of the arteries and veins shown in the illustrations. However, you should be able to identify the most prominent structures. Use the illustrations and photographs to assist you.

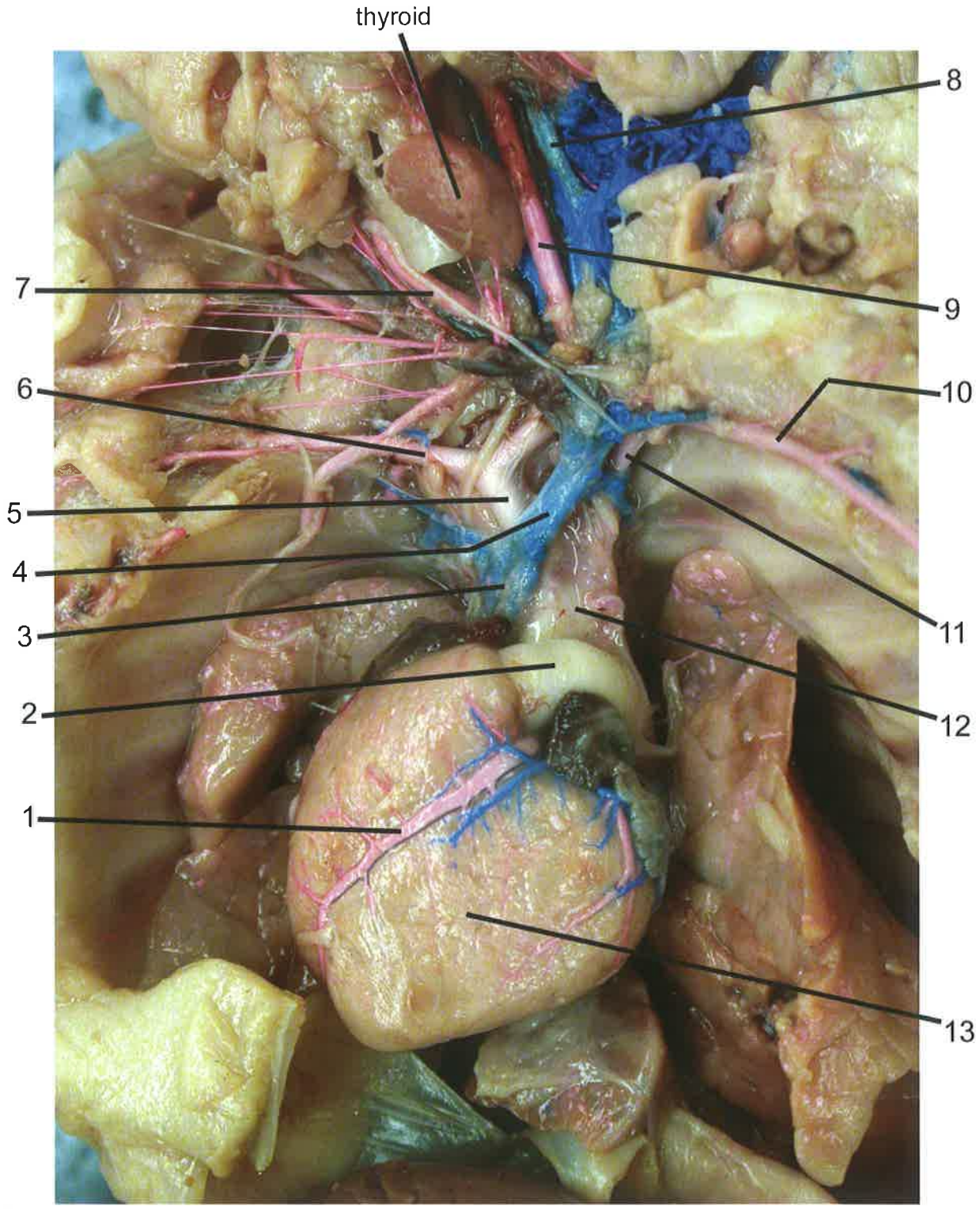
One of the features of mammals is the four-chambered heart. Through the periodic contractions of the chambers blood is pumped out through the arteries into the body. Having four chambers allows for **double circulation** of blood through two separate circuits, the **systemic circuit** and the **pulmonary circuit**. The systemic circuit runs throughout the body. The left atrium and left ventricle are responsible for the flow of blood in the systemic circuit. The pulmonary circuit runs through the lungs to obtain oxygen and deposit the waste gas, carbon dioxide. The right atrium and right ventricle are responsible for the flow of blood in the pulmonary circuit. This is in contrast to other vertebrates such as the fish that only has a single circuit circulatory system.

The heart of a fetal pig is very similar to the human heart. One exception is that the fetal pig heart has the **azygous (hemiazygous) vein** that human hearts lack. This vein drains the **intercostals** into the coronary sinus (figures 24 & 27). There are other differences, but for purposes of comparative anatomy, the fetal pig makes a good model animal to study.

General Plan of Circulation – Adult Mammals – figure 29

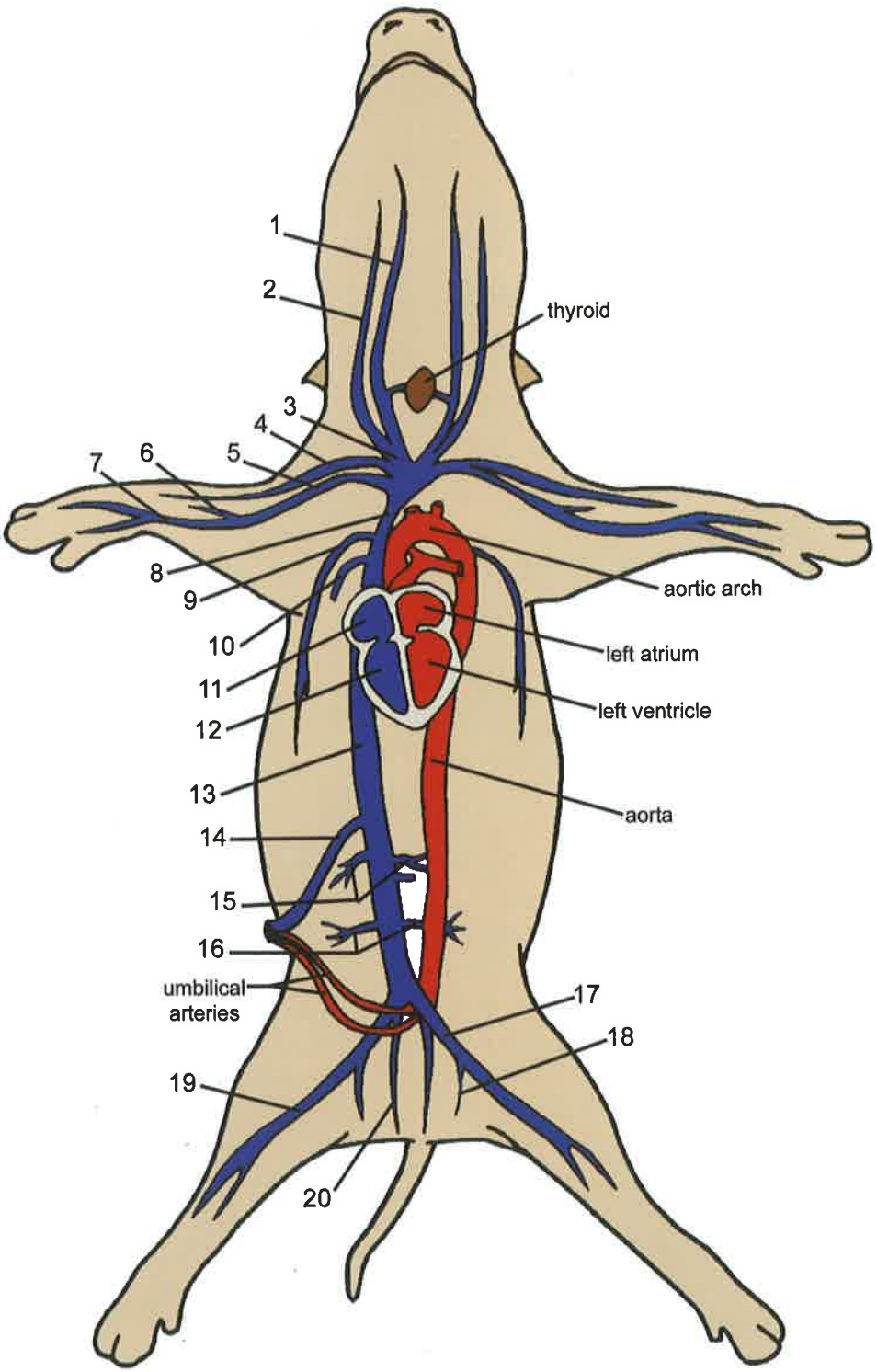
Blood flows through a series of vessels to transport oxygen and carbon dioxide throughout the body. In general, arteries and arterioles are thick-walled vessels that carry oxygen-rich blood away from the heart. Veins and venules are thin-walled vessels that carry oxygen-poor blood back towards the heart. The capillaries are where the gases are exchanged with the cells of the body.

figure 30 - Major arteries and veins in the thoracic cavity



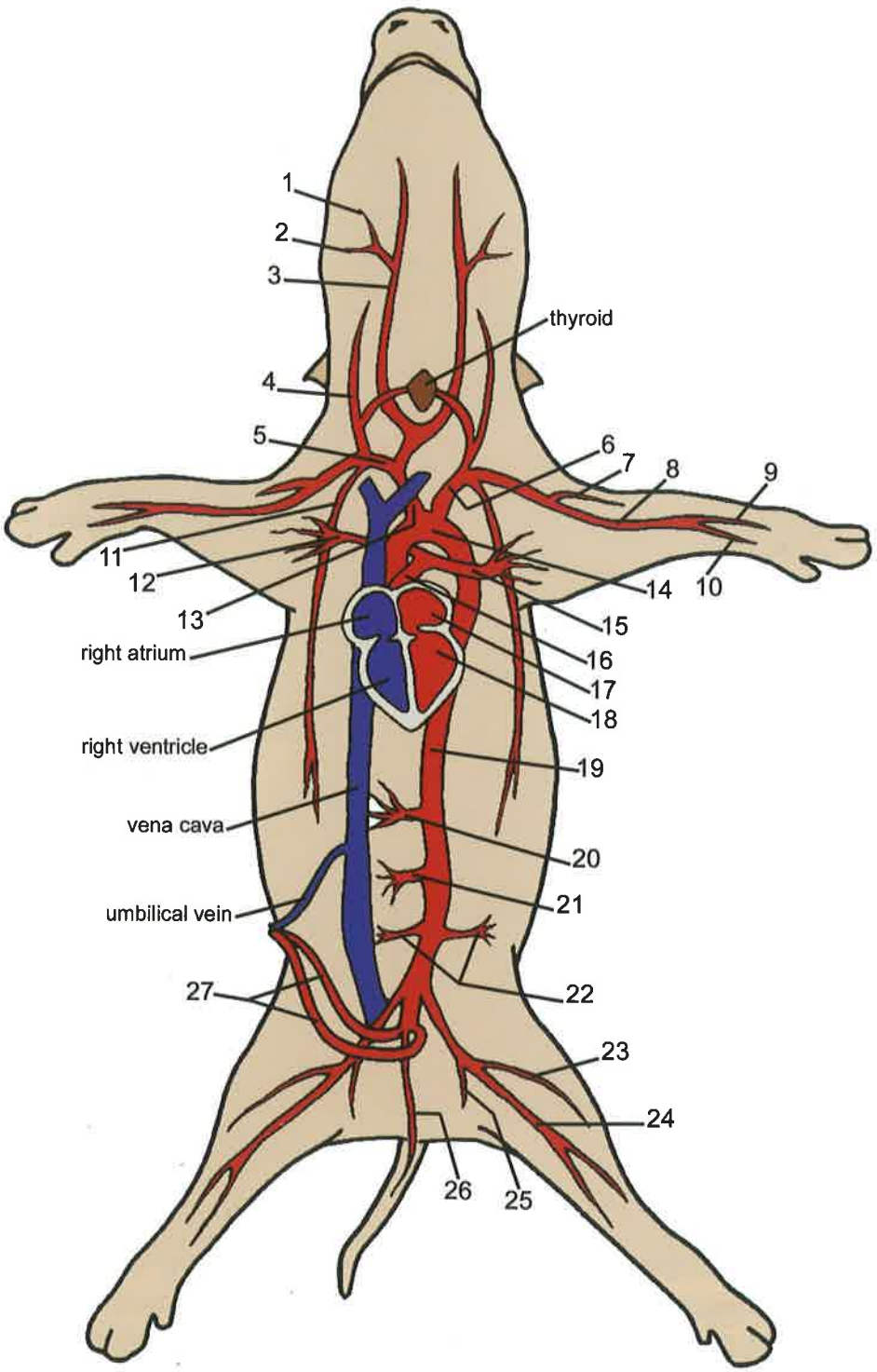
1-coronary artery; 2-pulmonary trunk; 3-superior vena cava;
4-right brachiocephalic vein; 5-brachiocephalic trunk; 6-right subclavian artery;
7-right common carotid artery; 8-jugular vein; 9-left common carotid artery;
10-brachial artery; 11-left subclavian artery; 12-aortic arch; 13-heart

figure 31 - Major veins



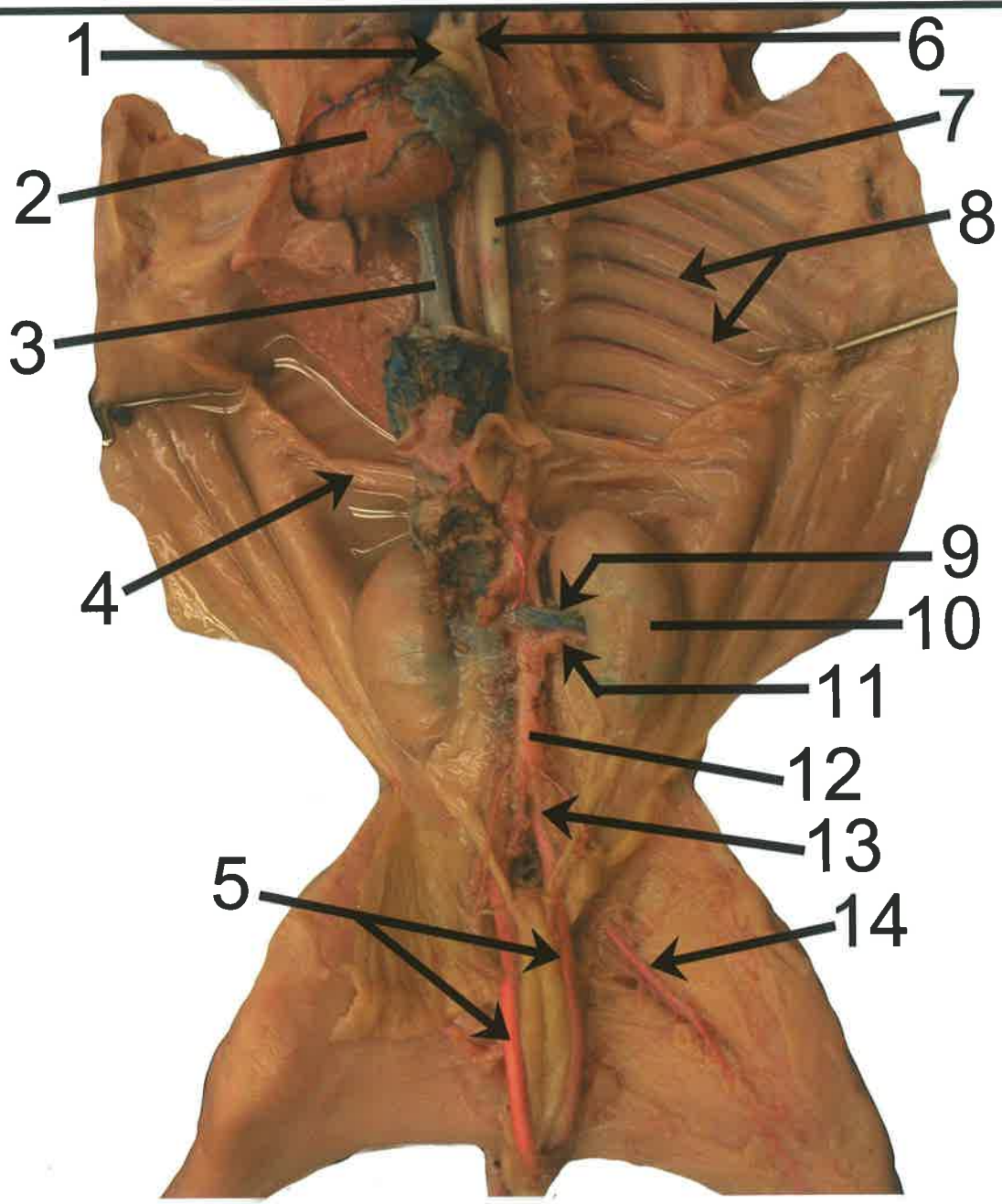
1-internal jugular; 2-external jugular; 3-right brachiocephalic; 4-cephalic; 5-right subclavian; 6-subscapular; 7-brachial; 8-superior vena cava; 9-sternal; 10-costocervical; 11-right atrium; 12-right ventricle; 13-inferior vena cava; 14-umbilical vein; 15-hepatic (to liver); 16-renal veins (to kidneys); 17-external iliac; 18-internal iliac; 19-femoral; 20-caudal

figure 32 - Major arteries



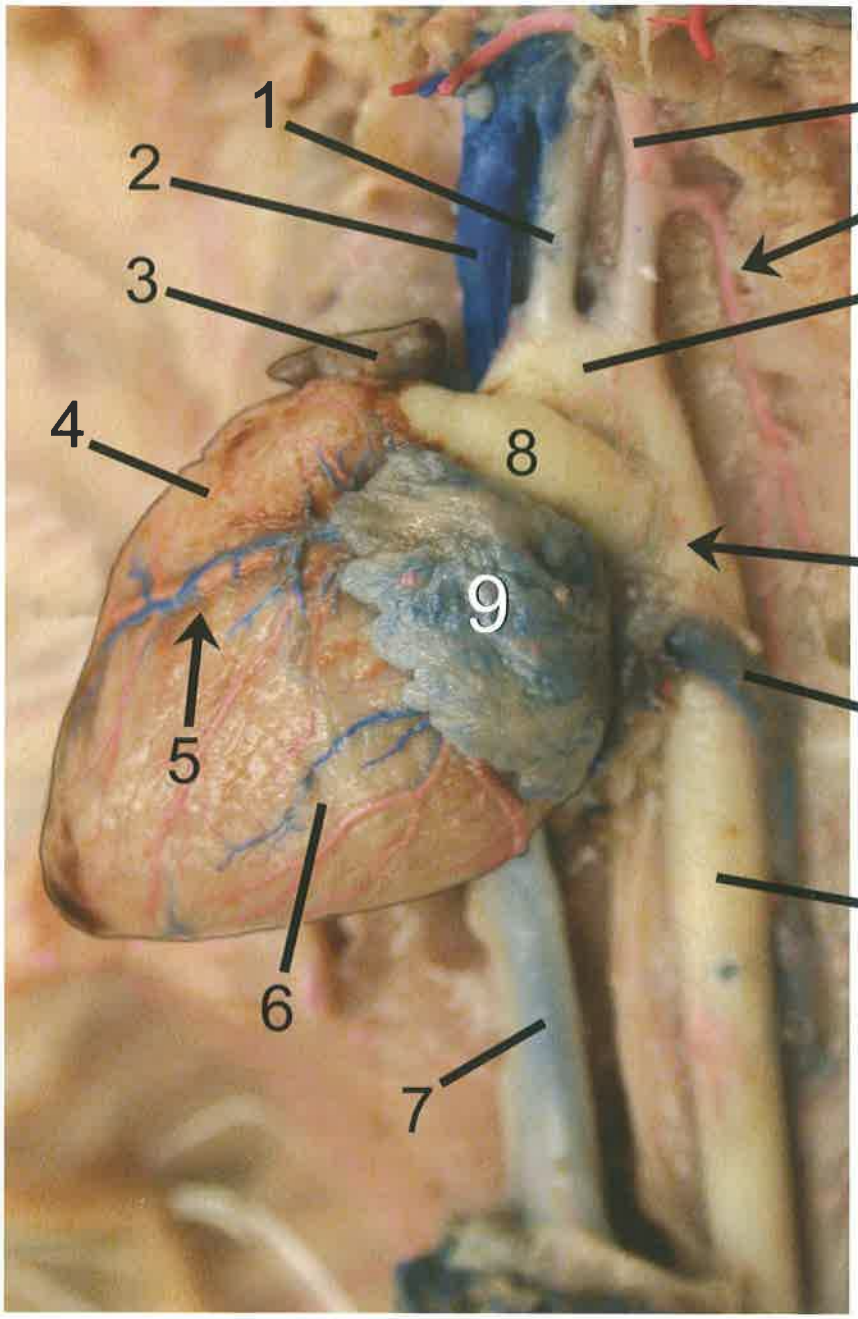
1-internal carotid; 2-occipital; 3-right common carotid; 4-thyrocervical; 5-right subclavian; 6-left subclavian; 7-subscapular; 8-brachial; 9-radial; 10-ulnar; 11-sternal; 12-right pulmonary (to right lung); 13-brachiocephalic trunk; 14-aortic arch; 15-left pulmonary (to left lung); 16-pulmonary trunk; 17-left atrium; 18-left ventricle; 19-aorta; 20-coeliac (to gastrohepatic that leads to stomach & liver); 21-anterior mesenteric (to intestine); 22-renal arteries (to kidneys); 23-saphenous; 24-femoral; 25-deep femoral; 26-caudal; 27-umbilical arteries

figure 33 - Major arteries and veins in the abdomen (liver and digestive organs removed)



1-pulmonary trunk; 2-heart; 3-inferior vena cava; 4-diaphragm; 5-umbilical arteries; 6-aortic arch; 7-descending aorta; 8-intercostal arteries and veins; 9-renal vein; 10-kidney; 11-renal artery; 12-descending aorta (continued); 13-external iliac artery; 14-femoral artery

figure 34 - Close-up of the heart



1-brachiocephalic trunk; 2-superior vena cava;
3-right atrium; 4-right ventricle; 5-coronary artery & vein;
6-left ventricle; 7-inferior vena cava; 8-pulmonary trunk;
9-left atrium; 10-left subclavian artery; 11-sternal artery;
12-aortic arch; 13-ductus arteriosus (fetal shortcut);
14-azygous vein; 15-descending aorta

Tips on Finding Arteries & Veins

Sometimes it can be difficult to find all of the arteries and veins shown in figures 31 and 32. During this phase of your dissection, use your blunt probe to follow the network of arteries and veins. The more carefully you remove the thin tissue covering these vessels the more you will be able to see. Trace the vessel from a known point to identify the smaller arteries and veins. As mentioned before, it is better to begin with the venous system and then move on to the arterial system. Some of the major veins you should be able to find without difficulty are: the internal and external jugulars, the subclavian veins, the superior vena cava, the inferior vena cava, the renal veins, the external iliac veins, and the femoral veins. Some of the major arteries you should be able to find are: the common carotids, the subclavian arteries, the right pulmonary artery, the brachiocephalic trunk, the pulmonary trunk, the aortic arch, the aorta, the renal arteries, and the femoral arteries. Remember that arteries carry blood away from the heart and veins carry it towards the heart. This has no relevance to the level of oxygenation of the blood.

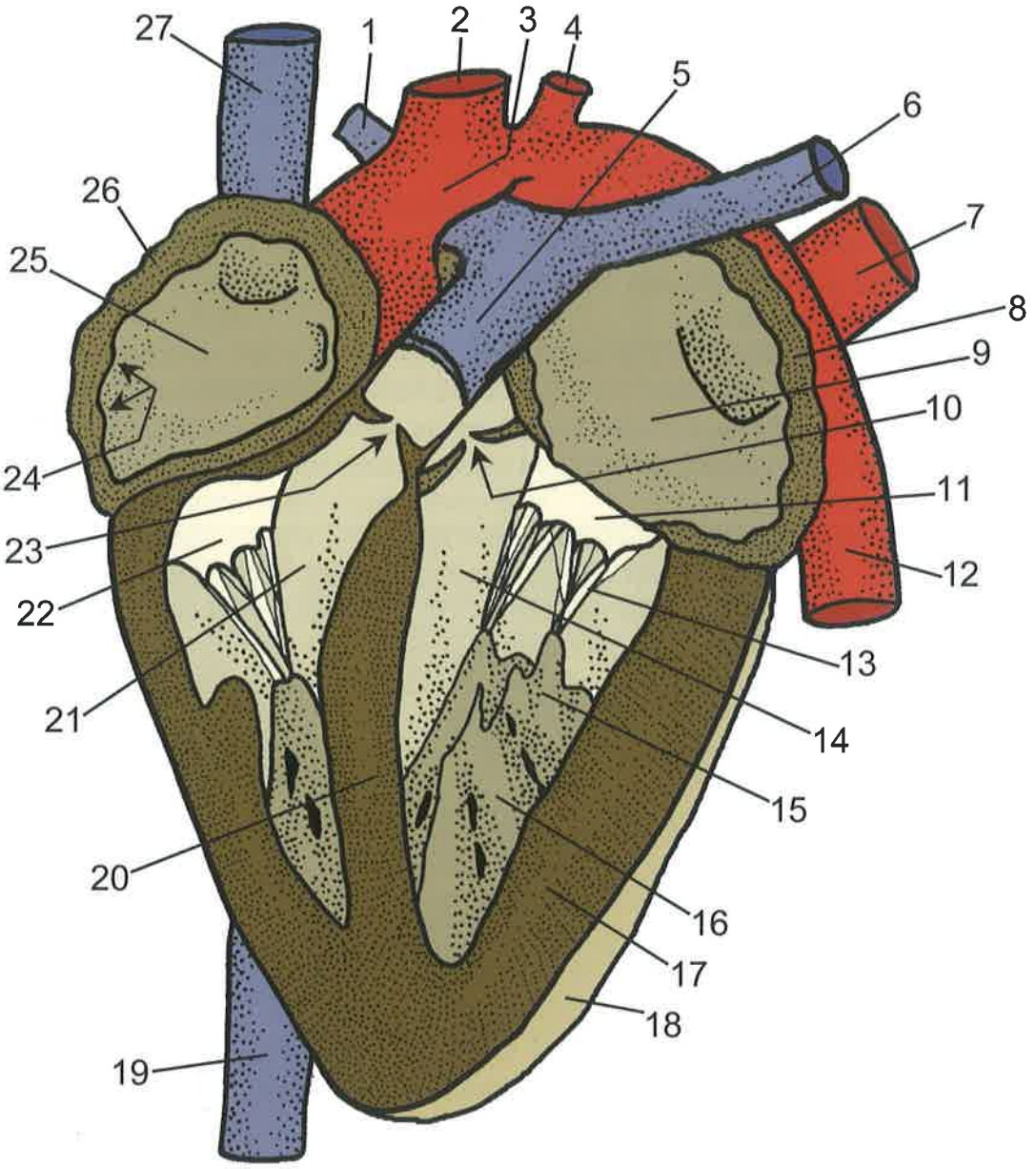
Structures of the Heart

In order to understand circulation, it is necessary to first learn about the heart. The fetal pig's heart will demonstrate some structures, but a larger heart is used for smaller structures such as the various valves inside of the heart. Many labs study a sheep or cow heart. There are detailed guides specifically written for the larger mammalian heart. Both hearts and accompanying guides are available from the Bio Corporation. This guide shows the basic anatomy of a sheep's heart in figure 35. Close-up photographs show the features of the fetal pig's heart in figures 30 & 34.

The following list of structures and functions correspond with figure 35

1. **Right pulmonary artery** – The right pulmonary artery carries deoxygenated blood from the pulmonary trunk to the right lung.
2. **Brachiocephalic trunk** – The brachiocephalic trunk extends off of the aortic arch to carry oxygenated blood to the upper extremities of the body.
3. **Aortic arch** – The aortic arch delivers oxygenated blood to the arteries of the upper body through the brachiocephalic trunk and the left subclavian artery (in the sheep) and to the arteries of the lower body through the descending aorta. In humans, the aortic arch has three (rather than two) arteries extending from it: the brachiocephalic artery, the left common carotid artery, and the left subclavian artery.
4. **Left subclavian artery** – The left subclavian artery extends from the aortic arch to deliver oxygenated blood to the vessels of the upper extremities.
5. **Pulmonary trunk** – The pulmonary trunk carries deoxygenated blood from the right ventricle to the left and right pulmonary arteries, which lead to the lungs.
6. **Left pulmonary artery** – The left pulmonary artery carries deoxygenated blood from the pulmonary trunk to the left lung.
7. **Pulmonary vein** – The pulmonary vein transports highly oxygenated blood from the capillaries of the lungs into the left atrium. The blood subsequently moves through the bicuspid valve into the left ventricle, out through the semilunar valves and to the rest of the body via the aorta.

figure 35 - Structures of the mammalian heart

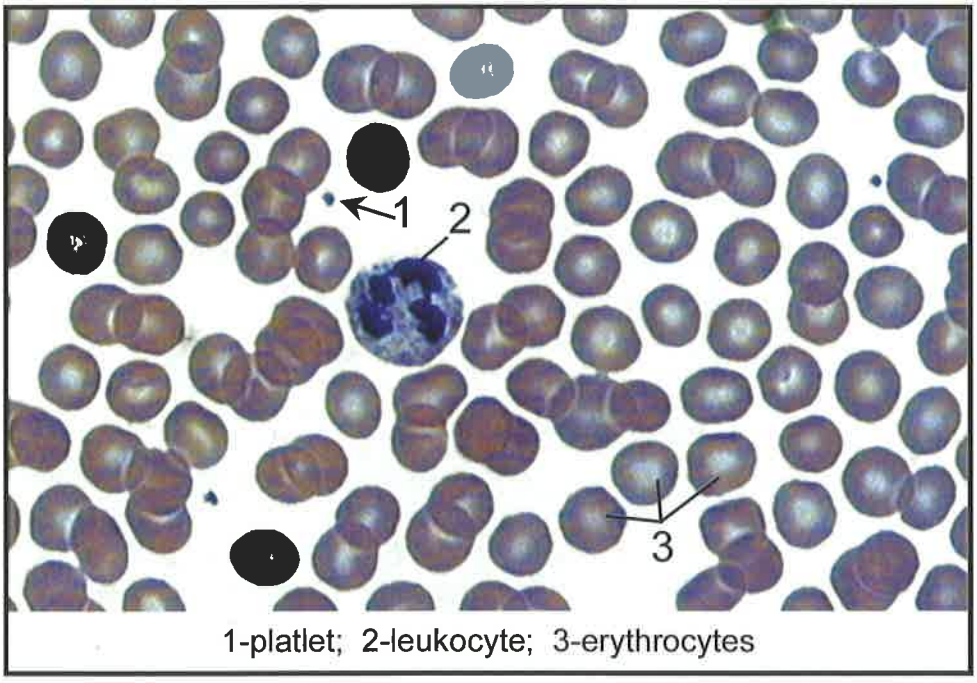


1-right pulmonary artery; 2-brachiocephalic trunk; 3-aortic arch; 4-left subclavian artery; 5-pulmonary trunk; 6-left pulmonary artery; 7-pulmonary vein; 8-left auricle; 9-left atrium; 10-aortic semilunar valve; 11-bicuspid (mitral) valve; 12-descending aorta; 13-chordae tendinae; 14-left ventricle; 15-papillary muscles; 16-endocardium 17-myocardium (contains Perkinje fibers); 18-epicardium / visceral layer of serous pericardium; 19-inferior vena cava; 20-interventricular septum; 21-right ventricle; 22-tricuspid valve; 23-pulmonary semilunar valve; 24-pectinate muscles; 25-right atrium; 26-right auricle; 27-superior vena cava

8. **Left auricle** – The left auricle increases the surface area available to the left and right atria for blood flow.
9. **Left atrium** – The left atrium is the upper left chamber of the heart. It accepts highly oxygenated blood from the lungs via the pulmonary veins and transports it to the rest of the body. The left atrium is considered part of the systemic circuit.
10. **Aortic semilunar valve** – The aortic semilunar valve prevents backflow of blood and keeps the blood flowing in a unidirectional manner from the left ventricle to the aortic arch.
11. **Bicuspid (mitral) valve** – This atrioventricular valve regulates the flow of blood from the left ventricle to the left atrium. It prevents blood from circulating the wrong way (back into the left atrium). Both the bicuspid and the tricuspid valves are considered atrioventricular valves.
12. **Descending aorta** – The aorta extends from the left ventricle (the first portion is commonly called the aortic arch) to the arteries in the lower regions of the body.
13. **Chordae tendinae** – These fibrous cords, along with the papillary muscles, hold the atrioventricular valves (the bicuspid valve and tricuspid valve) shut during the contraction of the ventricle.
14. **Left ventricle** – The left ventricle is the largest and most muscular chamber of the heart, located in the lower left quadrant. It needs to be muscular because it pumps blood throughout the systemic circuit (the body) via the aorta.
15. **Papillary muscles** – The contraction of the papillary muscles, along with the chordae tendineae, holds the atrioventricular valves (the bicuspid valve and tricuspid valve) shut during the contraction of the ventricle.
16. **Endocardium** – The endocardium is the internal layer of the heart wall. It is primarily composed of epithelial and connective tissue.
17. **Myocardium (contains Purkinje fibers)** – The myocardium is the middle layer that contains the cardiac muscle, which powers contraction. Within this layer are the Purkinje fibers that carry the electrical impulses that trigger contraction.
18. **Epicardium / visceral layer of serous pericardium** – The epicardium, also referred to as the visceral layer of serous pericardium, is the external layer on the surface of the heart.
19. **Inferior vena cava** – The inferior vena cava extends into the lower extremities of the body. It transports deoxygenated blood from the organs and tissues in the lower body back to the right atrium.
20. **Interventricular septum** – The interventricular septum separates the left and right ventricles. It contains the atrioventricular bundle branches and Purkinje fibers that carry electrical impulses from the atrioventricular node down the septum. These impulses cause the ventricles to contract.
21. **Right ventricle** – The right ventricle is part of the pulmonary circuit and pumps blood to the lungs to receive oxygen. Since it does not have to pump as far as the left ventricle, the right ventricle is slightly smaller and less muscular than the left ventricle.
22. **Tricuspid valve** – This atrioventricular valve regulates the flow of blood from the right ventricle to the right atrium. It prevents blood from circulating the wrong way (back into the right atrium).
23. **Pulmonary semilunar valve** – The pulmonary semilunar valve prevents backflow of blood and keeps the blood flowing in a unidirectional manner from the right ventricle to the pulmonary artery.

24. **Pectinate muscles** – The right atrium has a rough surface (in comparison to the surface of the left atrium) due to the presence of the ridged pectinate muscles.
25. **Right atrium** – The right atrium is the upper right chamber of the heart. It accepts deoxygenated blood (which has circulated through the upper and lower extremities of the body) from three major veins: the superior vena cava, the inferior vena cava, and the coronary sinus. It then transports it through the tricuspid valve to the right ventricle, to the pulmonary artery and to the capillaries of the lungs so that the waste CO_2 gas may be expelled. The right atrium contains the "pacemaker" of the heart called the sinoatrial (SA) node, which initiates each cardiac cycle. It is considered part of the pulmonary circuit.
26. **Right auricle** – The right auricle increases the surface area available to the left and right atria for blood flow.
27. **Superior vena cava** – The superior vena cava extends into the upper extremities of the body. It transports deoxygenated blood from the organs and tissues of the upper body back to the right atrium.

figure 36 - Components of blood in mammals



1-platlet; 2-leukocyte; 3-erythrocytes

About the Circulating Fluid of the Body: the Blood - figure 36

In order to better understand the heart and the circulatory system, it is necessary to know some facts about the circulating fluid of this system, the blood. The main function of the blood is to transport gases (oxygen and carbon dioxide) and nutrients throughout the body.

Blood consists of two main components: the non-formed liquid element and the formed cellular elements. The non-formed liquid element is **plasma**, which is made up of 91.5% water and 9.5% solutes. These solutes include proteins (such as globulins, albumins, and fibrinogen), urea, uric acid, fatty acids, glucose, glycerides, glycerol, enzymes, hormones, electrolytes, oxygen, and carbon dioxide. The formed elements include the red blood cells called **erythrocytes**, the white blood cells called **leukocytes**, and the **platelets** referred to as **thrombocytes**. The erythrocytes are the non-nucleated biconcave cells that contain the

main oxygen transporting protein called hemoglobin. This portion of the cell holds the pigment that gives blood its red color. The leukocytes are the nucleated cells that lack hemoglobin. These cells are less numerous than the erythrocytes and play a major role in the body's immune responses. The platelets are small, non-nucleated cell fragments. They aid in the clotting of the blood.

Adult Circulation - figures 37 & 38

Adult circulation differs from fetal pig circulation, since the mother provides the oxygen and nutrients to the fetus through the umbilical cord. In order to understand fetal circulation, it is necessary first to understand circulation in an adult mammal. The following is the cycle of typical circulation; (look for the distinction between the pulmonary and systemic circuits):

1. The vena cava delivers deoxygenated blood from the systemic circuit to the right atrium.
2. The blood passes through the tricuspid valve into the right ventricle.
3. From the right ventricle, the blood travels through the semilunar valve to the pulmonary trunk.
4. The pulmonary trunk divides into the pulmonary arteries. One leads to the right lung, the other to the left lung.

figure 37 - Adult circulation showing the systemic and pulmonary circuits

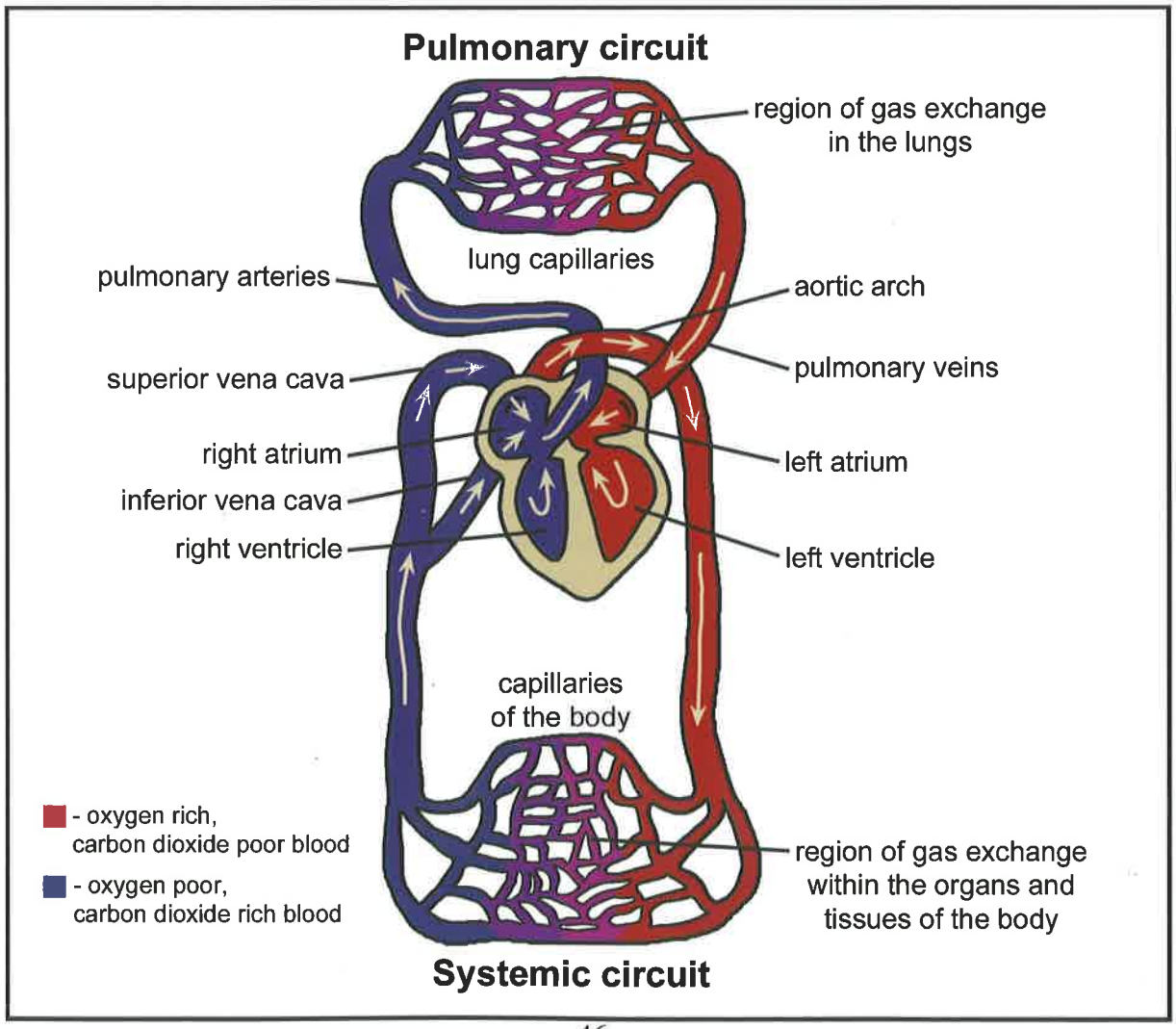
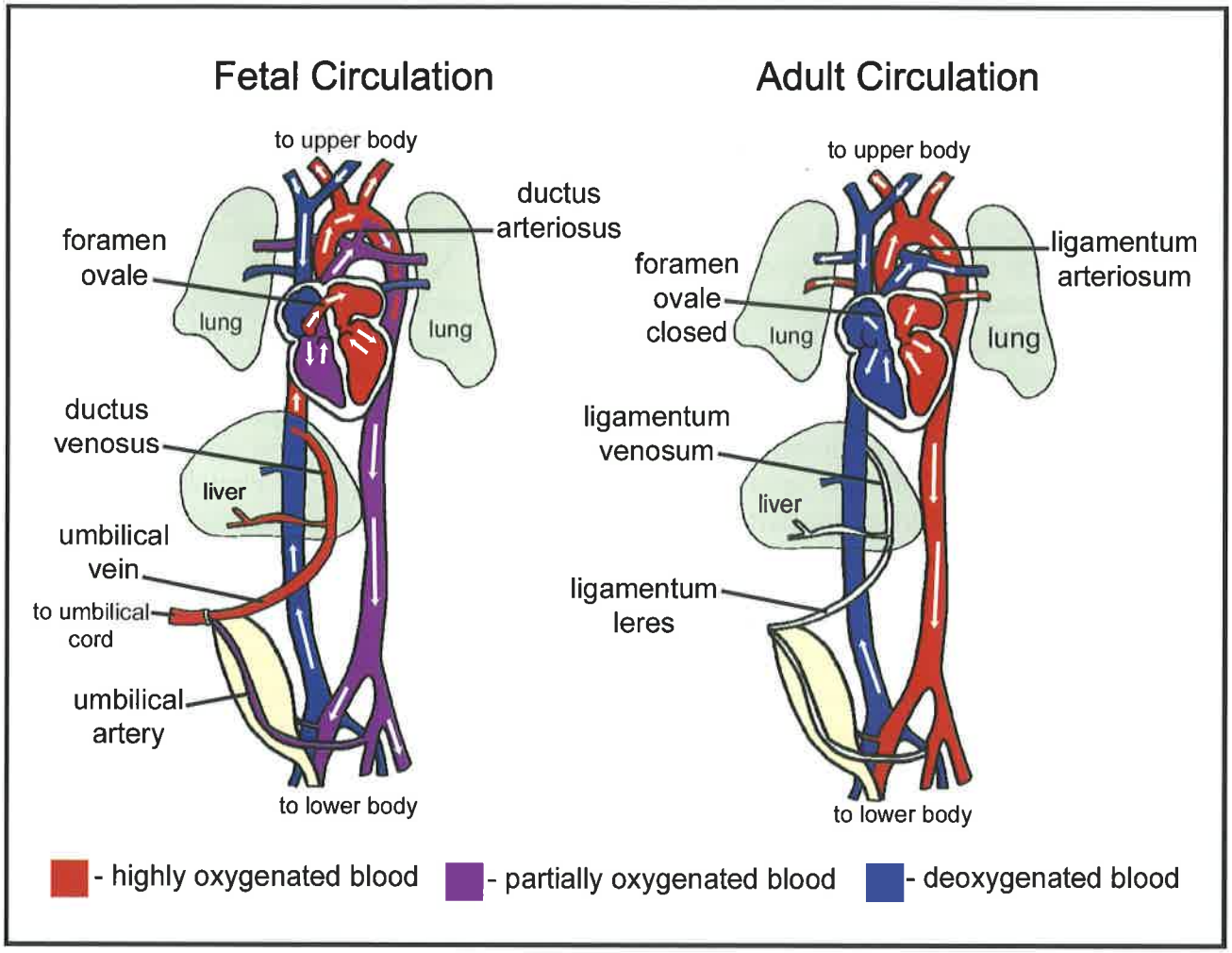


figure 38 - Comparison of fetal and adult circulation



5. The pulmonary arteries lead to smaller arterioles and even smaller capillaries that connect with the lung's alveoli where it receives oxygen.
6. The blood is now highly oxygenated.
7. From the capillaries the blood moves into the larger venules and even larger veins.
8. These veins converge into the pulmonary veins that lead into the left atrium.
9. The blood passes through the bicuspid valve and into the left ventricle.
10. The muscular left ventricle pumps the oxygenated blood through the semilunar valve into the aortic arch.
11. The blood passes down the descending aorta, which branches into all the major arteries of the body.
12. To protect the body from possible toxins the blood may be carrying, the blood passes through the hepatic portal system. The hepatic portal system includes the digestive organs, spleen, and liver. Recall that one of the many functions of the liver is detoxification of the blood.
13. Blood travels from the veins and capillaries of the liver into the hepatic veins.
14. From the hepatic veins the blood travels through the vena cava and back into the right atrium.
15. The cycle begins again – go back to #1!

Fetal Circulation – figure 38

Living in the liquid environment of the placenta, a fetal pig does not need to breathe air. In fact, it has no need for the entire pulmonary circuit. The mother provides all the oxygen and nutrients the fetus needs and removes the wastes through the umbilical cord. The umbilical vein delivers oxygen and nutrient-rich blood from the mother to the fetus. Recall that you tied a string to the umbilical vein to keep track of its location. The umbilical arteries return partially oxygenated blood back to the mother. So how does the fetal pig bypass the pulmonary circuit? Through three fetal modifications:

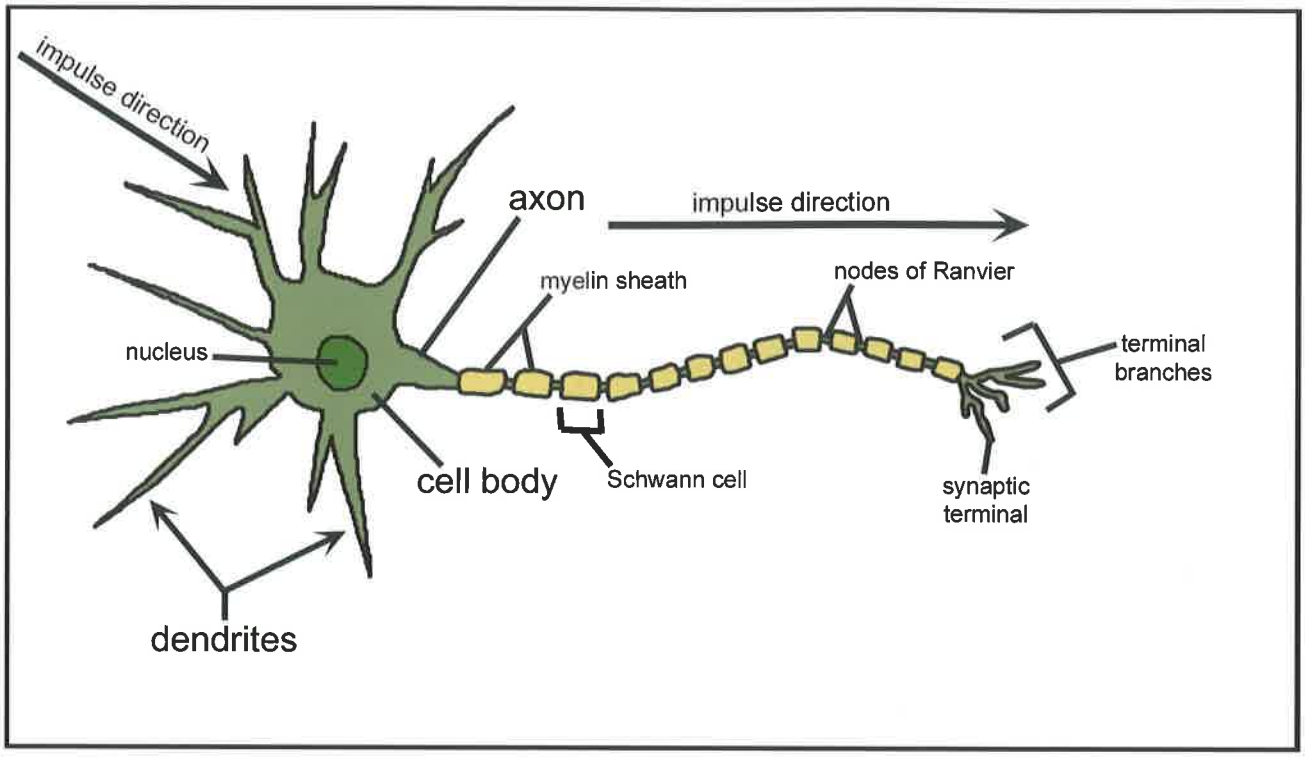
1. **Ductus venosus** – The ductus venosus bypasses the liver and provides a direct connection from the umbilical vein and the inferior vena cava. The caudal portion of the inferior vena cava transports a combination of oxygen-poor blood from the body and oxygen-rich blood from the placenta. After birth this connection degenerates into the ligamentum venosum.
2. **Foramen ovale** – The foramen ovale is a passageway connecting the right and left atria that transports partially oxygenated blood. Recall that during adult circulation the right atrium and right ventricle are part of the pulmonary circuit. Blood is shunted directly to the left atria so that it may be pumped throughout the body via the systemic circuit. This fetal modification allows the fetal pig to bypass this part of the pulmonary circuit. After birth, the foramen ovale closes and leaves an indentation called the fossa ovalis.
3. **Ductus arteriosus** – The ductus arteriosus is another mechanism to bypass the pulmonary circuit by connecting the pulmonary trunk with the aorta. Even though the pulmonary circuit is being avoided, some blood is transported to the lungs for growth and development.

The Nervous System – figures 39 – 42

The nervous system is responsible for distributing sensory and motor impulses. A nerve impulse is an electrical signal transmitted along **neurons**. A neuron consists of a **cell body** with a **nucleus**, branching extensions called **dendrites**, and a single extension called an **axon**. Dendrites transmit nerve impulses toward the cell body and the axon carries them away from the cell body to the synaptic terminal. The axon in the vertebrate peripheral nervous system is supported by a series of cells called **Schwann cells** that are protected by the **myelin sheath**. The myelin sheath functions as insulation to the cells. The spaces between the Schwann cells are referred to as the **nodes of Ranvier**. The axon ends in hundreds to thousands of **terminal branches**. At the terminal, the impulse connects with another nerve or an **effector** such as a muscle fiber. This junction is called a **synapse**. An effector is a cell or organ that responds to the nervous system in response to a stimulus. The stimulus is perceived through a **receptor**. Eyes, ears, and nose are considered organ receptors. Neurons are found throughout the body's nervous tissue and in the brain and spinal cord.

The nervous system in mammals and other higher vertebrates consists of the **central nervous system (CNS)** and the **peripheral nervous system (PNS)**. The central nervous system consists of the brain and the nerves along the spinal column (the spinal cord). The peripheral nervous system connects the central nervous system to the organs and other regions of the body. The peripheral nervous system is divided into the **sensory** and **motor pathways**. The motor pathways include the **voluntary nervous system** and the **involuntary nervous system**. The voluntary nervous system is associated with the control of voluntary skeletal muscle. The

figure 39 - Structures of a neuron



involuntary nervous system, referred to as the **autonomic nervous system**, is associated with involuntary body processes such as heart rate, blood pressure, breathing, and digestion. Each organ within the autonomic nervous system is controlled by the antagonism of the **sympathetic** and **parasympathetic nervous systems**. The sympathetic nervous system prepares the body for stress (the "flight or fight response") by increasing heart rate, respiratory rate, and blood pressure. At the same time, it slows down the digestive processes. In contrast, the parasympathetic nervous system lowers heart rate, lowers blood pressure, and increases digestion. The vagus nerve is the major nerve of the parasympathetic system and contains both sensory and motor neurons. In summary, the sympathetic system expends energy while the parasympathetic system conserves it.

figure 40 - Generalized relationship between the receptor and effector

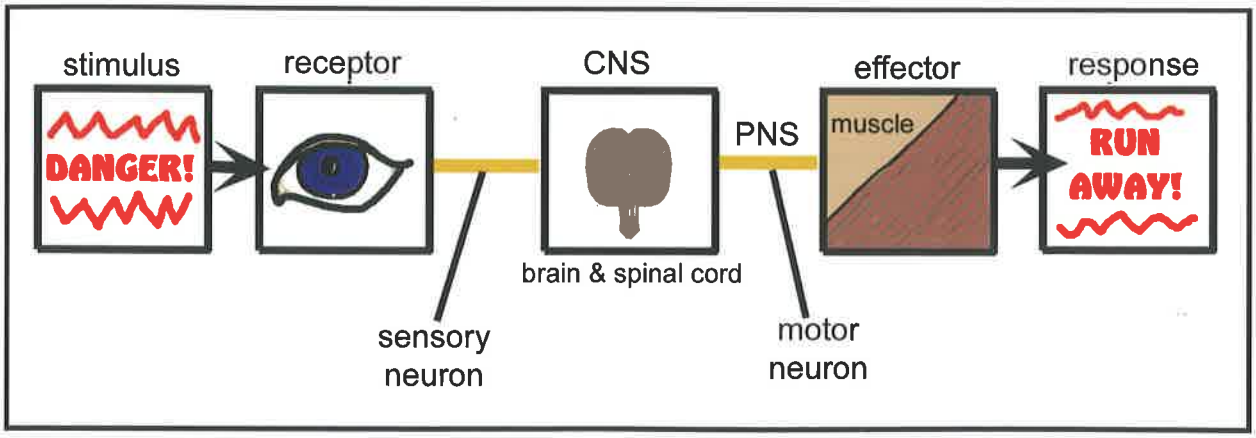
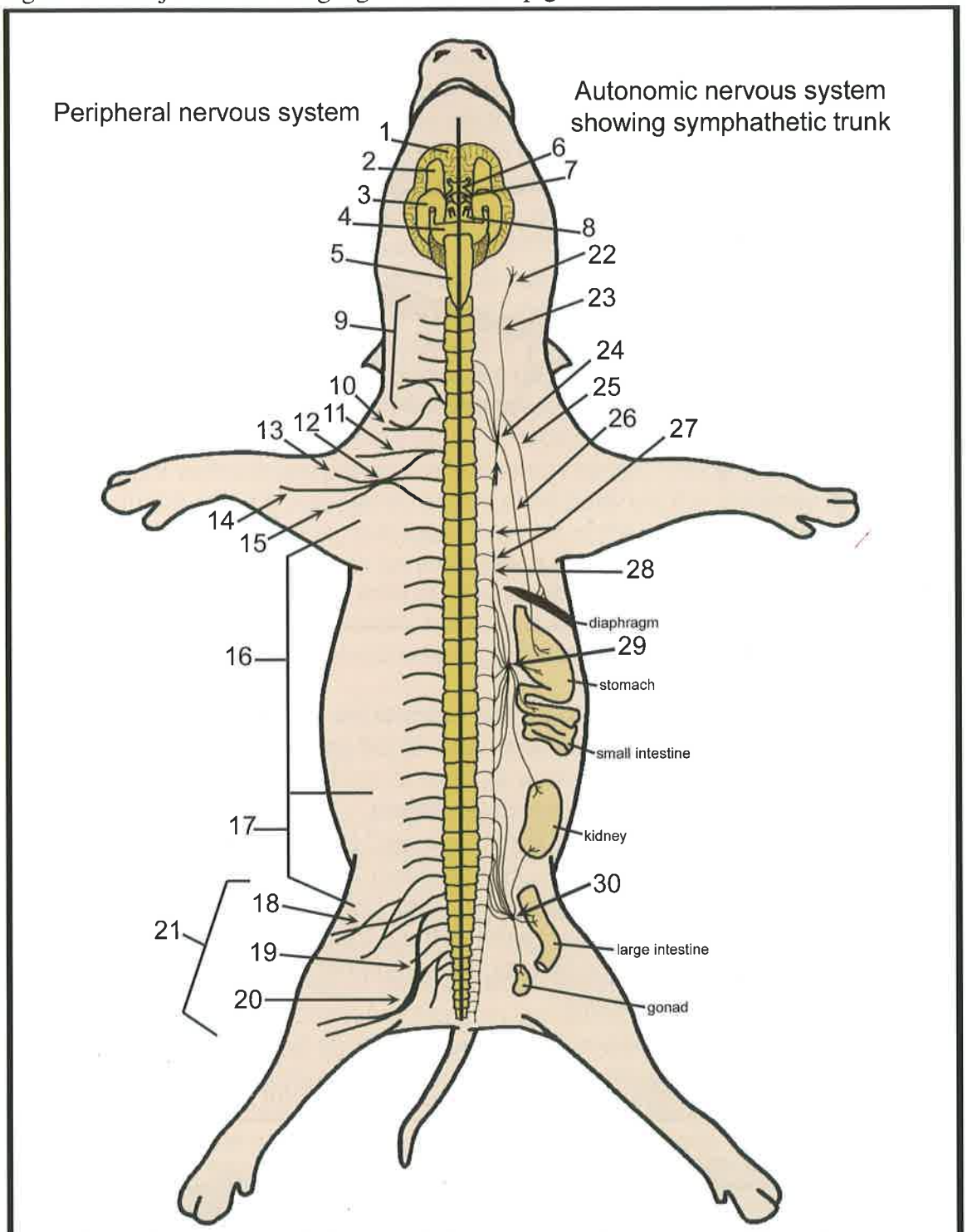


figure 41 - Major nerves and ganglia in the fetal pig

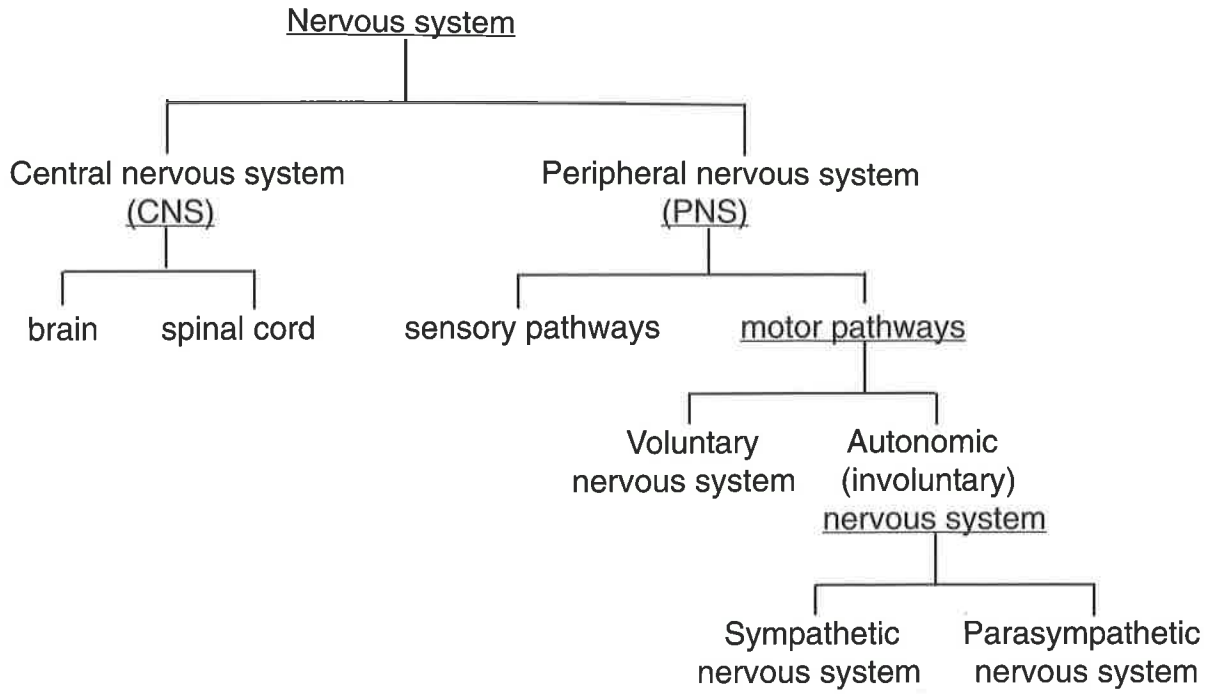


Brain: 1-cerebrum; 2-olfactory bulb; 3-rhinencephalon; 4-pons showing trigeminal nerve; 5-medulla oblongata; 6-optic chiasma showing optic nerves; 7-pituitary stalk; 8-cerebellum;

Peripheral nerves: 9-cranial nerves; 10-suprascapular nerve; 11-subscapular nerve; 12-brachial plexus; 13-radial nerve; 14-medial nerve; 15-ulnar nerve; 16-thoracic nerves; 17-lumbar nerves; 18-femoral nerve; 19-lumbosacral nerve; 20-sciatic nerve; 21-sacral nerves;

Sympathetic nerves & ganglia: 22-anterior cervical ganglion; 23-vagosympathetic trunk; 24-stellate ganglion; 25-phrenic nerve; 26-vagus nerve (part of parasympathetic system); 27-autonomic gangla; 28-sympathetic trunk; 29-celiacomesenteric ganglion; 30-mesenteric ganglion

The various pathways of the nervous system are outlined below:



Nerves – figures 41 & 42

Many of the nerves can be difficult to find. Nerves are a bundle of neurons bound together by connective tissue. They will appear as thin, white cords. The ganglia will appear as a dense gathering of nerves that serve as the centers for the coordination of nerve impulses. Primarily, ganglia occur within the peripheral nervous system and the autonomic nervous system. An example is the autonomic ganglia that follow the sympathetic chain along the sympathetic trunk (figure 41).

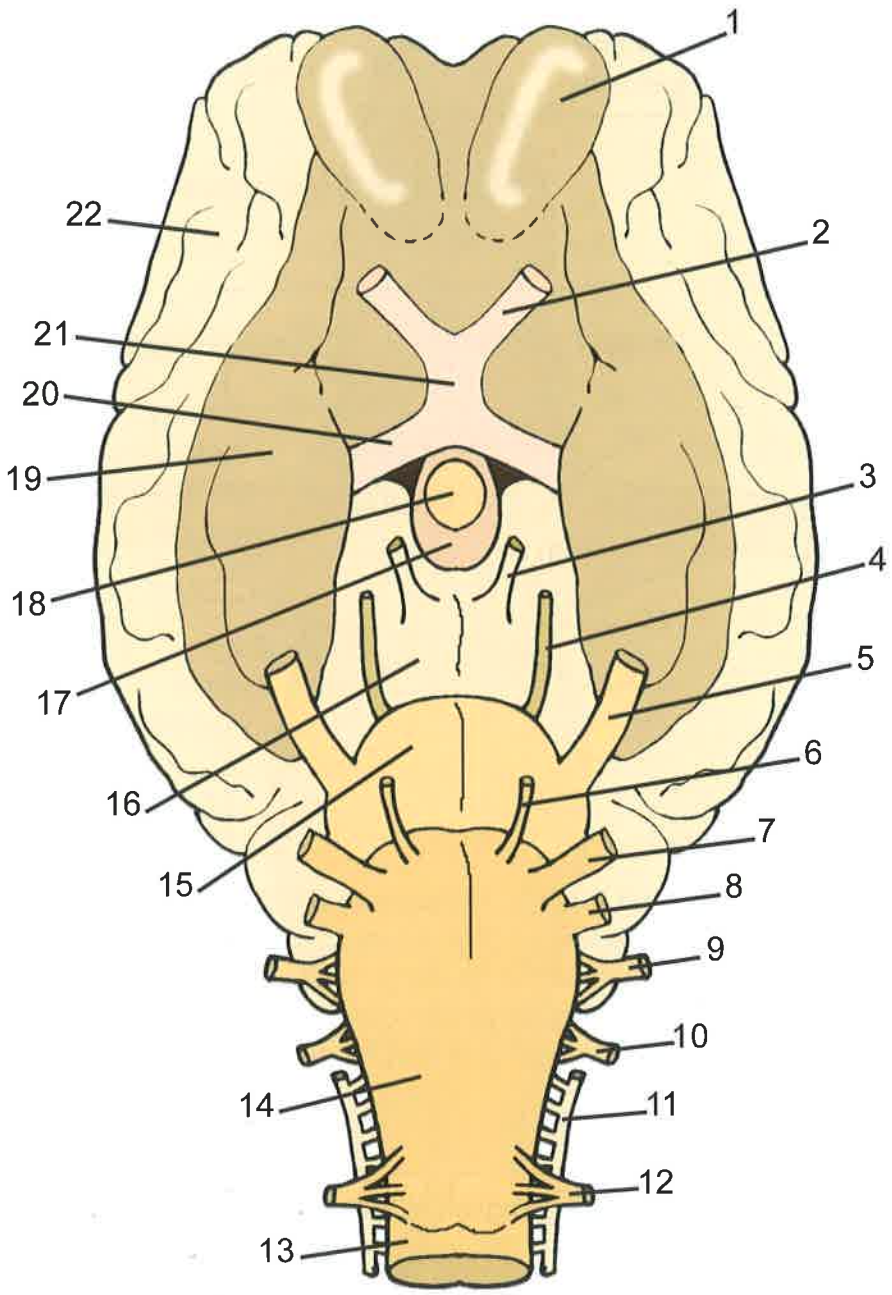
Sympathetic nerves & ganglia

- **Anterior cervical ganglion** – This ganglion is located near the common carotid artery.
- **Stellate ganglion** – At this ganglion the vagus nerve separates from the sympathetic trunk.
- **Phrenic nerve** – The phrenic nerve transports impulses to the diaphragm, causing it to contract and thus cause respiration.
- **Vagus nerve** – The vagus nerve is the major nerve of the parasympathetic nervous system. It carries both sensory and motor impulses.
- **Autonomic ganglia** – These ganglia run along the sympathetic trunk.

Peripheral nerves

- **Suprascapular nerve** – This is a large nerve that extends from the fifth and sixth cervical nerves and leads to the muscles above the scapula.
- **Subscapular nerve** – This nerve extends from the sixth and seventh cranial nerves and leads to the muscles below the scapula.

figure 42 - Ventral surface of the mammalian (sheep) brain showing the cranial nerves



1-olfactory bulb (I); 2-optic nerve (II); 3-oculomotor nerve (III); 4-trochlear nerve (IV); 5-trigeminal nerve (V); 6-abducens nerve (VI); 7-facial nerve (VII); 8-auditory nerve (VIII); 9-glossopharyngeal nerve (IX); 10-vagus nerve (X); 11-accessory nerve (XI); 12-hypoglossal nerve (XII); 13-spinal cord; 14-medulla oblongata; 15-pons; 16-cerebral peduncle; 17-hypothalamus; 18-infundibulum (pituitary stalk); 19-rhinencephalon; 20-optic tract; 21-optic chiasma; 22-cerebrum

- **Thoracic, lumbar, and sacral nerves** – These nerves communicate with the spinal cord. The names correspond with the names of the vertebral regions (figure 8).
- **Sciatic nerve** – The sciatic nerve follows the iliac artery and vein into the deep sacral region. It is considered one of the major nerves of the body.

The Cranial Nerves

Cranial nerves originate directly from the brain. There are 12 different types of cranial nerves in mammals: olfactory (I), optic (II), oculomotor (III), trochlear (IV), trigeminal (V), abducens (VI), facial (VII), auditory (VIII), glossopharyngeal (IX), vagus (X), accessory (XI), hypoglossal (XII). The cranial nerves are typically numbered in Roman numerals and sequentially indicate the location of the nerve from anterior to posterior. Some students find it helpful to use a mnemonic to remember the order of the cranial nerves: "**O**n **O**ld **O**lympus' **T**owering **T**ops **A** **F**inn **A**nd **G**erman **V**iewed **S**ome **H**ops". Notice that the first letter of each word corresponds with the first letter of each cranial nerve in order.

I. Olfactory nerve – The olfactory nerve is responsible for smell and carries sensory neurons to the brain. This nerve extends from the nose to the olfactory bulbs. The olfactory bulbs on the brain show evidence of this nerve.

II. Optic nerve – The optic nerve is responsible for vision and carries sensory neurons to the brain. This nerve extends from the eyes and meets at the optic chiasma.

III. Oculomotor nerve – The oculomotor nerve is responsible for the movement of the muscles in the eyelid and the eyeball and carries motor neurons to the brain. This nerve extends anterior to the pons.

IV. Trochlear nerve – The trochlear nerve is responsible for the muscle movement to turn the eye downward and laterally and carries motor neurons to the brain.

V. Trigeminal nerve – The trigeminal nerve is responsible for sensing touch and pain in the nose, eyelids, face, and tongue. It moves the muscles in the jaw (for chewing) and carries both sensory and motor neurons to the brain.

VI. Abducens nerve – The abducens nerve is responsible for moving the eye laterally and carries motor neurons to the brain.

VII. Facial nerve – The facial nerve is responsible for taste sensations and the control of the facial muscles. It controls the secretion of tears and saliva and carries both sensory and motor neurons to the brain.

VIII. Auditory nerve – The auditory nerve is responsible for hearing and equilibrium. It carries sensory neurons to the brain.

IX. Glossopharyngeal nerve – The glossopharyngeal nerve is responsible for taste and sensing blood pressure and carries both sensory and motor neurons to the brain.

X. Vagus nerve – The vagus nerve is the major nerve of the parasympathetic nervous system that lowers heart rate, lowers blood pressure, and increases digestion; carries both sensory and motor neurons to the brain. This nerve extends from the side of the medulla oblongata into the pharynx, larynx, heart, lungs, and stomach.

XI. Accessory nerve – The (spinal) accessory nerve is responsible for controlling the trapezius and sternocleidomastoid muscles and swallowing movements. It carries motor neurons to the brain.

XII. Hypoglossal nerve – The hypoglossal nerve is responsible for tongue movements and carries motor neurons to the brain.

Structures in the Mammalian Brain – figures 42 & 43

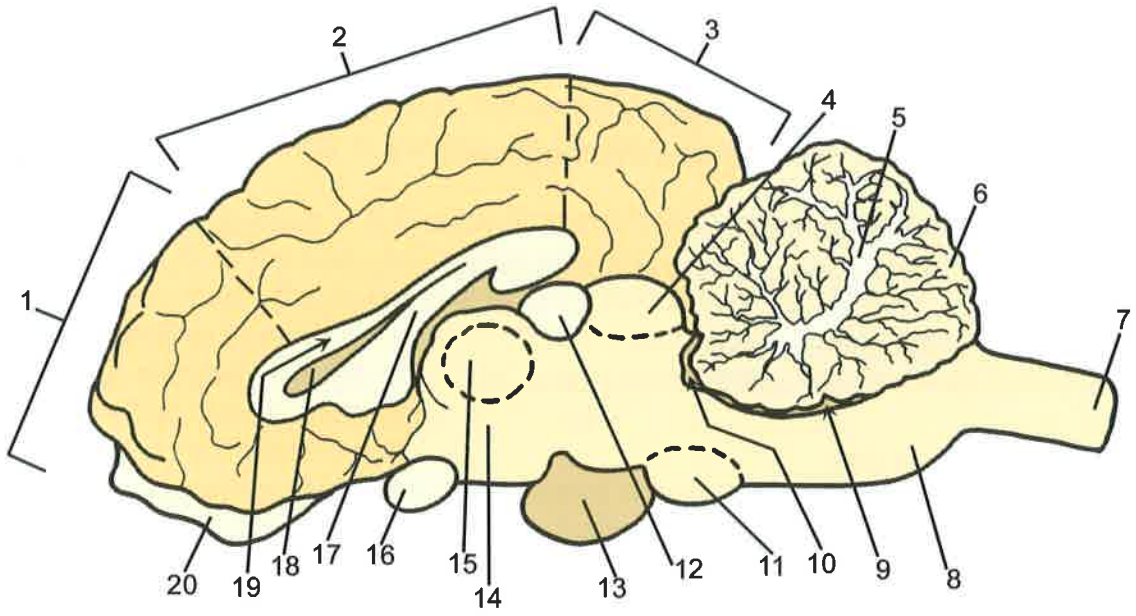
The main organ of the nervous system is the brain. Typically, a sheep's brain is used as an example of a mammalian brain. There is a separate guide that describes the sheep's brain in detail. Both the sheep's brain and the guide, "The Physiology of the Mammalian Brain", are available from the Bio Corporation. This guide includes an illustration of the sheep's brain in the ventral view (to show the cranial nerves) and the sagittal view.

The cerebrum consists of five major lobes: the frontal lobe, the parietal lobe, the temporal lobe, the occipital lobe, and the insular lobe. The temporal lobe, responsible for auditory senses, memory and learning is not shown in the illustration. The insular lobe is located within the cerebrum and is not visible from the surface.

The following list of structures and functions correspond with figure 43:

1. **Frontal lobe of the cerebrum** – The front part of the cerebrum responsible for personality, motivation, judgment, and voluntary motor coordination.
2. **Parietal lobe of the cerebrum** – The middle region of the cerebrum responsible for deciphering sensory input and some language abilities.
3. **Occipital lobe of the cerebrum** – The rear region of the cerebrum responsible for interpreting visual impulses.
4. **Corpora quadrigemina** – The part of the midbrain that consists of four small rounded knobs.
5. **Arbor vitae** – A gathering of white nerve tissue located within the cerebellum.
6. **Cerebellum** – This region of the hindbrain has a cauliflower-like appearance and is responsible for balance and equilibrium, motor coordination, and muscle tone.
7. **Spinal cord** – The spinal cord extends from the brain down the vertebral column. It connects the brain to the organs and muscles of the body. The spinal cord consists of nervous tissue commonly called white matter and grey matter. Your lab may have a slide for you to get a better view of the white and grey matter.
8. **Medulla oblongata** – This region of the hindbrain extends into the spinal cord and is responsible for autonomic functions such as respiration, blood circulation, heart rate, swallowing reflex, and other involuntary functions. In terms of evolution, this was one of the first and most vital structures to appear.
9. **Fourth ventricle** – The brain has several ventricles (or cavities) that contain the cerebrospinal fluid, which cushions and protects neurons. Note: not all ventricles are represented in this guide.
10. **Aqueduct** – This narrow channel connects the 3rd and 4th ventricles and is located in the midbrain.
11. **Pons** – The pons passes along the medulla oblongata and relays messages between the two halves of the cerebrum with the cerebellum.
12. **Pineal body (gland)** – This small round structure in the midbrain secretes the hormone melatonin. Melatonin is released in response to the stimulus of darkness and promotes sleep. The pineal body plays a role in daily biorhythms.
13. **Pituitary gland** – This gland is technically not part of the central nervous system, but is highly associated with it. The pituitary gland is an endocrine gland that triggers other endocrine glands through hormone signaling. It secretes hormones such as growth

figure 43 - Sagittal view of the mammalian (sheep) brain



1-frontal lobe of the cerebrum; 2-parietal lobe of the cerebrum; 3-occipital lobe of the cerebrum; 4-corpora quadrigemina; 5-arbor vitae; 6-cerebellum; 7-spinal cord; 8-medulla oblongata; 9-fourth ventricle; 10-aqueduct; 11-pons; 12-pineal body; 13-pituitary gland; 14-hypothalamus; 15-thalamus; 16-optic chiasma; 17-fornix; 18-lateral ventricle; 19-corpus collosum; 20-olfactory bulb

hormone, vasopressin (osmoregulation in the kidneys), gonadrotropic hormones (stimulate gonad development), oxytocin (stimulates uterine contraction during birth in females), thyrotropin (stimulates the thyroid secretions), and others.

14. **Hypothalamus** - This region of the forebrain, just below the thalamus, is the link between the neural and endocrine system. It regulates the physiological state of the body, maintains homeostasis, and responds to thirst and hunger stimuli.
15. **Thalamus** – The thalamus appears as a round white region in the diencephalon region of the forebrain. It is a sensory integration area of all parts of the nervous system to the cerebrum.
16. **Optic chiasma** – The optic chiasma is where the optic nerves cross. It is located just below the hypothalamus.
17. **Fornix** – The arched region below the lateral ventricle.
18. **Lateral ventricle** – The brain has several ventricles (or cavities) that contain the cerebrospinal fluid, which cushions and protects neurons. Note: not all ventricles are represented in this guide.
19. **Corpus collosum** – This thick band of white nerve fibers connects the right and left cerebral hemispheres, allowing them to communicate.
20. **Olfactory bulb** – This region of the telencephalon area of the forebrain is responsible for deciphering odors.

Anatomical terms:

Anterior – On or towards the head region.
Cranial – On or towards the head region in quadrupeds.

Posterior – On or towards the tail region.
Caudal – On or towards the tail region in quadrupeds.

Dorsal – Refers to the upper surface.
Superior – Refers to the upper surface in quadrupeds.

Ventral – Refers to the under surface.
Inferior – Refers to the under surface in quadrupeds.

Lateral – Refers to the side.
Medial – Refers to the midline.

Proximal – Refers to the attached end of a structure.
Distal – Refers to the free end of a structure.

Key terms
The definitions of the following terms are generalized and are only described as they pertain to the information in this guide. For more detailed definitions, use a dictionary or a biology text book.

Abduction – Moving an extremity or some other part of the body away from the ventral median axis of the body. Example: moving the arm out to one side. (ab = from)
Action – The movements produced by muscles.
Adduction – Moving an extremity or some other part of the body towards the ventral median axis of the body. Example: moving a raised arm back to a resting position. (ad = to)
Amphiarthrosis – A slightly movable joint (articulation). The limited movement is due to the connection of the bones to fibrocartilage. Example: the joints between the vertebrae.
Antagonism – Two or more systems in an opposing relationship.
Antagonistic action – The complementary action produced by paired muscles; one muscle that produces contraction, the other that produces the opposite action, relaxation.
Aponeurosis – The connective tissue that covers a muscle and may connect a flat muscle to a bone.
Appendicular skeleton – In vertebrates, the bones of the extremities, pelvic girdle, and pectoral girdle.
Axial skeleton – In vertebrates, the skull and the vertebral column.
B-cells – A type of lymphocyte that is responsible for the humoral immune response. B-cells differentiate into antibody producing plasma cells when triggered by antigens.
Belly – The central part of a muscle.
Bile – An alkaline solution of bile salts, bile pigments, cholesterol, and other components secreted by the liver. Bile is stored in the gallbladder and delivered to the duodenum

through the bile duct. In the duodenum, bile functions in the emulsification, digestion, and absorption of fats.

Bipedal – An animal with the ability to walk on two legs.

Blastopore – In embryology, the opening to the future gut of the embryo in the gastrula stage.

Carnivore – An animal that obtains its nutrients by eating other animals.

Cephalization – A gathering of ganglia, or nervous tissue and formation of a head in the anterior region.

Closed circulatory system – A system of circulation in which the blood is enclosed within vessels throughout the body cavity (the coelom).

Coelom – A body cavity that is completely lined with mesoderm tissue.

Complete digestive system – A system of digestion in which food moves through the animal through an entryway (usually the mouth) and an exit-way (usually the anus).

Copulation – The sexual union of two individuals.

Corpuscle – A small rounded body.

Deuterostome development – In embryological development, the blastopore develops into the anus; exhibits radial and indeterminate cleavage.

Diaphysis – The shaft of a long bone.

Diarthrosis – A completely movable joint (articulation). Example: the knee.

Diurnal – Most active during the day.

Ectotherm – An animal that lacks an internal regulation of its body temperature and thus must attain its heat from the surrounding environment.

Endocrine gland – A ductless gland that generally produces hormones distributed in the bloodstream.

Endotherm – An animal with the ability to internally regulate its body temperature through metabolic heat.

Epiphysis – The ends of a long bone where growth occurs.

Euchordates – An informal group of animals that include the urochordates, cephalochordates, and animals with a cranium.

Exocrine gland – Any gland that produces secretions and uses a duct for distribution.

Extension – Increasing the angle of a joint.

Fascia – A sheet of connective tissue. Example: the layer of adipose tissue (a type of loose connective tissue) that lies under the dermis.

Flexion – Decreasing the angle of a joint.

Ganglion / ganglia (pl.) – A bundle of nerve cell bodies and the centers for the coordination of nerve impulses in vertebrates.

Gestation – In a viviparous animal, the time period between fertilization and birth.

Gonad – An animal's reproductive organ.

Herbivore – An organism that eats only vegetation.

Heterodont – Having different types of teeth. Example: canines, molars, incisors.

Homeostasis – The maintenance of a constant internal environment.

Homeotherm – An animal that has the ability to maintain its internal temperature within a narrow limit.

Hydrophilic – Having an affinity for water.

Insertion – The end of a muscle that is connected to a movable part of the skeleton.

Integument – A protective body covering in animals. In mammals, the integument consists of the epidermis, dermis, and various glands.

Lactation – In mammals, the time period when the mother nourishes it's young by producing milk in the mammary glands.

Lymphocytes – A type of white blood cell that plays a role in immune responses. There are two principle types of lymphocytes, B-cells and T-cells.

Marsupial – A pouched mammal considered more primitive than placental mammals. The pouch holds the immature young after birth and protects while they develop and mature. Within the pouch, they are nourished by the mammary glands. Examples: kangaroo, opossum, koala bear. Most marsupials are from Australia.

Metamerism – The segmentation of the body.

Monotreme – A mammal that lays eggs. After the young hatch, they move to a pouch where they are protected and nourished in a similar manner as the marsupials. The mammary glands of monotremes are primitive and lack nipples. The milk is transferred through specialized ducts.

Negative pressure breathing - In mammals, the process of breathing done by pulling air down into the lungs through the contraction of the diaphragm. This results in inhalation. When the diaphragm relaxes and moves up, the lungs are restored to their smaller volume, which results in exhalation.

Nephron – An excretory component in the vertebrate kidney. It is composed of the glomerulus, Bowman's capsule, and the renal tubule.

Nocturnal – Most active at night.

Omnivore – An organism that eats both plants and animals.

Origin – The end of the muscle connected to a fixed, typically rigid part of the skeleton.

Oviparous – Laying or spawning eggs that develop and hatch externally. Fertilization may occur internally (e.g. birds) or externally (e.g. fish).

Ovulation – The period of time during which an ovum (egg) is released from the ovary through a follicle. It is received by the fallopian tube / oviduct.

Papilla – (singular=papilla; plural=papillae) Any projection from the surface of an animal tissue or organ.

Pericardial sinus – A cavity that houses the heart and related structures.

Phagocytosis – The process by which a cell engulfs solid particles.

Placental mammals – The largest group of mammals that nourish the embryo within the mother by means of a placenta.

Protochordate – The name given to a group of chordates (see section on "Phylum Chordata" for the four features of chordates on page 1 of this guide) that lack a cranium (skull). Protochordates include cephalochordates such as the lancelet, Amphioxus, and urochordates such as the sea squirt.

Quadrupedal – An animal that walks primarily on four legs.

Sexual dimorphism – Showing visible differences between males and females.

Spermatogenesis – The development of sperm from undifferentiated germ cells.

Striated muscles – A type of muscle that is striped in appearance. Striated muscles are found in voluntary skeletal muscle and involuntary cardiac muscle.

Synarthrosis – A joint (articulation) that is completely immovable. The lack of movement is due to the interlocking connection of the bones to fibrous tissue. Example: the sutures of the skull.

T-cells – A type of lymphocyte that is responsible for the cell-mediated immune response and interacts directly with foreign invaders such as viruses or bacteria.

Tendon – A type of connective tissue that is non-elastic and joins muscle to bone. Tendons are attached to the muscle and pulls on the bone producing joint movement.

Triploblastic development – Forming three germ layers: endoderm, mesoderm, and ectoderm. Various tissue types can arise from these three germ layers.

Ungulate – An animal that grazes and has hooves.

Vestigial structure – An organ or structure having no known function, but showing hints to an ancestral past. This structure may be completely functional in related groups of animals.

Viviparous – Giving birth to live young. Fertilization is internal and the embryo is nourished internally by the placenta.