Fetal Pig Coloring Book

A Laboratory Manual

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HOW TO USE THIS BOOK

This coloring book has been designed to assist in learning the anatomy of the fetal pig—either being used independently to learn the anatomy, or as an adjunct to dissection. In either case, labeling the diagrams or coloring in the structure will aid in remembering these anatomical features and their relationships and understanding functions. When used with dissection, the coloring book may be used prior to working with the specimen in the laboratory, or as a review to solidify one's memory and understanding of the material.

We suggest the following procedures when using this coloring book. When first learning structures, you may look at the key at the bottom of the page, find the corresponding structure, and write in the term next to the structure before coloring the anatomical structure. This is a great technique to learn names and appearances of anatomical features. On the other hand, when using this book to review and reinforce learning, one would examine the drawings, fill in the blanks with the appropriate terms in pencil, and then check the key at the bottom of the page. Correct any mistakes and then color in the illustration in a way that cements your learning.

In most cases, the choice of colors is up to you. In a few instances, the choice of colors is designated by anatomical convention. Arteries are generally drawn in bright red, veins in deep blue, bile ducts in green, and nerves are usually yellow.

COLORING TECHNIQUES

Colored pencils usually give the best result, as they do not bleed through the page and obscure fine detail. Begin using light pressure when you color; you can always go back and deepen the color as you work on the drawings. Use the same color for the same structure when it appears in more than one drawing; use related colors for related structures—for example, using different shades of blue for different structures in the same organ system. Plan your colors before beginning each drawing, so that you can follow the anatomical conventions noted above, color related structures in similar or related colors, and continue your own color codes from one drawing to the next. Using that method will help you to easily find a structure and reinforce the relationships of its function and organ system by color as well as name and shape.

TERMINOLOGY

Before examining the anatomy of the fetal pig, you should become familiar with terminology that describes the orientation of the structures. Commonly used terms are paired to describe opposite directions.

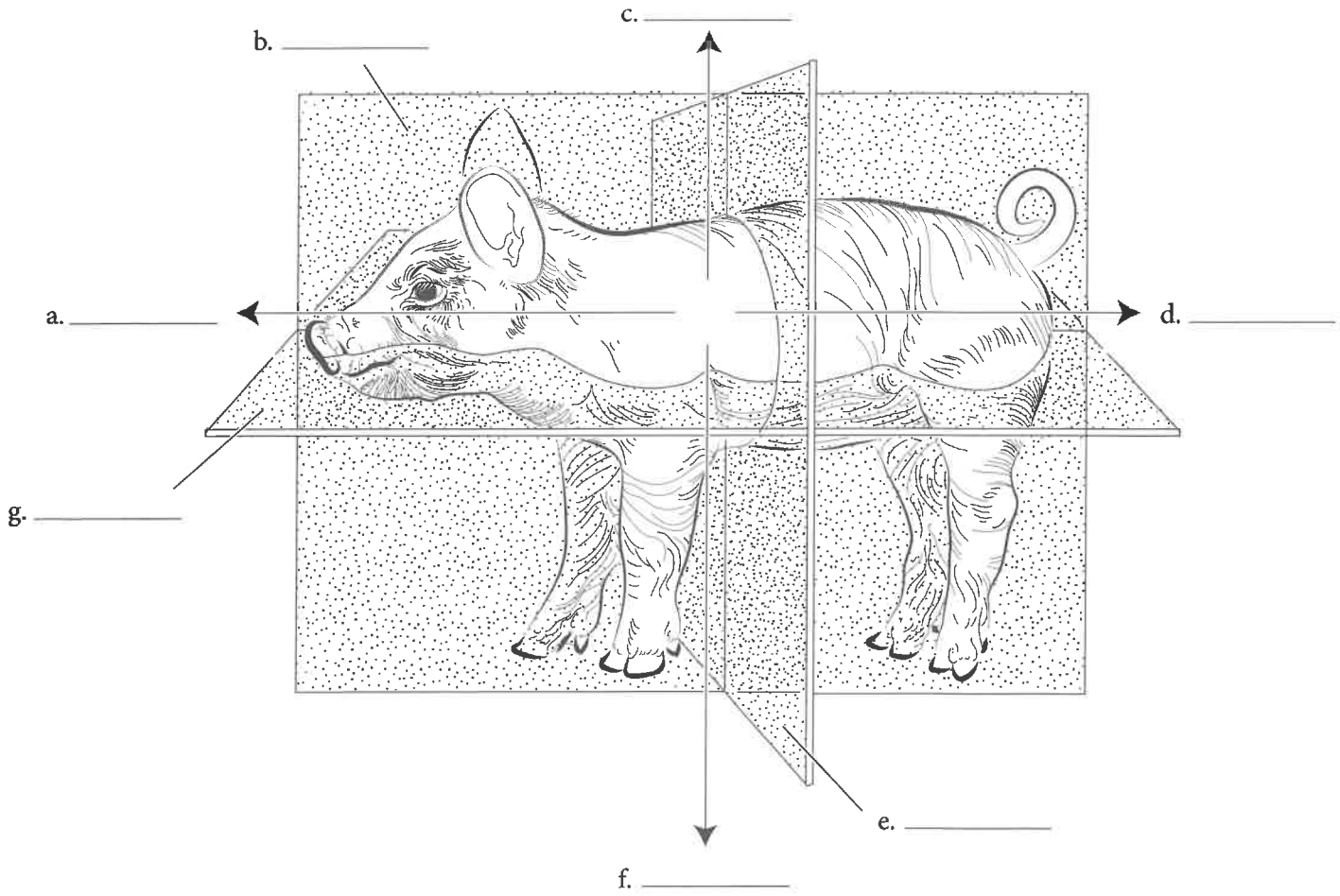
left and right	on the pig's left or right, regardless of your point of view
dorsal	toward the back
ventral	toward the belly
cranial	toward the head
caudal	toward the tail
medial	toward the center of the body
lateral	away from the center of the body
proximal	closer to the trunk, along a limb
distal	further from the trunk, along a limb
superficial	lying closer to the surface of the body
deep	lying under or below, away from the surface of the body

Two other terms—anterior and posterior—may be used differently for the pig than for the human. Anterior denotes the "front" of the body (in the direction of travel) or toward the head in the pig, but it is sometimes used to refer to the ventral side in bipeds like humans. Posterior is opposite to anterior, and it refers to caudal in the pig, but may be used to describe the dorsal side in humans.

Another helpful concept is the hierarchy of organization within the pig's body. Individual cells become specialized in many ways; groupings of similar cells with a common function are tissues. Several tissues of different types but working together to accomplish a function may be said to form a single organ. Similarly, groups of organs with a common purpose are organized into systems that make up the entire pig. In this coloring book, chapters each address a system of the body, and may contain drawings and descriptions of the organs, and tissue types that contribute to that system's functions.

PLANES OF SECTION

Planes of section are used in describing anatomical positions. These planes are perpendicular to one another, and provide a way to show a two-dimensional representation of a three-dimensional animal. If you were to figuratively slice completely through the pig from head to tail, cutting it into left and right portions, this would be a **sagittal** section. The midsagittal section would divide the pig into equal halves. A **frontal** or horizontal plane splits the animal into top and bottom portions, while a transverse or cross section cuts across the pig, creating front (**cranial**) and rear (**caudal**) portions.



Answer Key:

a. Cranial (Anterior)
b. Sagittal plane
c. Dorsal (Superior)
d. Caudal (Posterior)
e. Transverse plane
f. Ventral (Inferior)
g. Frontal plane

You should begin your study of the pig with the external view. While most superficial structures are familiar because they are similar in all mammals, their morphology and even terminology may vary from one species to another. The external features also reveal interesting details about the fetal pig. The length of the pig from the tip of its nose to the base of the tail can be used to estimate fetal age; parturition (birth) typically occurs after 112–115 days of gestation and the average pig is 30 cm long at birth or slightly more. Much of this growth occurs during the later stages of gestation; at 56 days, the fetus is only 4 cm long.

An obvious fetal structure is the **umbilical cord**, which connected the fetus to the placenta during gestation. The **placenta** is composed of two layers—one derived from the inner lining of the sow's uterus and the other consisting of the fused chorion and allantois membranes derived from embryonic tissues. These two layers lie in close proximity to allow diffusion of nutrients, oxygen, and waste materials between the blood of the fetus and that of the mother.

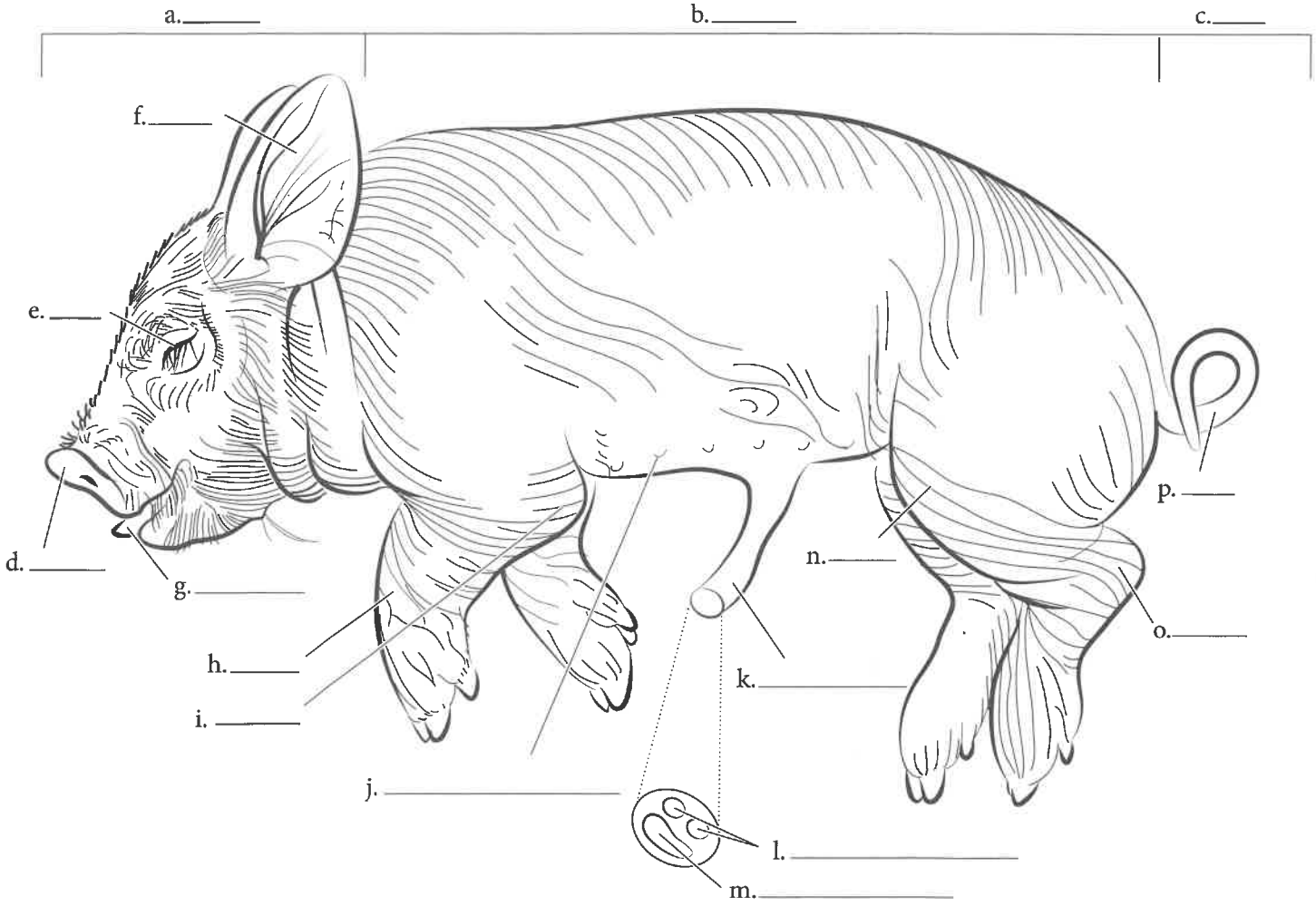
The head of the pig, as in all mammals, concentrates some important sense organs to collect information about the world around the pig. Senses of hearing, sight and smell are associated with the ears, eyes, and snout. The external ear, also known as the **auricle** or **pinna**, collects and concentrates sound for entry into the sensory portion located in the inner ear. It is also at the head where the individual will take in oxygen through the external nares in the snout, and both food and water through the mouth.

Observing the morphology of the appendages will help the student to understand locomotion of the animal. The feet are elongated and pigs walk on the tips of their toes, both adaptations that better enable them to escape predators by running away. Walking on the toes is characteristic of animals known as **ungulates**, or hoofed mammals. All ungulates have fewer than five toes; in the pig, the first toe has been lost (corresponding to the human thumb or large toe), and the second and fifth toes are greatly reduced. The pig walks primarily upon the two remaining toes (hooves) on each foot. The hooves are derived from epidermal tissues, as are the nails on human fingers and toes, or the claws on the foot of a dog or cat.

The body of the pig may be divided into three major regions—the head, trunk, and tail. Many sensory organs are concentrated in the **head**, while the **trunk** provides protection for delicate internal organs and is a site of attachment for the appendages used in locomotion. Locate the organs found in the head region and identify their functions. The external **nares** are located in the snout and form the beginning of the air passages for the respiratory system. The mouth is the site of food ingestion and contains the tongue and teeth for tasting and chewing food. The ear and eye are responsible for the senses of hearing and sight.

The appendages include two forelimbs and two hindlimbs. The **elbow** and **knee** of the pig are located close to the trunk, and the **wrist** and **ankle** are raised off the ground because the pig literally walks on its toes. Locate these joints in the diagram.

A cross section of the umbilical cord shows that it contains three blood vessels—two **umbilical arteries** that carry deoxygenated and waste-laden blood into the placenta from the fetus, and a single large **umbilical vein** that carries oxygenated and nutritionally enriched blood from the placenta toward the fetal heart.

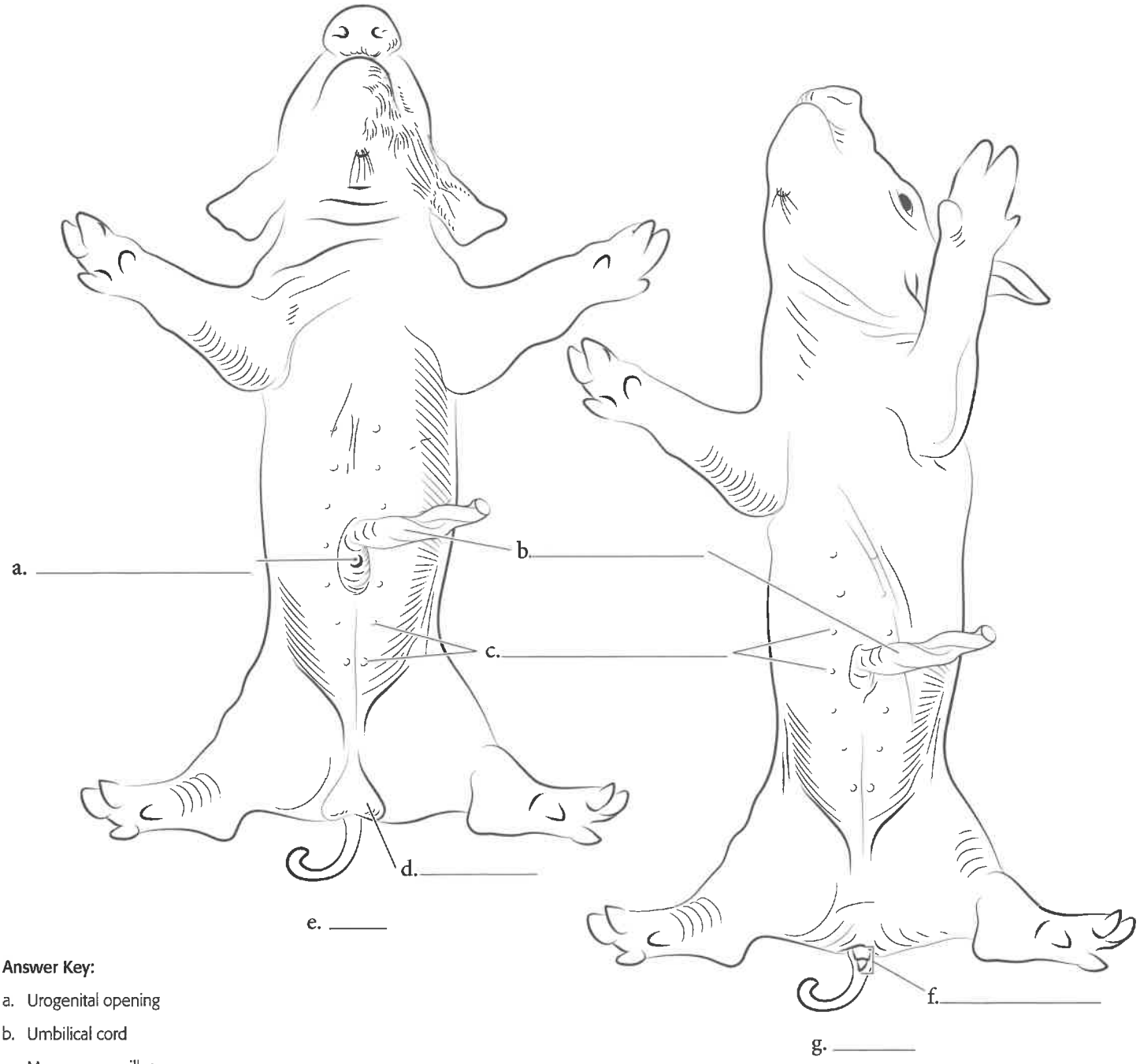


Answer Key:

a. Head
b. Trunk
c. Tail
d. Snout
e. Eye
f. External ear (auricle, pinna)
g. Tongue
h. Wrist
i. Elbow
j. Mammary papilla
k. Umbilical cord
l. Umbilical arteries
m. Umbilical vein
n. Knee
o. Ankle
p. Tail

SEX DIFFERENCES

You can tell the sex of a fetal pig by observing several structures on the ventral surface. Both males and females have 5–7 pairs of teats, or **mammary papillae**, along the ventral surface of the trunk, but they will become functional mammary glands only in the adult female. In males, a urogenital opening is found on the abdomen, just caudal to the umbilical cord, and is the opening for the penis. The male's **scrotum** is a sac of skin beneath the anus and between the hind legs. The testes will descend into the scrotum from the abdominal location where they develop, and this usually occurs before the pig is born, so the scrotum may contain the testes in larger fetal pigs. The urogenital opening of females is found on a spike-like **urogenital papilla** located ventral to the anus and tail.



Answer Key:

a. Urogenital opening
b. Umbilical cord
c. Mammary papillae
d. Scrotal sac
e. Male
f. Urogenital papilla
g. Female

The vertebrate skeleton is composed of bones that not only protect delicate internal organs, but provide structure for the body and an attachment site for muscles used in locomotion. Bones serve as a reservoir for calcium and other minerals, and may contain marrow where blood cells are formed. The skeletons of all mammals are essentially the same, although individual bones may be different in shape or strength because of the organism's mode of locomotion. The principal differences between the pig and human, for example, arise as a result of the quadruped locomotion of the pig versus the pipedal form of the human.

In the fetal pig, the bones of the skeleton develop as cartilage, which is later replaced by the harder bone tissue of the adult. The adult skeleton contains cartilage in addition to bone; it provides functions including support, calcium storage, and cushioning between bones at joints such as those where long bones come together. Preserved skeletons of humans or other adult animals contain only the bone tissues, but since fetal skeletons consist of cartilage, students rarely study skeletons of fetal pigs and examine human or cat adult skeletons. In this coloring book, however, you will see the shape and relationships of the bones as they are found in the pig.

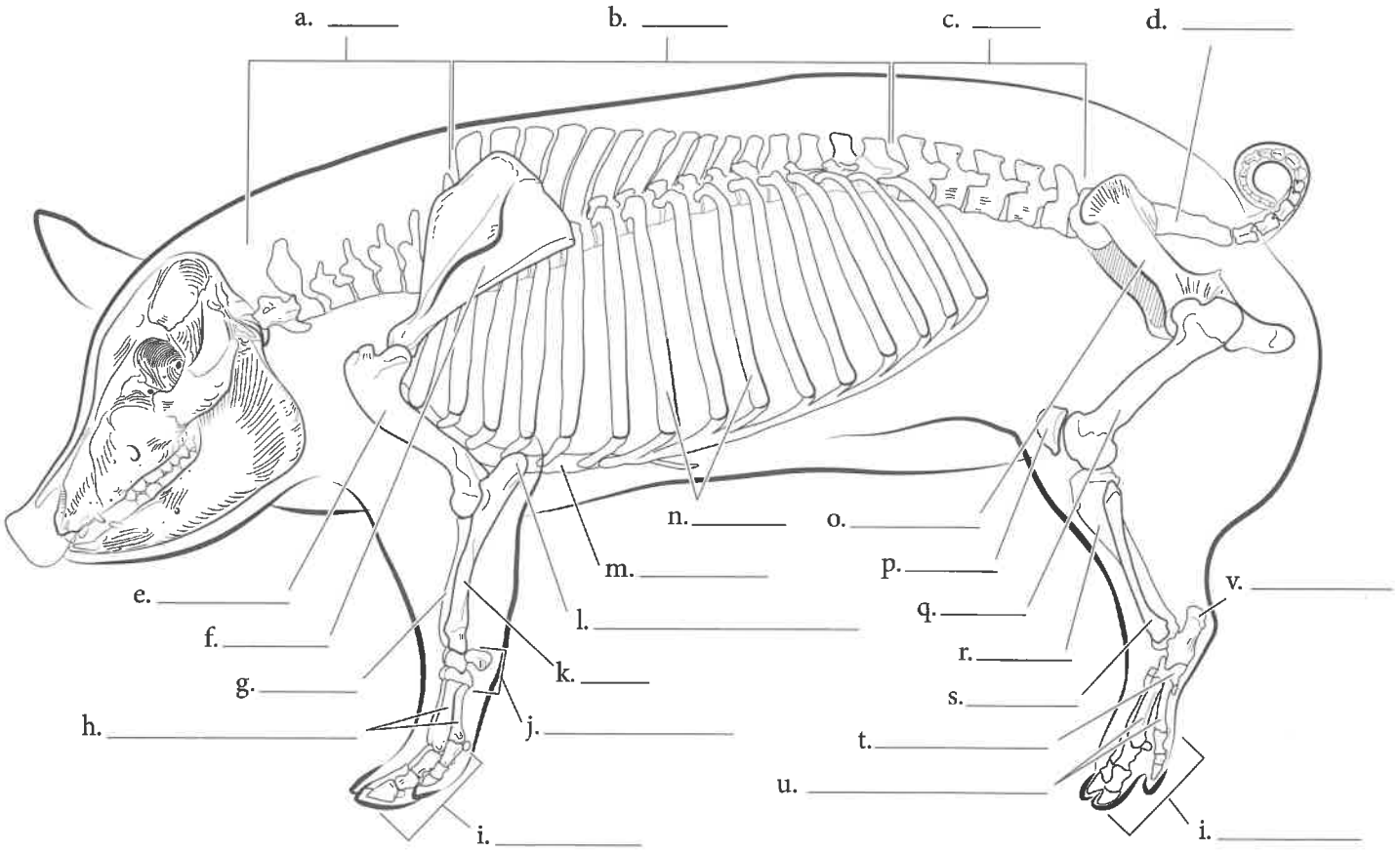
The skeleton is divided into two major divisions—the **appendicular skeleton** including the bones of the appendages and their supporting **pelvic** and **pectoral girdles**, and the **axial skeleton** consisting of the **skull** and **vertebrae**. Use different colors for the two skeletal divisions to help you remember their names and locations.

Bones articulate with one another at joints, allowing for varying degrees and ranges of movement. Where bones meet one another, try to understand the range of motion of the joint, as it will help you to remember the names and locations together.

SKELETON, LATERAL

The vertebrae are part of the axial skeleton and can be divided into five regions. The **cervical** or neck region has seven, including the cranial two vertebrae which have special names—the atlas and axis; the **thoracic** or chest region may have anywhere from 13–17; the **lumbar** or abdominal region has five; the **sacrum** in the adult pig is composed of four vertebrae fused together and articulates with the bones of the pelvis; and the remaining caudal vertebrae are located in the tail. Each vertebra has a central canal for the passage of the spinal cord, with varying bony processes extending dorsally or laterally to provide attachment for muscles or articulation with other vertebrae or ribs. Thoracic vertebrae provide the attachment point for the **ribs**, some of which are connected by cartilage with the **sternum** or breastbone (true ribs), while others have cartilage that connects to an adjoining rib (false ribs).

The pectoral girdle supports the forelimbs and includes the **scapula** or shoulder blade; unlike humans, there is no clavicle in the pig. The pelvic girdle supports the hindlimbs and includes several bones which fuse to form the coxal bone in the pig, called the **os coxae**. The bones of the legs are analogous in most mammals, including the pig and humans. Find and color the forelimb bones—**humerus, ulna**, and **radius**, along with the wrist bones, the **carpals**, and the forefoot bones, the **metacarpals** and **phalanges**. Find and color the bones of the rear leg—**femur, tibia** and **fibula**, as well as the ankle bones, the **tarsals**, and the foot bones, the **metatarsals** and phalanges.



Answer Key:

a. C1–7
b. T1–T15 (variable from 13 to 17)
c. L1–5
d. Sacrum
e. Humerus
f. Scapula
g. Radius
h. Metacarpal bones
i. Phalanges
j. Carpal bones
k. Ulna
l. Olecranon
m. Sternum
n. Ribs
o. Hip bone (Coxal bone, Os coxae)
p. Patella
q. Femur
r. Tibia
s. Fibula
t. Tarsal bones
u. Metatarsal bones
v. Calcaneus

Muscles are bundles of cells capable of contraction. **Somatic** or voluntary muscles function along with the skeleton for locomotion or moving one body part in relation to another, while **visceral** or smooth muscles are found in organs such as the digestive tract where food is moved along by contraction of smooth muscles; a third type is cardiac muscle which pump bloods through the body.

In almost every case, the fetal pig has the same somatic muscles as humans, although there are some variations in size or location due largely to the quadruped/biped differences. Each muscle has a characteristic location—attaching to skeletal elements by connective tissue called tendons. Each muscle originates or attaches to a bone (its **origin**) which remains in a fixed position when the muscle contracts. The other end of the muscle inserts on or attaches to a bone (its **insertion**) which is usually free to move. Also, each muscle performs a characteristic function or **action**, such as: **adductors** move a body part toward the midline, while **abductors** draw a body part away from the midline of the body; **protractors** move a limb forward while **retractors** move that limb backwards; **flexors** move a limb or body part against another body part, while **extensors** straighten a limb or body part; and **constrictors** contract or shorten a body part. Note that many of the actions are paired with an opposite activity in another muscle. Since muscles can only contract or shorten, they cannot push a body part back after moving it in one direction. A second muscle must return the body part to its original position after the first muscle relaxes.

You should develop a strategy for coloring muscles: For example, select a pair of related colors (such light and dark blues) to represent all adductors and their correlated abductors, or another pair for all flexors and extensors. This will aid your memory of the function for each muscle.

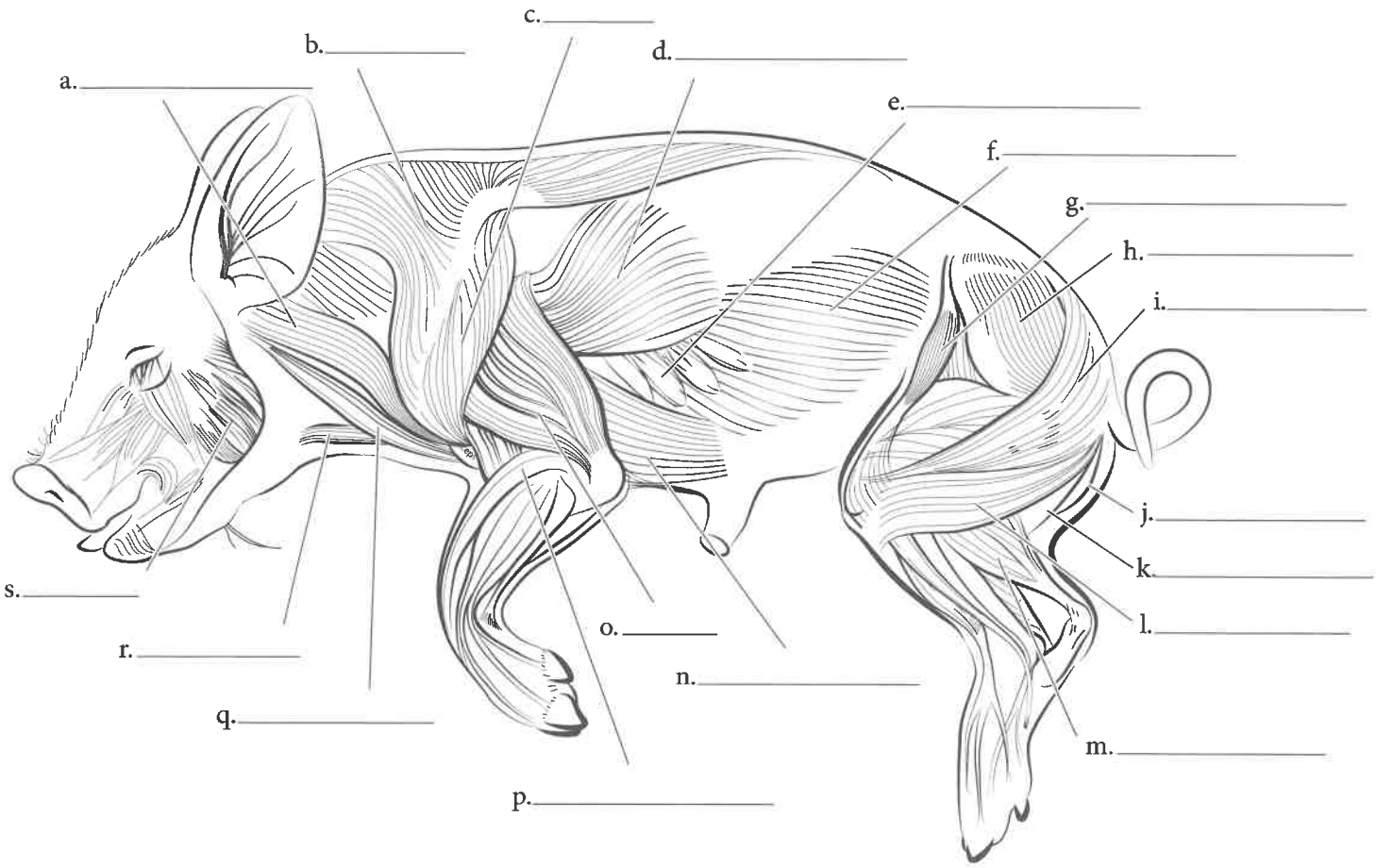
LATERAL MUSCLES

The **masseter** is a large muscle that controls the closing of the jaw; it originates on the zygomatic arch region of the skull and inserts on the coronoid process of the mandible.

In the shoulder region, the **trapezius** is a grouping of thin, broad muscles that originate on the vertebrae of the neck and thorax and insert on the scapula; they function in moving the shoulder forward or backwards. The fan-shaped **serratus anterior** originates on several ribs and vertebrae; it inserts on the dorsal portion of the scapula, helping to move it forward and back. The **brachiocephalic**, **deltoid**, and **latissimus dorsi** all insert on the humerus and function to move the forelimb. Since the pectoral girdle does not actually articulate with the vertebral column, several muscles including the serratus anterior act like a sling to transfer some of the weight of the trunk to the scapula and forelimb.

In the abdominal region, large sheetlike muscles such as the **external oblique** are part of the body wall that completely surrounds the internal organs.

In the pelvic region, several major muscles connect across both the hip and knee joints, controlling both the thigh and lower leg simultaneously. The **tensor fasciae latae** both extends the lower leg and protracts the thigh. The **biceps femoris**, **semitendinosis**, and **gluteus superficialis** act to flex the lower leg and retract the thigh. The gluteus medius both retracts and abducts the thigh. The **semimembranosis** acts to retract the thigh.



Answer Key:

a. Brachiocephalic (Brachiocephalicus)
b. Trapezius
c. Deltoid
d. Latissimus dorsi
e. Serratus anterior (Serratus ventralis)
f. External oblique
g. Tensor fasciae latae
h. Gluteus medius
i. Gluteus superficialis (Gluteus maximus)
j. Semimembranosus
k. Semitendinosus
l. Biceps femoris
m. Gastrocnemius
n. Pectoralis minor
(Pectoralis ascendens, Pectoralis profundus)
o. Triceps
p. Extensor carpi radialis
(Extensor carpi brachialis)
q. Sternomastoid
r. Sternohyoid
s. Masseter

VENTRAL MUSCLES

In the neck region, a group of muscles along the midline originate on the sternum and assist in swallowing. The **sternohyoid** inserts on the small hyoid bones, and the deeper sternothyroid (not shown) inserts on the thyroid cartilage. The **sternomastoid** originates on the cranial end of the sternum and inserts on the mastoid process at the rear of the skull to enable turning and depressing the head. The **platysma** is a large sheet-like muscle of the skin that is not attached to bone, but to the fascia—a fibrous connective tissue found between the shoulder muscles and the skin. Such muscles allow the pig to "twitch" regions of its skin without moving the underlying bones.

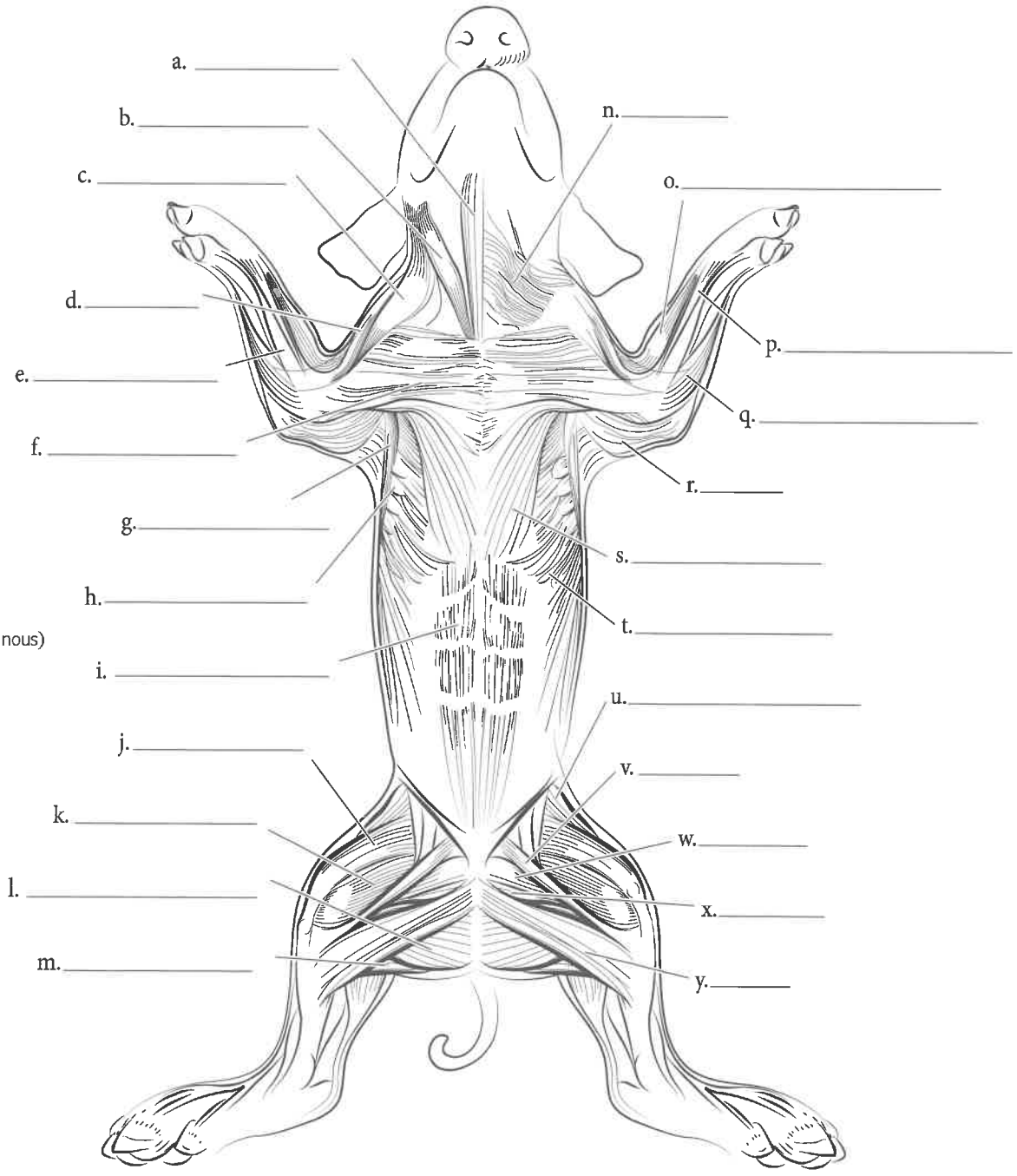
On the ventral side of the chest, the **pectoralis superficialis** originates on the sternum and inserts on the humerus, functioning in adducting and retracting the forelimb. The brachiocephalic muscle helps to adduct the forelimb while the **brachialis** flexes the lower forelimb. Other forelimb muscles such as the **palmaris longus** control wrist flexion and other movements of the wrist.

Along the trunk, a group of thin, sheet-like muscles of the body wall function to support the abdominal wall and assist in breathing. The external oblique and the deeper **internal oblique** and transversus abdominis (not shown) originate on ribs and fascia and insert at the ventral side on a connective tissue structure known as the linea alba. Serving a similar function is the **rectus abdominis** which extends linearly along the ventral midline.

In the pelvic region, several large muscles originate on parts of the pelvis and move the hind legs. Inserting on the tibia; the **gracilis** adducts and retracts the thigh and flexes the lower leg, while the **sartorius** adducts the thigh and extends the lower leg. The **adductor** muscle inserts along the length of the femur where it not only adducts but also retracts the thigh. The small **pectineus** also inserts on the femur and adducts the thigh.

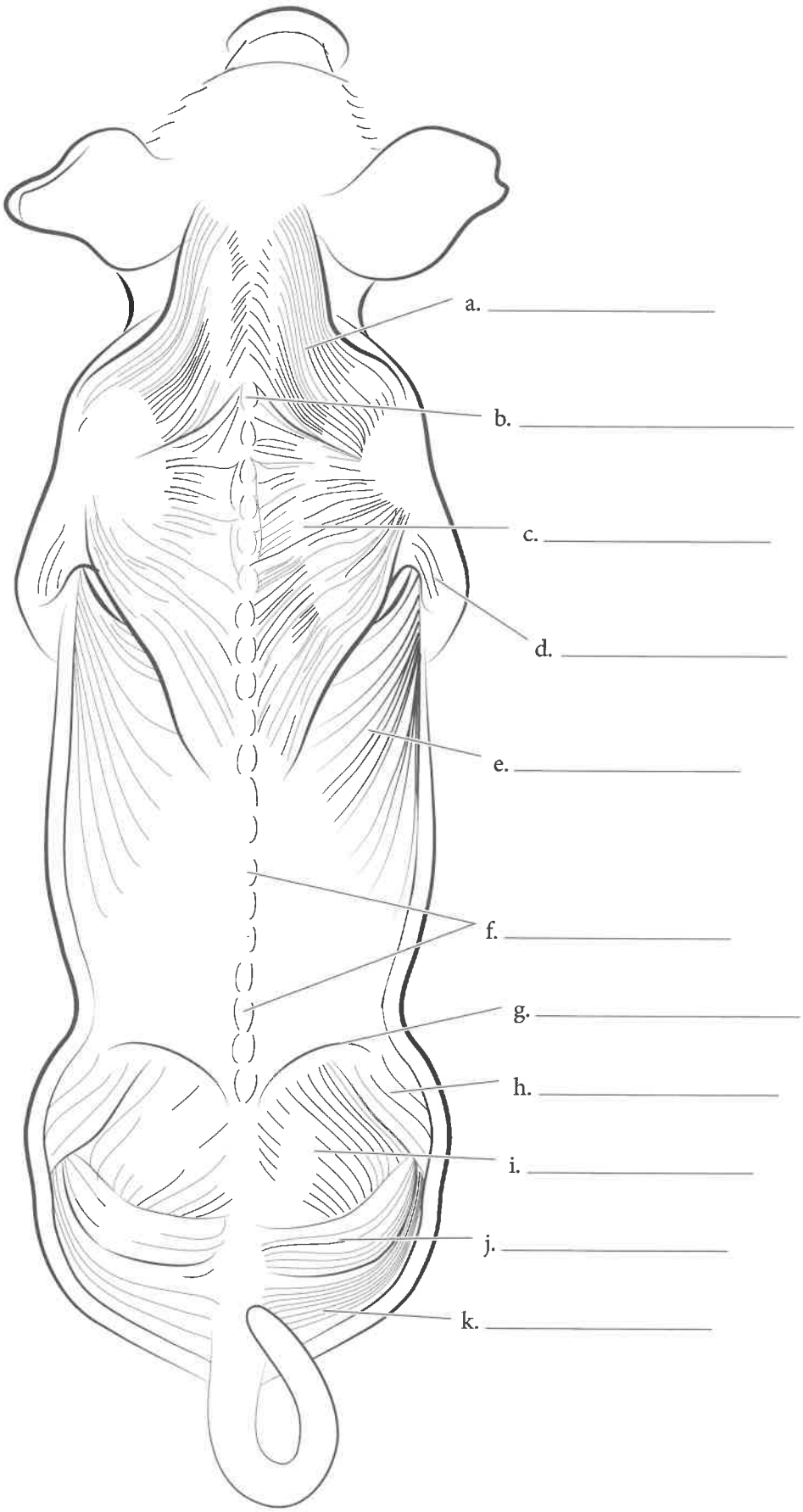
Answer Key:

a. Sternohyoid
b. Sternomastoid
c. Brachiocephalic (Brachiocephalicus)
d. Brachialis
e. Palmaris longus
f. Pectoralis major (Pectoralis transversus, Pectoralis superficialis)
g. Latissimus dorsi
h. Serratus anterior (Serratus ventralis)
i. Rectus abdominis
j. Rectus femoris
k. Vastus medialis
l. Semimembranosus (Semimembranous)
m. Semitendinosus (Semitendinous)
n. Platysma
o. Extensor carpi radialis (Extensor carpi brachialis)
p. Flexor carpi radialis
q. Flexor carpi ulnaris
r. Triceps
s. Pectoralis minor (Pectoralis ascendens, Pectoralis profundus)
t. External oblique
u. Tensor fasciae latae
v. Sartorius
w. Pectineus
x. Adductor
y. Gracilis



DORSAL MUSCLES

The superficial back and neck muscles of the pectoral region include the **acromiotrapezius** muscles that originate on the spinous processes of the cervical and first thoracic vertebrae and insert on the scapula to move it forward and toward the middorsal line; the **spinotrapezius** also originates on the spines of thoracic vertebrae, inserts on the scapula, and functions to move it dorsally and posteriorly. In humans, the trapezius is a single muscle but its origins and insertions are similar to the group of trapezius muscles of the pig. Other muscles shown here serve to move the forelimb and the hind limb.



Answer Key:

a. Acromiotrapezius muscle
b. First thoracic vertebra
c. Spinotrapezius muscle
d. Triceps muscle
e. Latissimus dorsi muscle
f. Spinous processes of vertebrae
g. Iliac crest of hip bone
h. Tensor fasciae latae muscle
i. Gluteus medius muscle
j. Gluteus superficialis muscle
k. Biceps femoris muscle

Like other mammals, the pig has an internal cavity within which many major organs develop, including those of the digestive, respiratory, circulatory, and excretory systems. In order to view these organs during dissection, one must carefully open the superficial layers of skin and muscle to reveal the organs beneath. Their arrangement in relation to one another is often important to their functions. Therefore, although we will examine each system in detail later, it is important that you understand how they fit together.

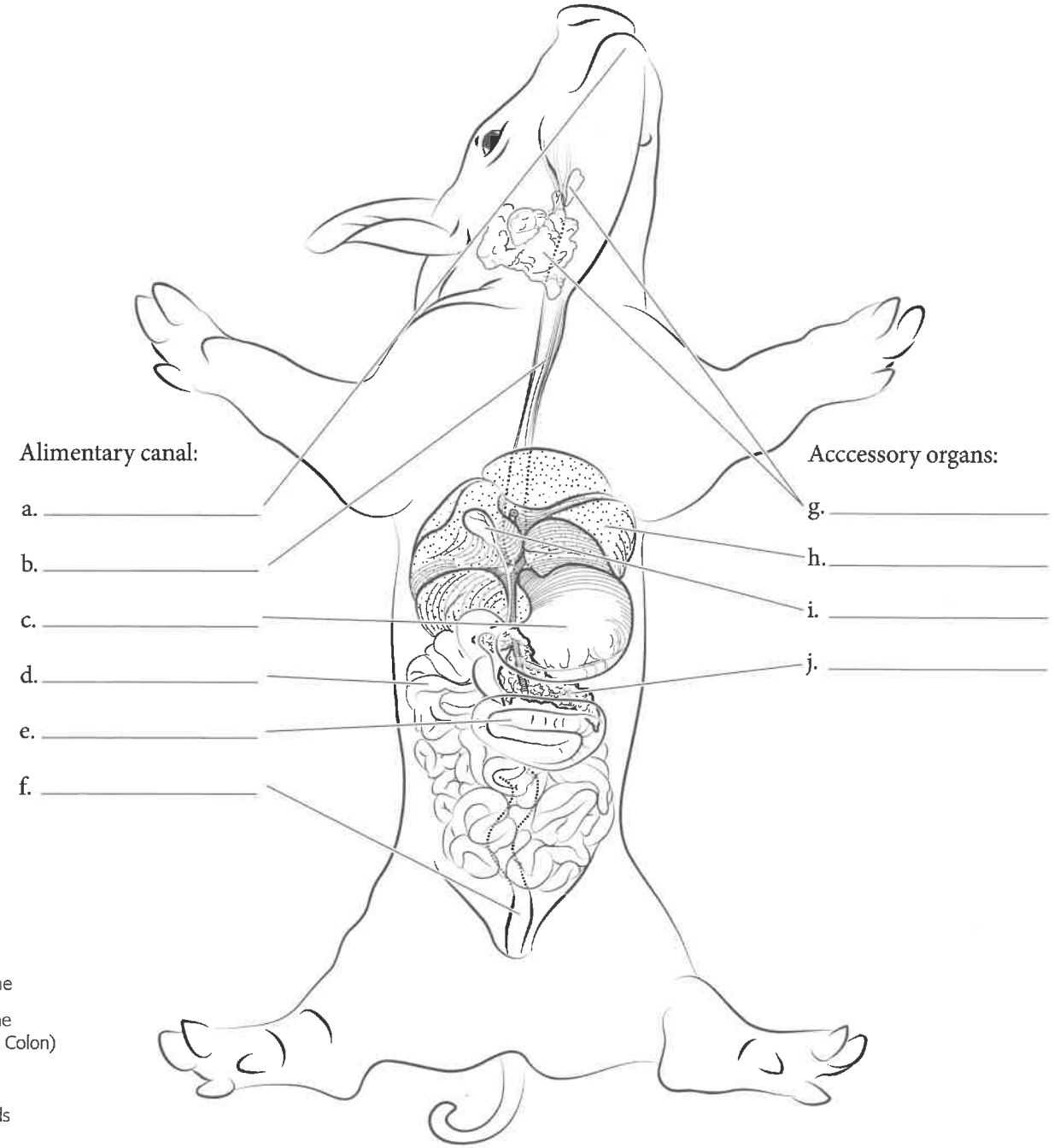
From the ventral aspect in the neck region, one can see the thyroid cartilage of the larynx and the trachea of the respiratory system, both located ventral to the esophagus which serves the digestive system. Nearby, blood vessels carry blood to the head region.

The large body cavity in the trunk, the coelom, is divided into two major regions by the **diaphragm**—a muscular organ of the respiratory system. The cranial portion is called the thoracic cavity and contains the heart and lungs, as well as many important blood vessels of the circulatory system and air passages of the respiratory system. The esophagus of the digestive system passes through the thoracic cavity dorsal to these other organs.

The caudal portion of the coelom is the abdominal cavity, which includes many organs of the digestive, excretory, reproductive, and endocrine systems. The esophagus emerges through the diaphragm into the stomach, and the digestive system continues with the small and large intestines. Accessory organs in the digestive system include the liver and pancreas. The excretory system includes paired kidneys which lie dorsal to the abdominal cavity, and the ventral urinary bladder, which is shown deflected away to reveal the other organs. The reproductive organs form in the abdominal cavity (female) or near the kidneys (male), but cannot be seen in this view. The only endocrine organ visible from this view is the pancreas, which contains endocrine tissue as well being a part of the digestive system.

In this overview diagram, you will find it useful to color the organs using a different color for each system. Begin to use the convention that arteries are colored bright red to denote oxygenated blood, while veins are colored bright blue to represent deoxygenated blood.

Like humans, pigs are omnivores, and their digestive system is more like humans than other mammals. This means that the digestive system is optimized for ingesting and digesting both animal flesh and herbaceous materials. The digestive system is essentially a long tube running from the **mouth** where food is ingested, through specialized digestive regions such as the stomach and intestines, to the anus where undigested waste materials are eliminated; in all, the pig's intestinal tract is about 15 times the length of its body! From the mouth, food travels through the **esophagus** into the **stomach**, which is very acidic and begins the digestion of proteins. In the **small intestine**, most digestion of protein, carbohydrate, and fat occurs, as well as the nearly all absorption of these nutrients; it may be divided into three regions—a short duodenum, long jejunum, and short ileum. In the large intestine or **colon**, water is absorbed, microorganisms may break down some undigested nutrients, and the wastes are compacted for elimination. The pig's colon is structured differently from the human: Although relatively longer than that in humans, the pig's colon is not much larger in diameter than the small intestine. In addition, the ascending colon is arranged in a highly coiled structure called the **spiral colon**, which leads to the transverse and descending colon. The final straight stretch of colon before the anus is the **rectum**. The digestive system also includes the associated organs that assist in processing the food, such as the **liver**, **gall bladder**, and **pancreas**.



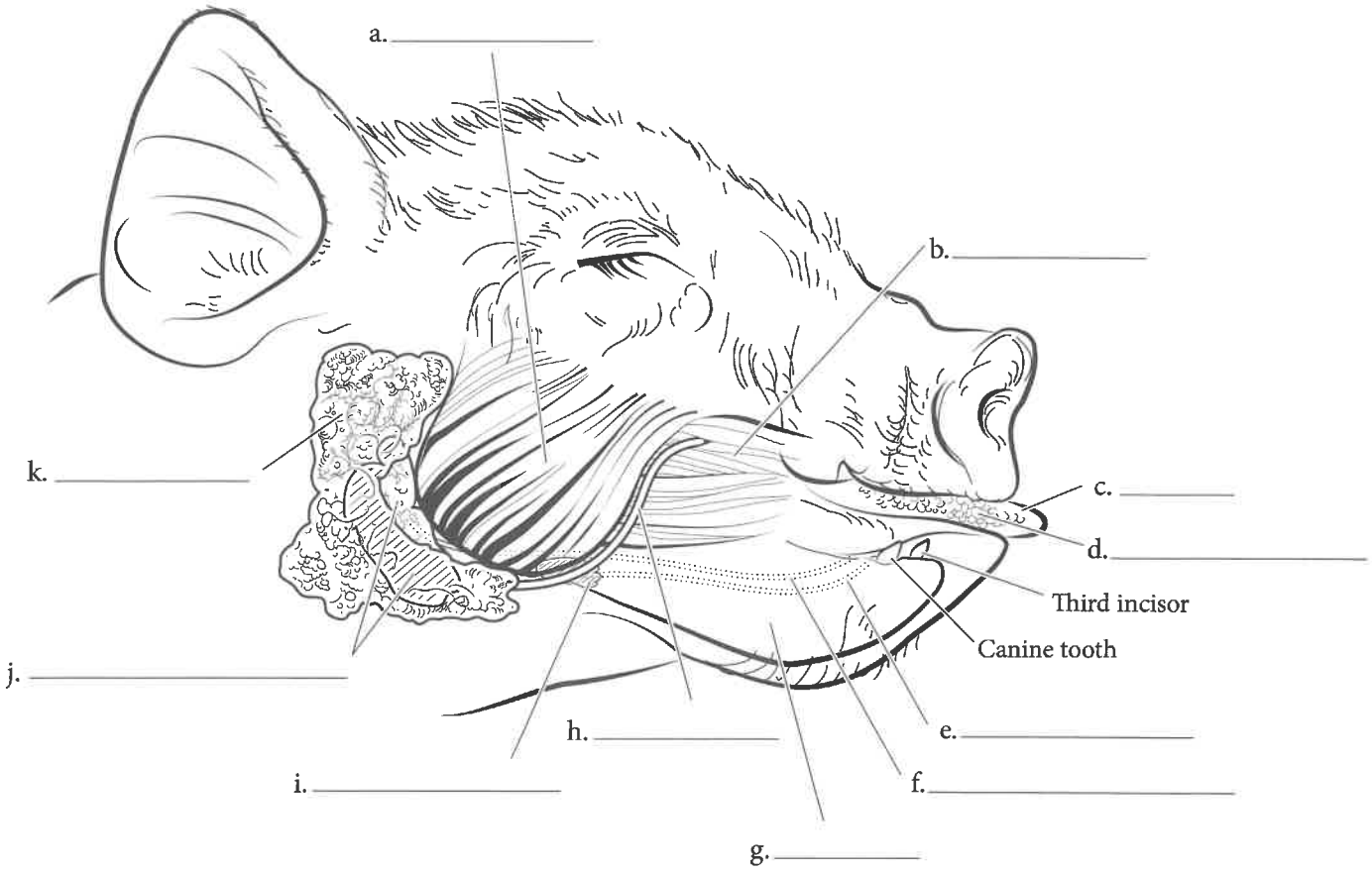
Answer Key:

a. Mouth
b. Esophagus
c. Stomach
d. Small intestine
e. Large intestine (Spiral colon, Colon)
f. Rectum
g. Salivary glands
h. Liver
i. Gall bladder
j. Pancreas

SALIVARY GLANDS

Below the skin of the head are a number of structures that play a role while digestion is beginning in the mouth. Jaw muscles that provide power for biting and chewing include the masseter which closes the jaw and the **buccinator** which helps in closing the jaw as well as keeping the cheeks taut during chewing. Also important in biting and chewing are teeth; adult pigs have 42 teeth—three **incisors**, one **canine**, four **premolars**, and three **molars** on each side of the upper jaw; three incisors, one canine, three premolars, and three molars on each side of the lower jaw.

Salivary glands begin the process of digestion as food is chewed; saliva provides water to moisten food, mucus to lubricate food, salivary amylase to begin digesting starches, and antibacterial agents to kill microorganisms in the mouth. The parotid gland is located superficial to the masseter muscle; the **submadibular gland** is found deep to the **parotid gland** and posterior to the masseter; and the **sublingual gland** is located ventrally. Each has a duct to carry saliva from the gland into the oral cavity.



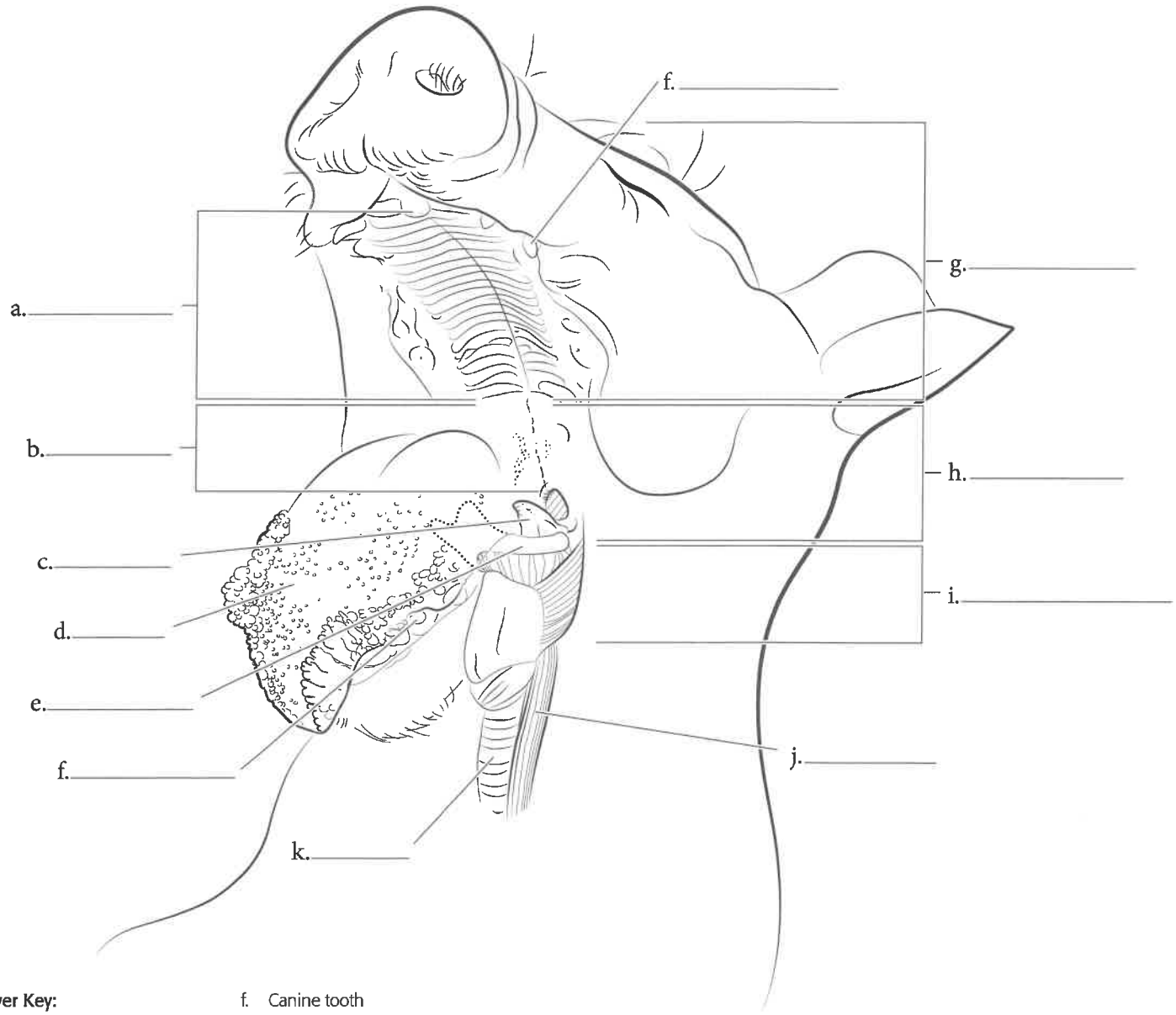
Answer Key:

a. Masseter muscle
b. Buccinator muscle
c. Tongue
d. Marginal papillae
e. Sublingual duct
f. Submandibular duct
g. Mandible
h. Parotid duct
i. Sublingual gland
j. Submandibular gland—deep to parotid gland (Mandibular, Submaxillary)
k. Parotid gland

ORAL CAVITY AND PHARYNX

Opening the oral cavity widely allows one to view the structure of this important portal to the digestive system, and to understand how it interfaces with the respiratory system. Food enters the oral cavity through the mouth, is chewed and formed into a compact mass by the teeth and **tongue**, and leaves the oral cavity through the esophagus. The throat, or **pharynx**, is a common passageway with regions that serve both the digestive and respiratory systems. The roof of the oral cavity is formed by the bony **hard palate** which separates it from the nasal cavity; the **soft palate** continues caudally—it separates the **nasopharynx** dorsally from the **oropharynx** below. The **laryngopharynx** is dorsal to the larynx and leads to the esophagus which carries food to the stomach.

The cartilaginous **epiglottis** prevents swallowed food from entering the **glottis**—the opening to the **larynx**, which then opens into the **trachea** or windpipe. The **hyoid** is a bone at the base of the tongue that supports and interacts with the cartilage of the larynx. Besides the teeth, the major structure in the oral cavity is the tongue, a muscular organ with taste buds located on its surface. Notice the marginal papillae that form a fringe-like edge to the tongue in the fetal pig and assist the newborn in suckling. As the pig's diet gradually changes from milk to solid food, the marginal papillae will regress.

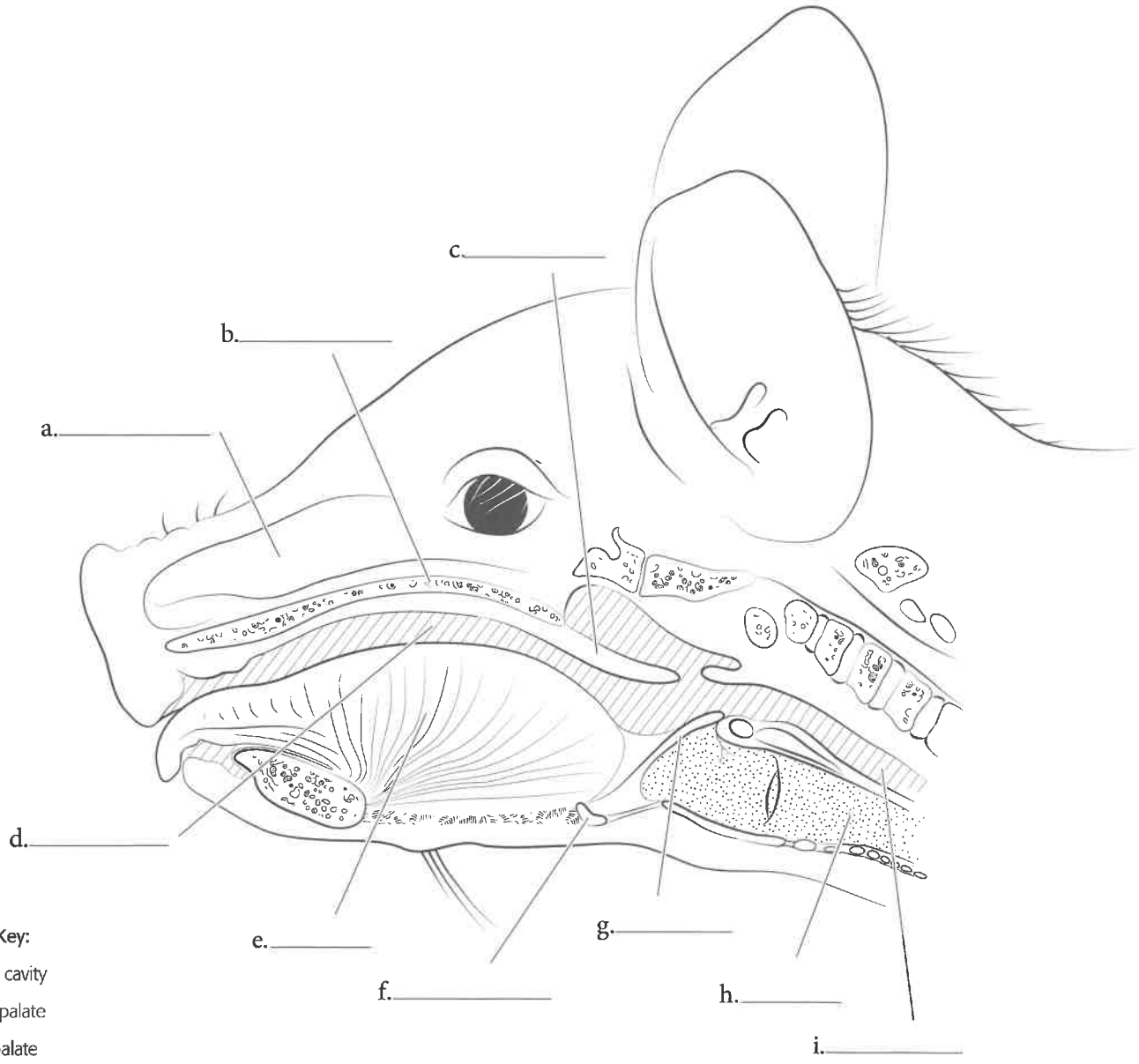


Answer Key:

a. Hard palate
b. Soft palate
c. Epiglottis
d. Tongue
e. Hyoid bone
f. Canine tooth
g. Nasopharynx
h. Oropharynx
i. Laryngopharynx
j. Esophagus
k. Trachea

SAGITTAL SECTION HEAD AND NECK, SWALLOWING

A sagittal section provides another view of the digestive and respiratory systems in the head. Follow the paths of food and air during swallowing and breathing. During swallowing, muscles contract to raise the tongue so that it presses food and water against the hard palate. The tongue then elevates the soft palate and pushes the epiglottis over the glottis to partially close the laryngeal opening, as shown in this illustration. Pharyngeal muscles force food and water into the esophagus; smooth muscle contractions there carry the material on to the stomach. Draw an arrow showing the path of food during swallowing, naming each region it moves through and the structures that influence its path. After swallowing is complete, the muscles at the base of the tongue relax, allowing the epiglottis to move forward again, and opening the glottis to air passage. Using another color, draw an arrow to show where air moves when the individual is not swallowing.

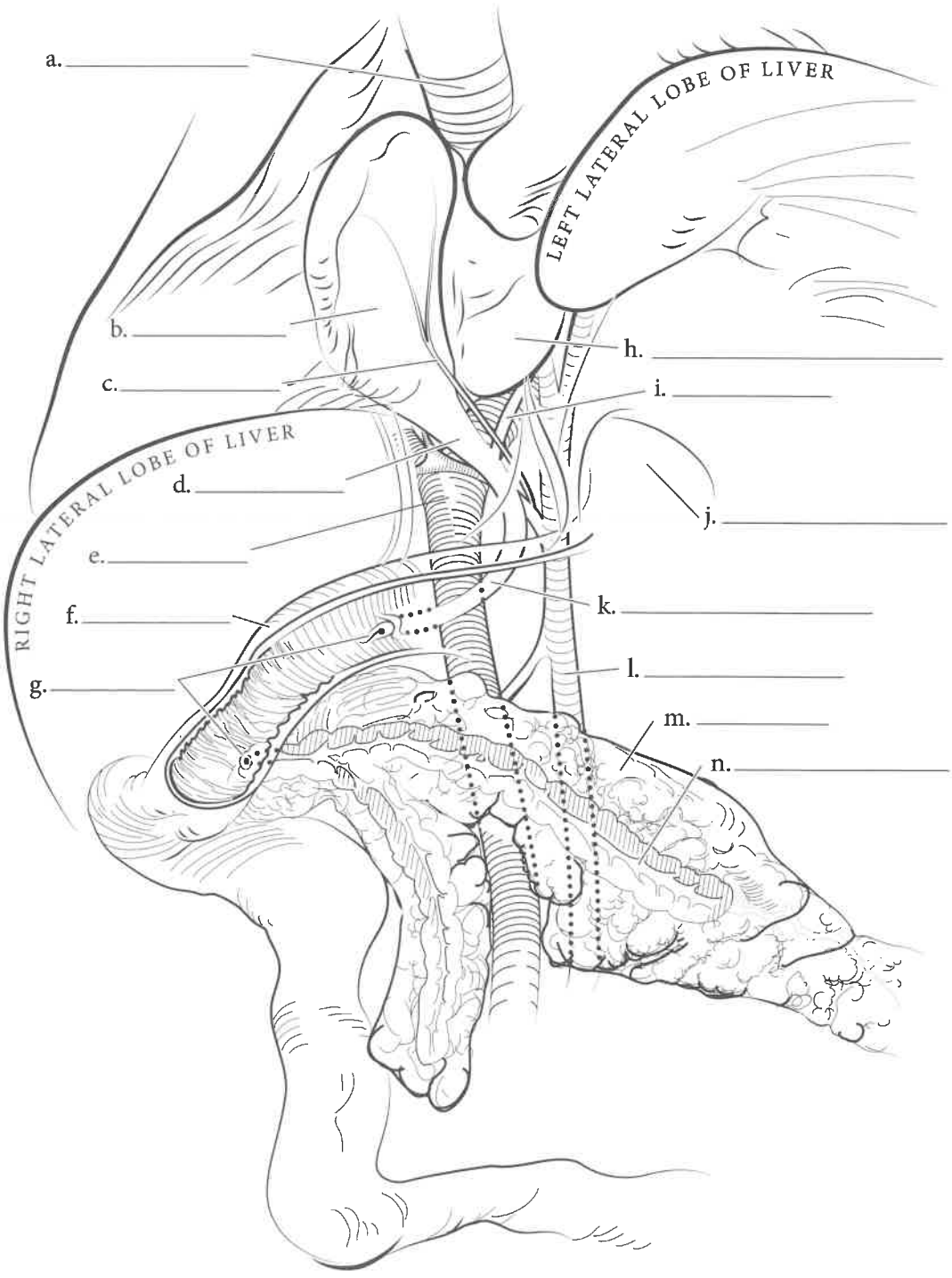


Answer Key:

a. Nasal cavity
b. Hard palate
c. Soft palate
d. Oral cavity
e. Tongue
f. Hyoid bone
g. Epiglottis
h. Trachea
i. Esophagus

GALL BLADDER AND PANCREAS

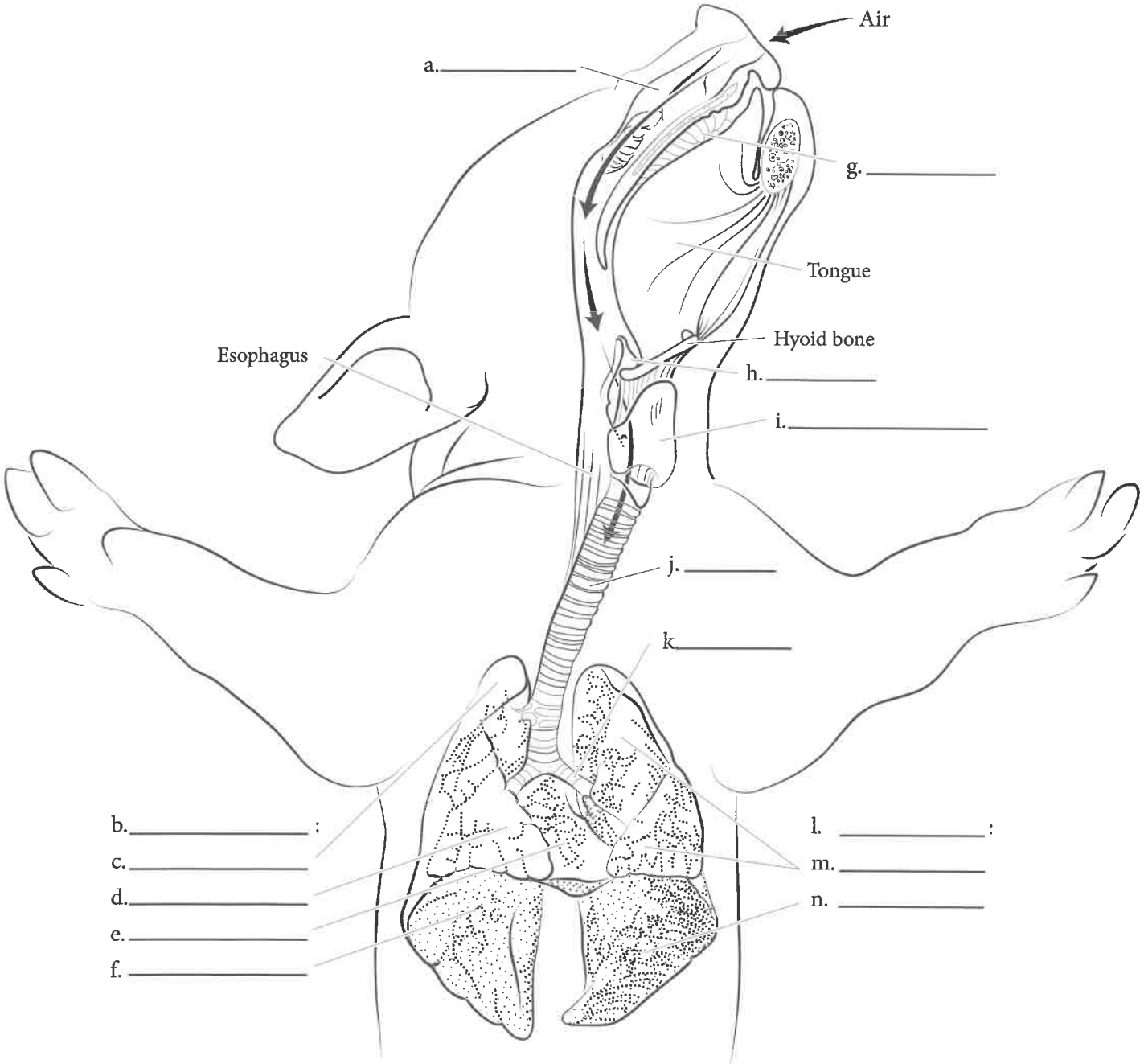
Accessory organs of the digestive system are shown from the ventral aspect, as they lie in the abdominal cavity adjacent to the small intestine. The largest organ of the abdomen is the liver; in the pig there are five lobes—right lateral, right central, left central, left lateral, and caudate. (In contrast the human has four lobes—right, left, caudate, and quadrate.) Nutrients absorbed during digestion are delivered first to the liver through the **hepatic portal vein**, which collects blood from the capillaries serving the intestines. The liver functions include detoxification of various chemicals; recycling of degraded red blood cell components; storage of excess glucose as glycogen; metabolism of carbohydrates, lipids, and proteins; and synthesis of plasma proteins, cholesterol, and bile. Between the right medial and quadrate lobes of the liver is the greenish-brown gall bladder; it functions to store bile made by the liver, and to release it when needed for digestion and absorption of lipids in the small intestine. Bile drains from the gall bladder through the **cystic duct** to the **common bile duct** (which also drains the **hepatic duct** bringing bile directly from its synthesis in the liver) and then enters the **duodenum**, the first section of the small intestine. The pancreas is an elongated, granular organ lying between the stomach and the small intestine. The pancreas functions in digestion by secreting digestive enzymes and bicarbonate into the small intestine via the **pancreatic duct**. Another function of the pancreas is endocrine in nature—the islets of Langerhans scattered throughout the organ secrete insulin and glucagon directly into the bloodstream where they are carried throughout the body and function to lower and raise blood glucose, respectively; somatostatin is also secreted to regulate both insulin and glucagon levels.



Answer Key:

a. Umbilical vein
b. Gall bladder
c. Cystic artery
d. Cystic duct
e. Portal vein
f. Duodenum
g. Ampullae of duodenum
h. Quadrate lobe of liver
i. Hepatic duct
j. Esophageal notch of liver
k. Common bile duct
l. Hepatic artery
m. Pancreas (dissected to reveal pancreatic duct)
n. Pancreatic duct

The respiratory system is responsible for bringing oxygen into the **lungs** where it diffuses into the bloodstream, and for carrying off carbon dioxide waste. The respiratory system begins at the snout, where air enters the **nasal cavity** through the external nares. After passing through the pharynx, which is shared with the digestive system, air enters the trachea through an opening called the glottis. The glottis is protected by a flap of tissue—the epiglottis—which prevents food and water from entering the respiratory passages. After passing through the larynx, which contains the vocal cords and is protected by the thyroid cartilage, air enters the trachea. The trachea is held open for air passage by cartilaginous rings, which are incomplete on the dorsal side. The trachea divides to form two **bronchii** for air to enter both of the paired lungs. As in humans, each lung is divided into lobes; in the pig, the right lung has four lobes instead of three, while the left has two lobes as in humans. The diaphragm is a bell-shaped muscle that completely separates the thoracic and abdominal cavities, by its attachment to the body wall in all directions. To function in breathing, the sheet-like diaphragm muscle contracts, moving it downward to enlarge the thoracic cavity. As the lungs expand with the thoracic cavity, air is drawn in. As the diaphragm relaxes and space for the lungs decreases, air is forced out.

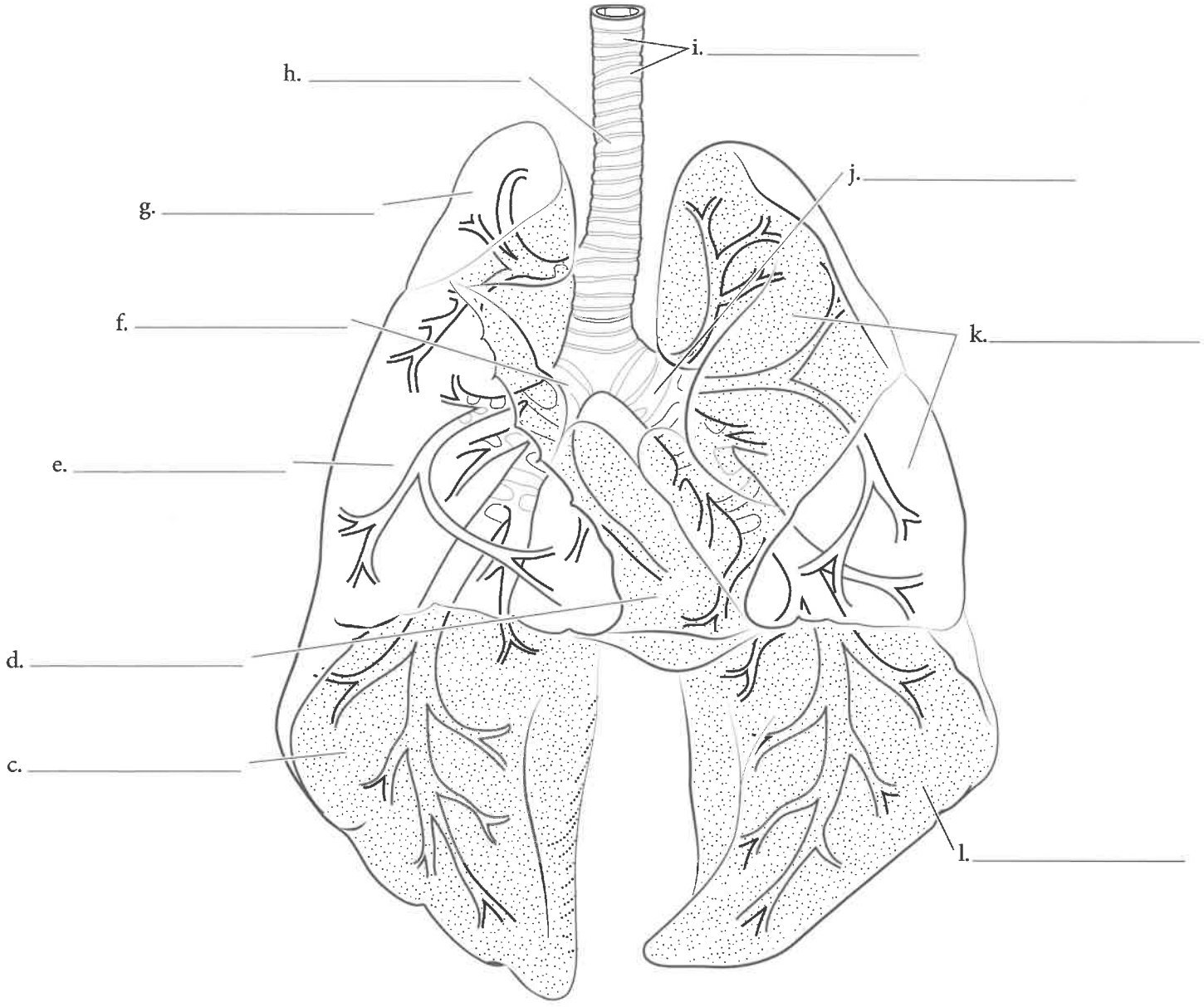


Answer Key:

a. Nasal cavity
b. Right lung
c. Cranial lobe
d. Middle lobe
e. Caudal lobe
f. Accessory lobe
g. Oral cavity
h. Epiglottis
i. Thyroid cartilage
j. Trachea
k. Bronchus
l. Left lung
m. Cranial lobe
n. Caudal lobe

LUNG, TRACHEA, AND BRONCHI

The right lung has four lobes—**cranial, middle, caudal,** and **accessory,** while the left has only two lobes—**cranial** and **caudal,** although the cranial lobe is divided by a deep fissure into two sections. In the fetal pig, this tissue is quite compact since the pig has never taken a breath and inflated the lungs. After birth, however, the lungs become quite spongy when air reaches all parts of the lung in a branching system of tubes, beginning with the trachea which brings air from the larynx into the thoracic cavity. The trachea divides into two bronchi which then branch into many **bronchioles** that eventually terminate in the **alveoli** where gas exchange takes place. The lungs are also liberally supplied with blood vessels—so that the blood can take up oxygen from the air and release waste carbon dioxide at the same time.

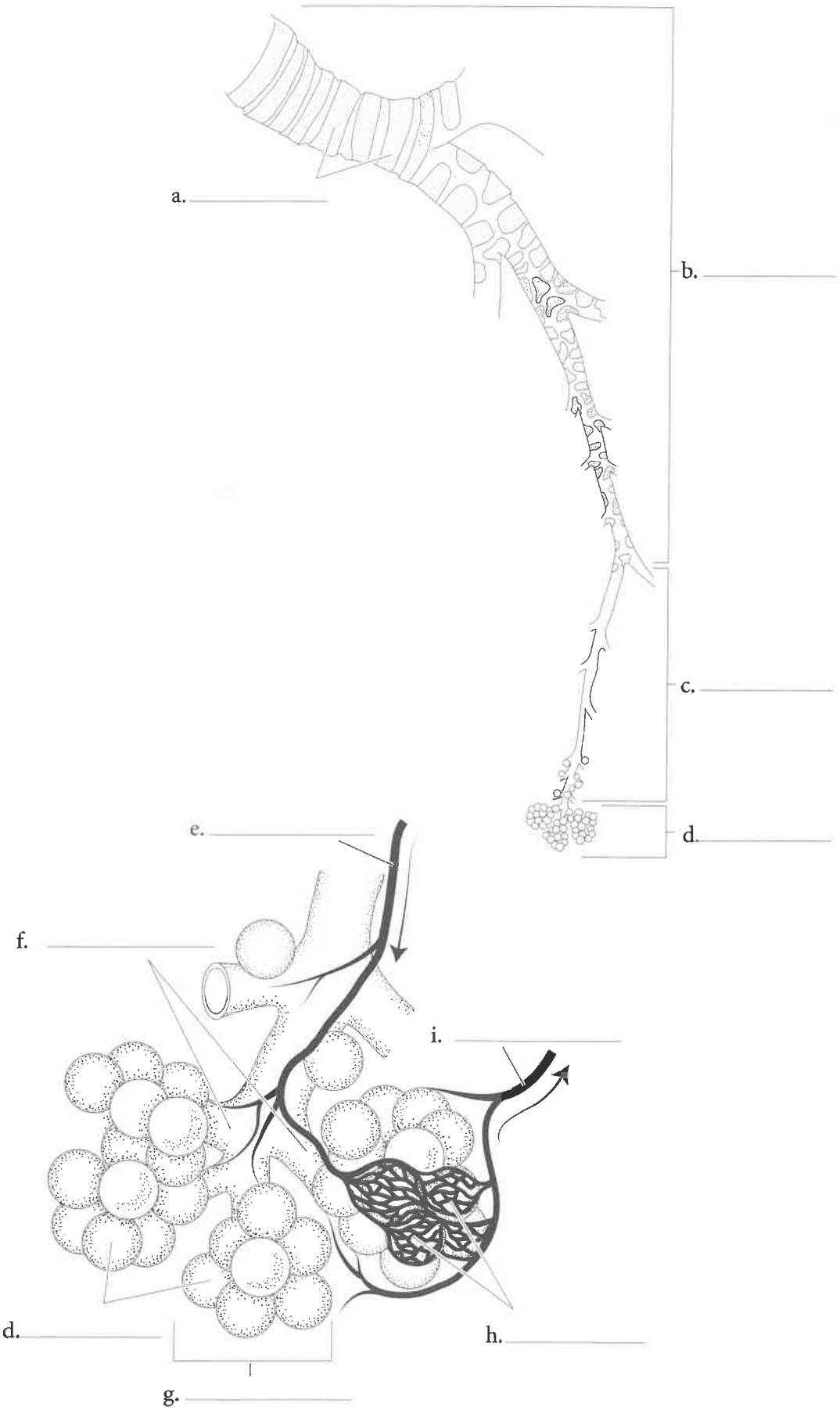


Answer Key:

a. Right lung
b. Left lung
c. Right caudal lobe
d. Right accessory lobe
e. Right middle lobe
f. Right bronchus
g. Right cranial lobe
h. Trachea
i. Tracheal cartilages
j. Left bronchus
k. Left cranial lobe
l. Left caudal lobe

BRONCHI AND ALVEOLI

Large ducts such as the trachea and bronchi cannot maintain an open air passage without structural support from cartilage in their walls. The bronchial walls also have layers of smooth muscle and the lumen can expand or contract. Smaller bronchioles do not require cartilage for structural support and continue to branch until each branch of the bronchiole ends in a thin-walled chamber—the alveolus. The thin epithelial cells of the alveolus are in intimate contact with the thin-walled capillaries, allowing gas exchange to take place between the air in the alveolus and the blood in the capillaries. This oxygenated blood that has also been cleansed of excess carbon dioxide will return to the heart to be circulated to all tissues of the body for a fresh supply of oxygen. It is important to remember that, unlike the systemic circulation, pulmonary arteries carry deoxygenated blood (usually colored blue) while pulmonary veins carry oxygenated blood (usually colored bright red).



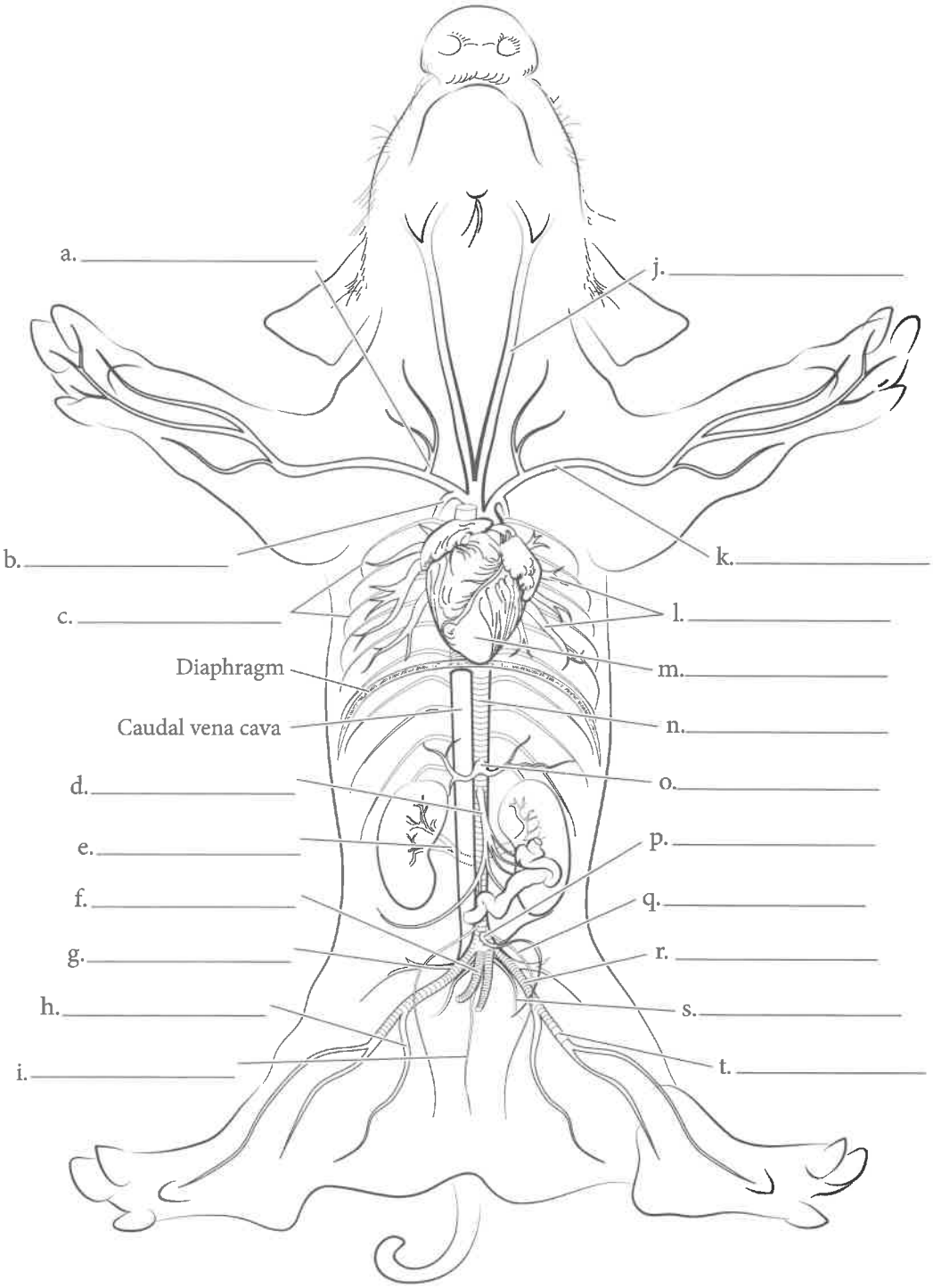
Answer Key:

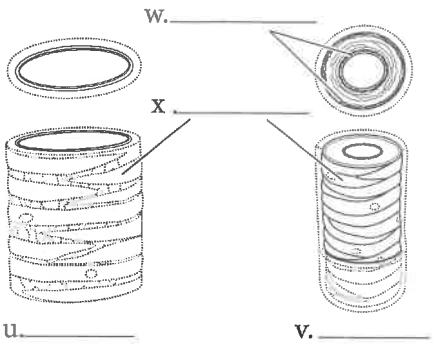
a. Cartilage
b. Bronchi
c. Bronchioles
d. Alveoli
e. Pulmonary artery
f. Alveolar ducts
g. Alveolar sac
h. Capillaries
i. Pulmonary vein

The circulatory system transports nutrients, oxygen, carbon dioxide, hormones, and dissolved waste products to and from individual cells. The circulatory system itself includes a four-chambered heart along with networks of vessels to carry blood between the heart and tissues throughout the body. Pigs have a double circulation—a pulmonary circuit to the lungs and a systemic system to distribute the oxygenated blood to the rest of the body.

Arteries are thick-walled vessels because they have a substantial layer of smooth muscle and elastic fibers, which allows for expansion of vessels during heart contractions and modulation of blood pressure by constricting or dilating the arteries. Arterial distribution of blood occurs through the **pulmonary trunk** and **aort**—the great vessels that leave the heart. The pulmonary trunk divides into right and left **pulmonary arteries**; each further branches to provide blood to each of the lobes of the lung. The aorta divides as it arches to the left shortly after exiting the heart; the **ascending aorta** supplies blood to regions anterior to the heart, and the **descending aorta** serves tissues and organs posterior to the heart.

Names of arteries are usually related to the organs and tissues they supply or to their location in the body. Although it is occasionally difficult to discern that connection, learn each artery's name along with the parts of the body supplied by it as you color each vessel. Label the structures in the diagrams—following convention, color arteries red. The exception is to color the pulmonary arteries blue (because they carry deoxygenated blood away from the heart).





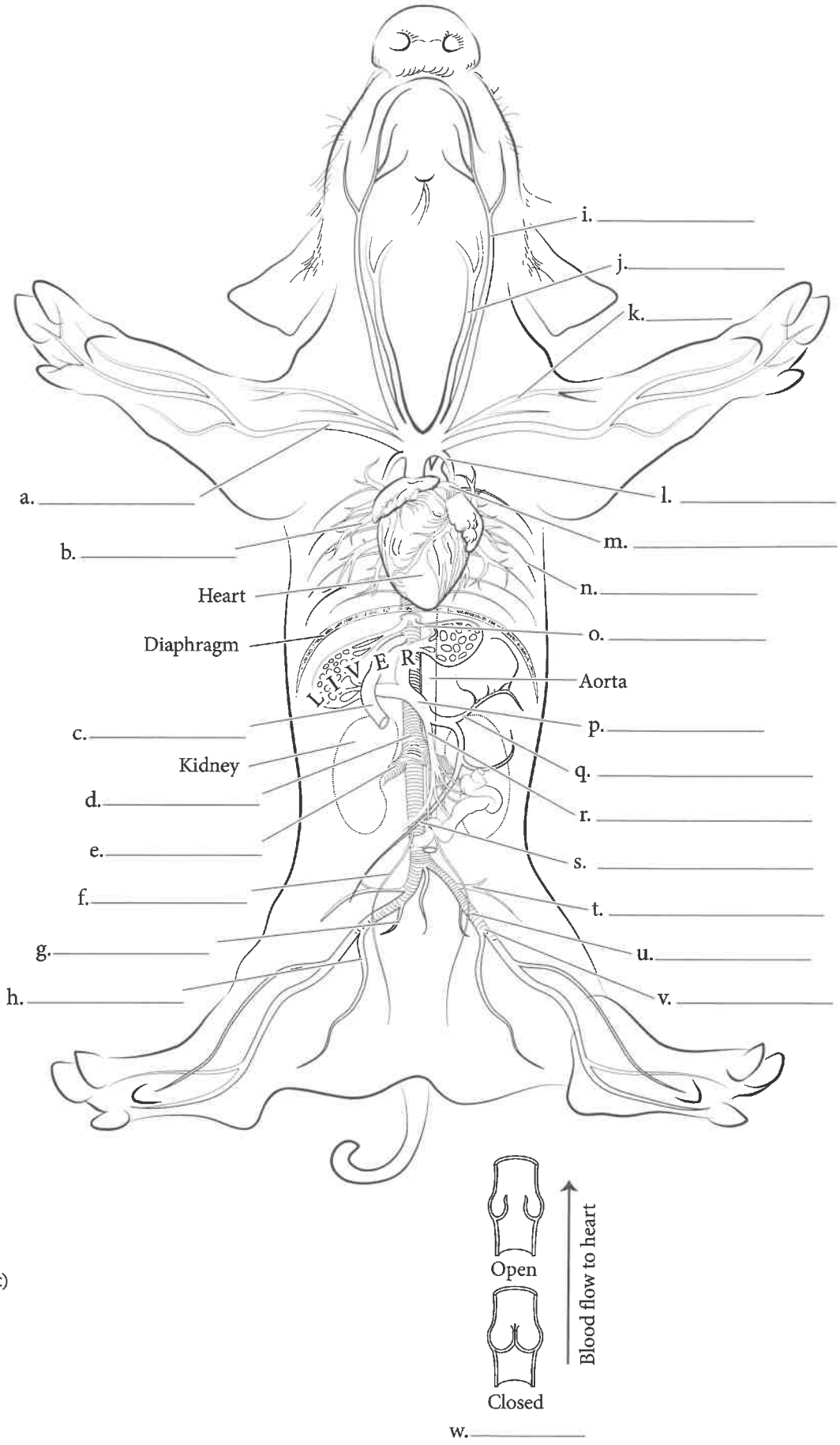
Answer Key:

a. Thyrocervical trunk
b. Internal thoracic
c. Intercostal
d. Cranial mesenteric
e. Renal
f. Umbilical (cut)
g. Circumflex iliac
h. Deep femoral
i. Median sacral
j. Common carotid
k. Subclavian
l. Pulmonary
m. Heart
n. Aorta
o. Celiac
p. Caudal mesenteric
q. Genital
r. External iliac
s. Internal iliac
t. Femoral
u. Vein
v. Artery
w. Elastic fibers
x. Smooth muscle

VENOUS SYSTEM

The walls of **veins** are thinner than those of arteries, and they have little smooth muscle or elastic fibers. They can expand to accept blood but do not actively contract again. However, veins have one-way valves to prevent backflow. Veins carry blood back to the heart; **pulmonary veins** (two from each side) enter the heart directly as they return blood which has been oxygenated in the lungs. The veins of the systemic circulation empty into the **cranial** or **caudal vena cava**. The two venae cava enter the right atrium independently.

Again, the names of veins are usually related to their location and function. As you color each vein, learn its name along with the parts of the body that it drains. Label the structures in the diagram—again, following convention, color veins blue. The exception is to color the pulmonary veins red (because the blood here is oxygenated).



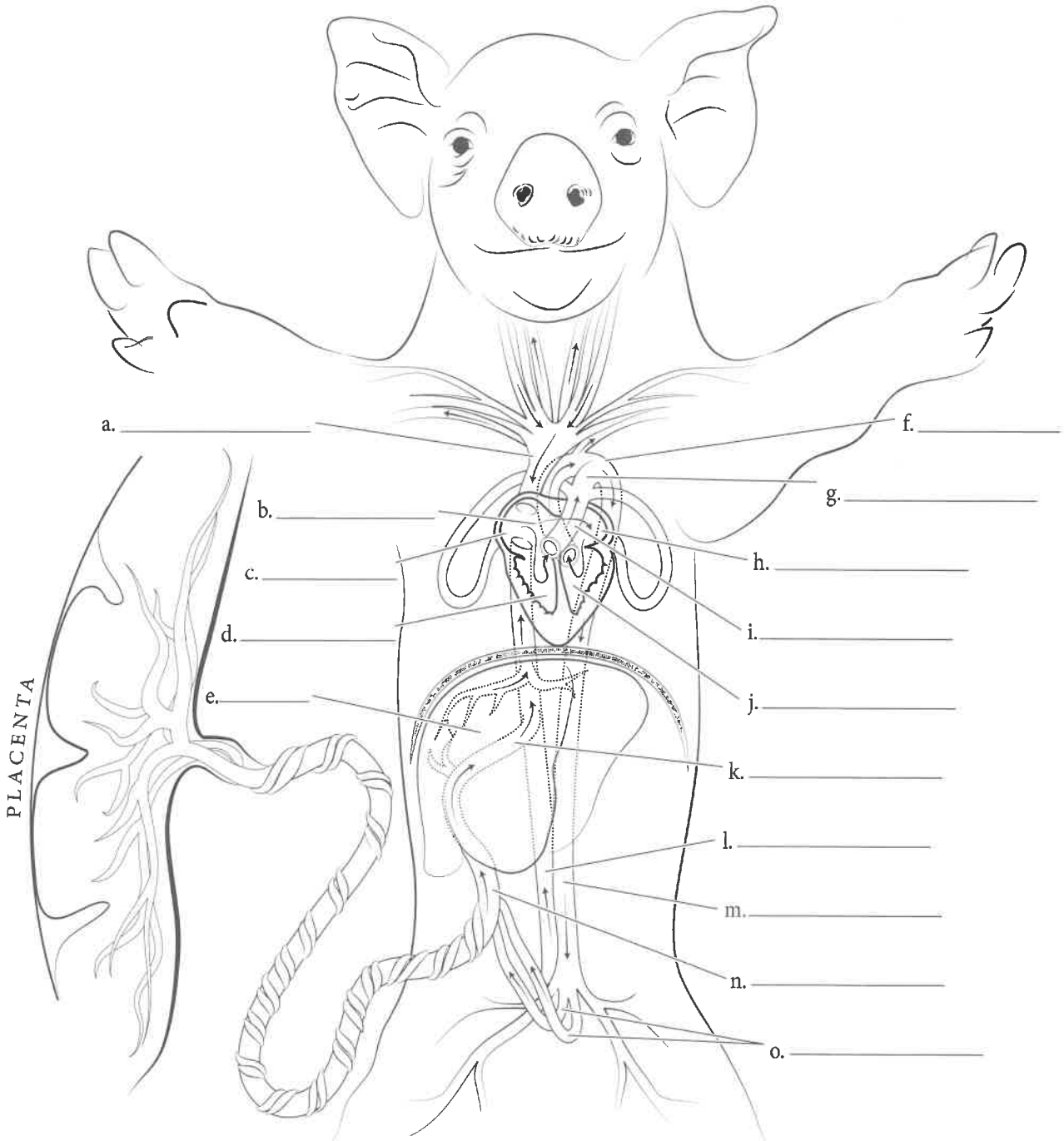
Answer Key:

a. Right subclavian
b. Pulmonary
c. Umbilical (cut)
d. Caudal vena cava (Inferior vena cava)
e. Right renal
f. Genital
g. Internal iliac
h. Deep femoral
i. External jugular
j. Internal jugular
k. Cephalic
l. Internal thoracic
m. Pulmonary trunk
n. Intercostal
o. Hepatic
p. Portal
q. Gastro-splenic
r. Cranial mesenteric (Superior mesenteric)
s. Caudal mesenteric (Inferior mesenteric)
t. Circumflex iliac
u. External iliac
v. Femoral
w. Venous valve

FETAL CIRCULATION

Since a fetal pig has not yet breathed air on its own, its blood is oxygenated externally in the placenta rather than in the lungs; several fetal adaptations make distribution of oxygen and nutrients more efficient. These "shortcuts" will close shortly after birth to allow blood to flow to the lungs for gas exchange.

The umbilical arteries bring fetal blood to capillaries of the placenta where gases and nutrients can diffuse between fetal and maternal blood. Oxygenated and nutrient-rich blood then returns to the fetus through the umbilical vein, which joins the hepatic portal vein and enters the liver. However, much of the blood instead goes through a "bypass" called the **ductus venosus**, from the umbilical vein directly into the caudal vena cava—and proceeds to the heart for distribution to the rest of the body. Reaching the right atrium, this blood would normally be destined for the lungs, but in the fetus, a hole called the **foramen ovale** between the two atria allows the blood from the umbilical vein to pass largely from the vena cava through the right atrium and into the left atrium, from which it is pumped into the systemic circulation. A final fetal adaptation is the **ductus arteriosus**, which allows oxygen-poor blood to largely bypass the lungs. Instead, much of the blood entering the pulmonary trunk is shunted over to the aorta, shortly after the arteries to the head and neck have branched off, allowing oxygen-poor blood to mix with nutrient-rich blood destined for the posterior half of the body, including



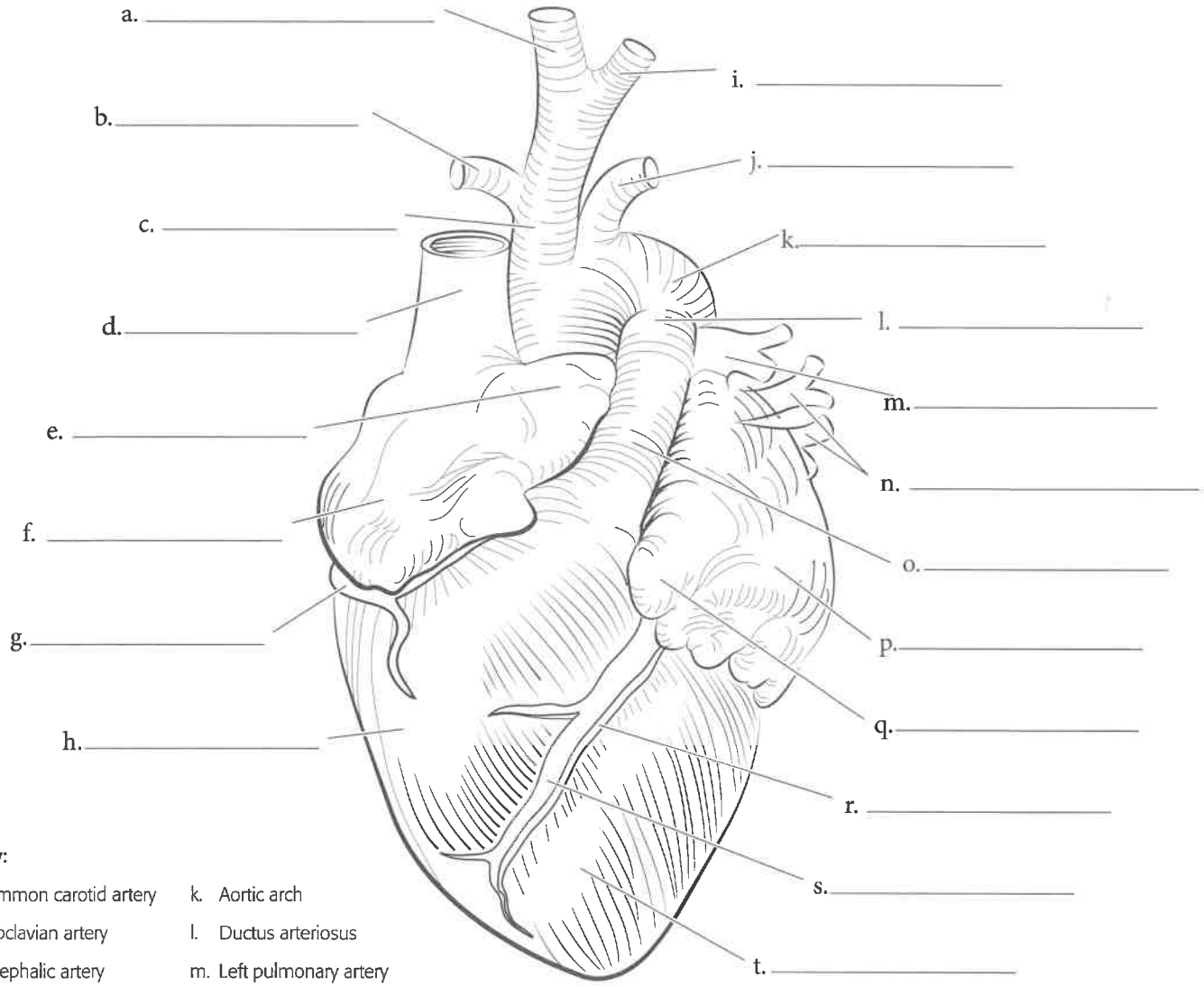
Answer Key:

a. Cranial vena cava
b. Foramen ovale
c. Right atrium
d. Right ventricle
e. Liver
f. Aortic arch
g. Ductus arteriosus
h. Left atrium
i. Pulmonary trunk
j. Left ventricle
k. Ductus venosus
l. Caudal vena cava
m. Aorta
n. Umbilical vein
o. Umbilical arteries

VENTRAL HEART

Seen from the ventral aspect, the left atrium and ventricle are on the right, the right atrium and ventricle are on the left. The apex or base points caudally; the great vessels emerge at the cranial end of the heart. **Coronary arteries** are obvious on the surface of the heart; they emerge from the base of the aorta too deep for the source to be visible externally. The large **left coronary vein** is also seen on this aspect. The pulmonary trunk is the most obvious great vessel; the aorta arises from the left ventricle behind the pulmonary trunk, divides to give rise to the brachocephalic and left subclavian arteries, and arches to the left. As the aorta passes over the pulmonary trunk in the fetus, the ductus arteriosus connects the two vessels to shunt more of the blood away from the non-functional lungs and into the aorta. From this aspect, the cranial vena cava is evident as it enters the right atrium; the caudal vena cava enters the same atrium on the dorsal, caudal side. This deoxygenated blood goes from the right atrium, into the right ventricle, and out the pulmonary trunk. Distal to the ductus arteriosus, the pulmonary trunk divides to form the left and right pulmonary arteries to supply the lungs. Blood returning from the lungs through the pulmonary veins enters the left atrium, on its way to the left ventricle and the aorta.

Label all vessels entering or emerging from the heart; color them appropriately according to the oxygenation status of the blood. To do this properly, you will need to know the role each plays in the systemic or pulmonary circulation, so it is a good time to test yourself on your ability to trace the path of blood through both circulations, and through the heart.

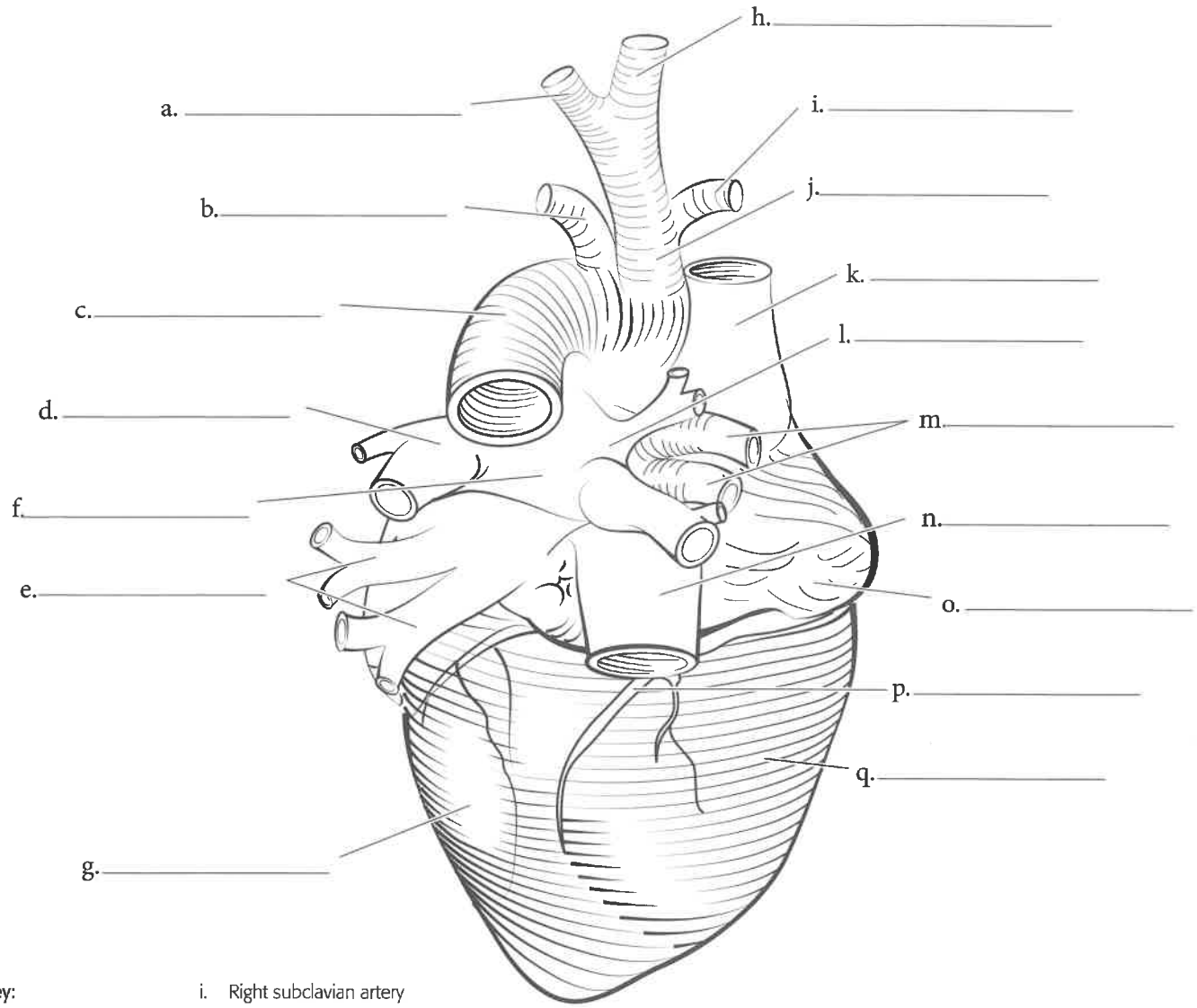


Answer Key:

a. Right common carotid artery
b. Right subclavian artery
c. Brachiocephalic artery
d. Cranial vena cava
e. Right auricle
f. Right atrium
g. Right coronary artery
h. Right ventricle
i. Left common carotid artery
j. Left subclavian artery
k. Aortic arch
l. Ductus arteriosus
m. Left pulmonary artery
n. Left pulmonary veins
o. Pulmonary trunk
p. Left atrium
q. Left auricle
r. Left coronary artery
s. Great cardiac vein
t. Left ventricle

DORSAL HEART

On the dorsal aspect of the heart, the two pulmonary arteries are clearly visible below the aortic arch; each divides to provide blood flow to the individual lobes. Below them can be seen two pulmonary veins on each side as they enter the left atrium to return oxygenated blood from the lungs. Entering the right atrium are two large vessels—the cranial vena cava at the top, and the caudal vena cava below. They carry deoxygenated blood from the anterior and posterior parts of the systemic circulation into the right side of the heart to be pumped out the pulmonary trunk.



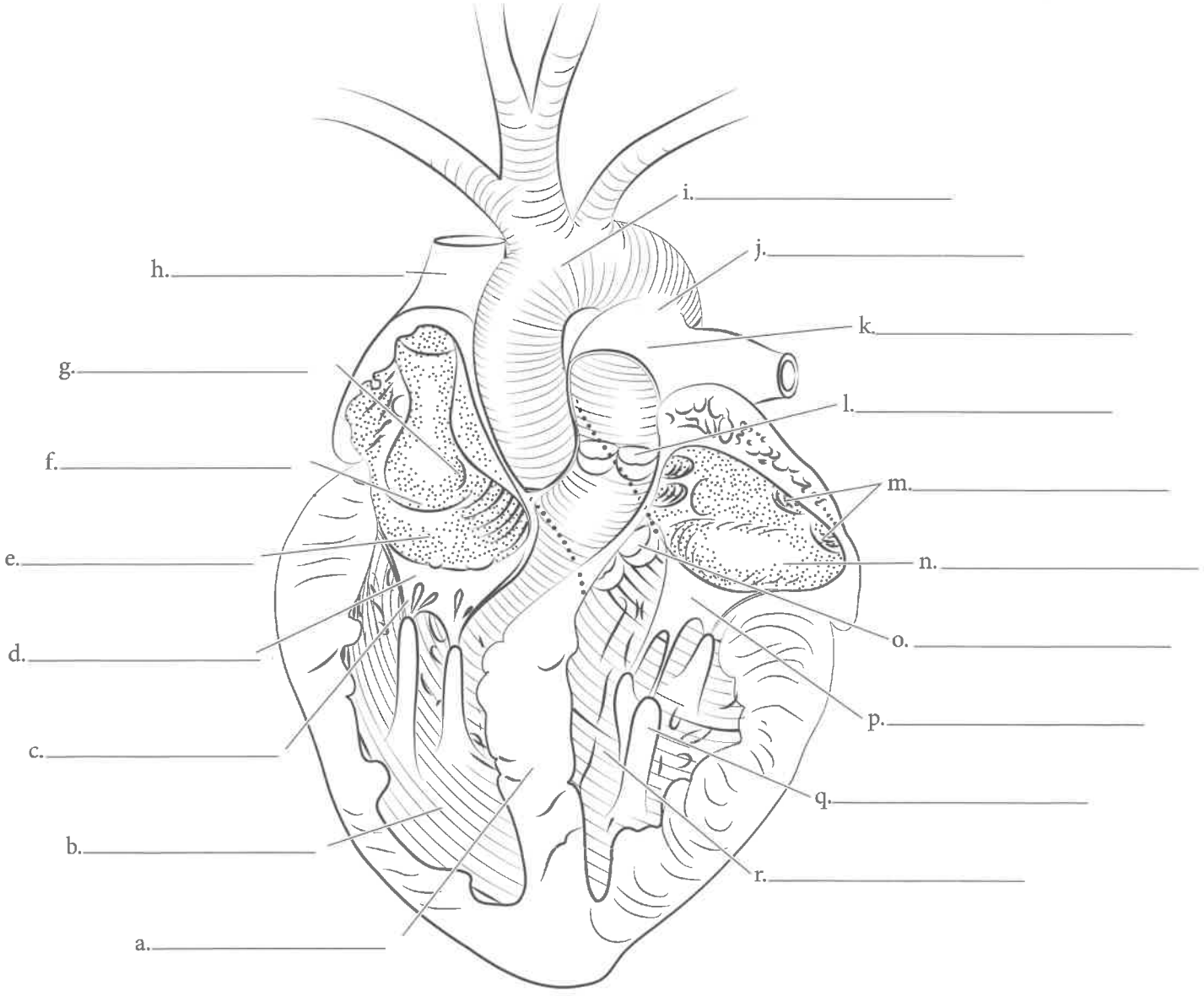
Answer Key:

a. Left common carotid artery
b. Left subclavian artery
c. Aortic arch
d. Left pulmonary artery
e. Left pulmonary veins
f. Left atrium
g. Left ventricle
h. Right common carotid artery
i. Right subclavian artery
j. Brachiocephalic artery
k. Cranial vena cava
l. Right pulmonary artery
m. Right pulmonary veins
n. Caudal vena cava
o. Right atrium
p. Right coronary artery
q. Right ventricle

FRONTAL PLANE OF HEART

Looking at the inside of the heart from the ventral view, all four chambers of the heart are visible. Color the structures in the same order as the blood flows to each on its route through the heart. Two kinds of valves keep the blood from flowing backwards. The **atrioventricular valves** open when the ventricle relaxes, allowing blood to flow from the atrium into the ventricle. These valves are connected via the **chordae tendinae** to papillary muscles which are stimulated to contract along with the adjacent ventricular muscle; this action pulls the valve flaps closed, preventing blood from backing up into the atrium when the ventricle contracts. On the right side, this valve is called the **tricuspid**, on the left it is called the **bicuspid** or sometimes the mitral valve, especially in humans. The other heart valves are **semilunar valves**, placed between the ventricles and the pulmonary trunk or the aorta; these cup-like valves close as they fill with blood when it begins to back up as the ventricle relaxes.

Atrial walls are quite thin as they only need to create enough force to empty the atrium into the ventricle when the atrioventricular valve opens. The interatrial septum is perforated by the foramen ovale in the fetus, allowing placental blood entering the right atrium through the caudal vena cava to largely exit to the left atrium for distribution throughout the systemic circulation. Note the interventricular septum between the two ventricles, and the thick ventricular walls which can contract with enough force to push the blood out of the heart, through the arteries, capillaries, and veins, and back to the heart again. The left ventricular wall is much thicker than the right since more force is needed to get blood throughout the systemic circulation than the shorter passage through the lungs.

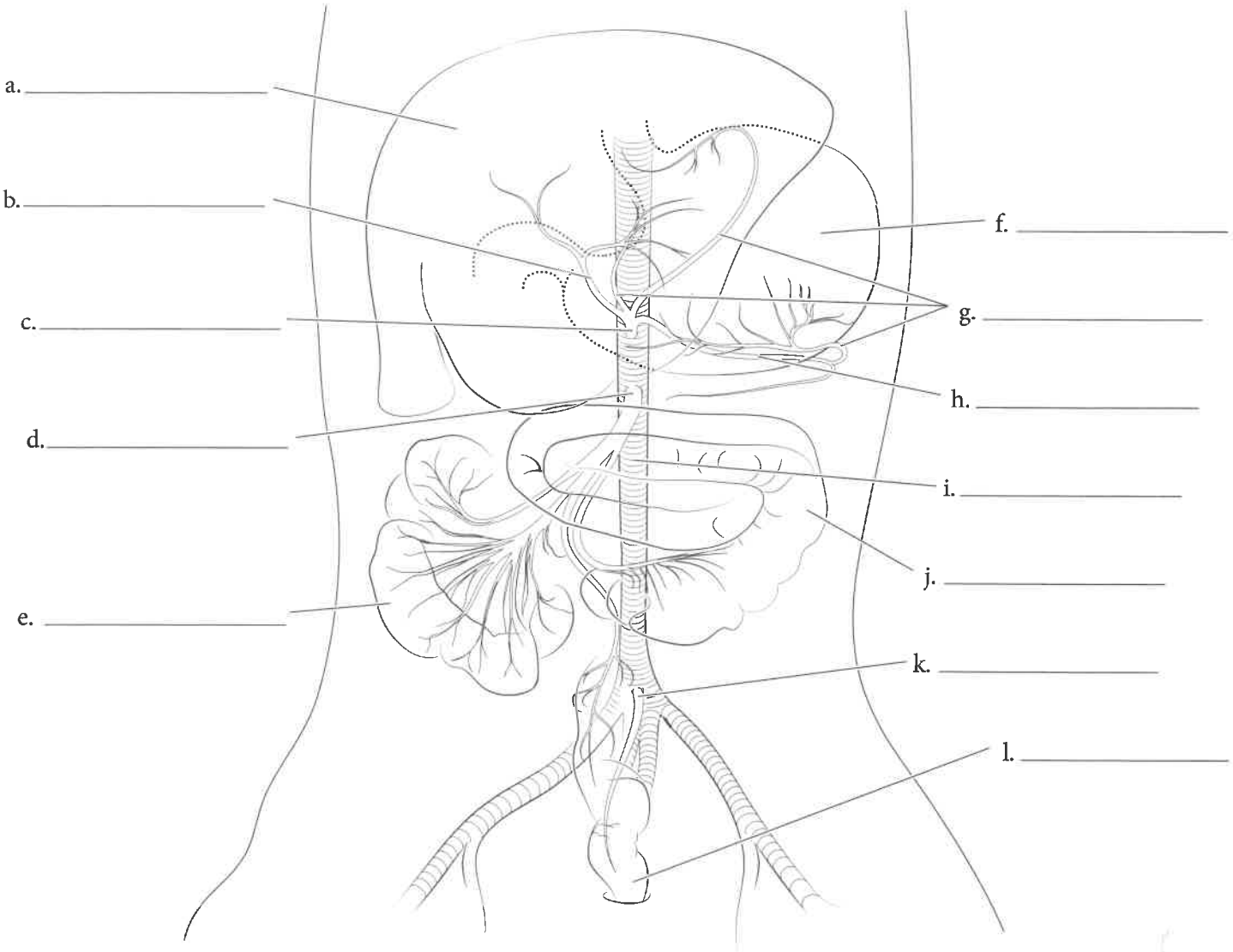


Answer Key:

a. Interventricular septum
b. Right ventricle
c. Chordae tendineae
d. Right atrioventricular (tricuspid) valve
e. Right atrium
f. Caudal vena cava aperture
g. Foramen ovale
h. Cranial vena cava
i. Aortic arch
j. Ductus arteriosus
k. Pulmonary trunk
l. Pulmonary semilunar valve
m. Pulmonary vein apertures
n. Left atrium
o. Aortic semilunar valve
p. Left atrioventricular (bicuspid, mitral) valve
q. Papillary muscle
r. Left ventricle

VENTRAL ARTERIES OF DIGESTIVE ORGANS

Several unpaired vessels arising off the abdominal aorta provide oxygenated blood to organs of the digestive system. The **celiac trunk** divides into branches named for the organs they supply: the hepatic artery to the liver, the gastric arteries to the stomach, and the **splenic artery** to the spleen. The **cranial mesenteric artery** branches into numerous arteries passing throughout the mesentery to provide blood along the entire length of the small intestine, where nutrients are being absorbed. The **caudal mesenteric artery** supplies blood to much of the colon. As you color each artery, name the organ that it supplies and also color the digestive organs, using the same colors you used previously for each organ.



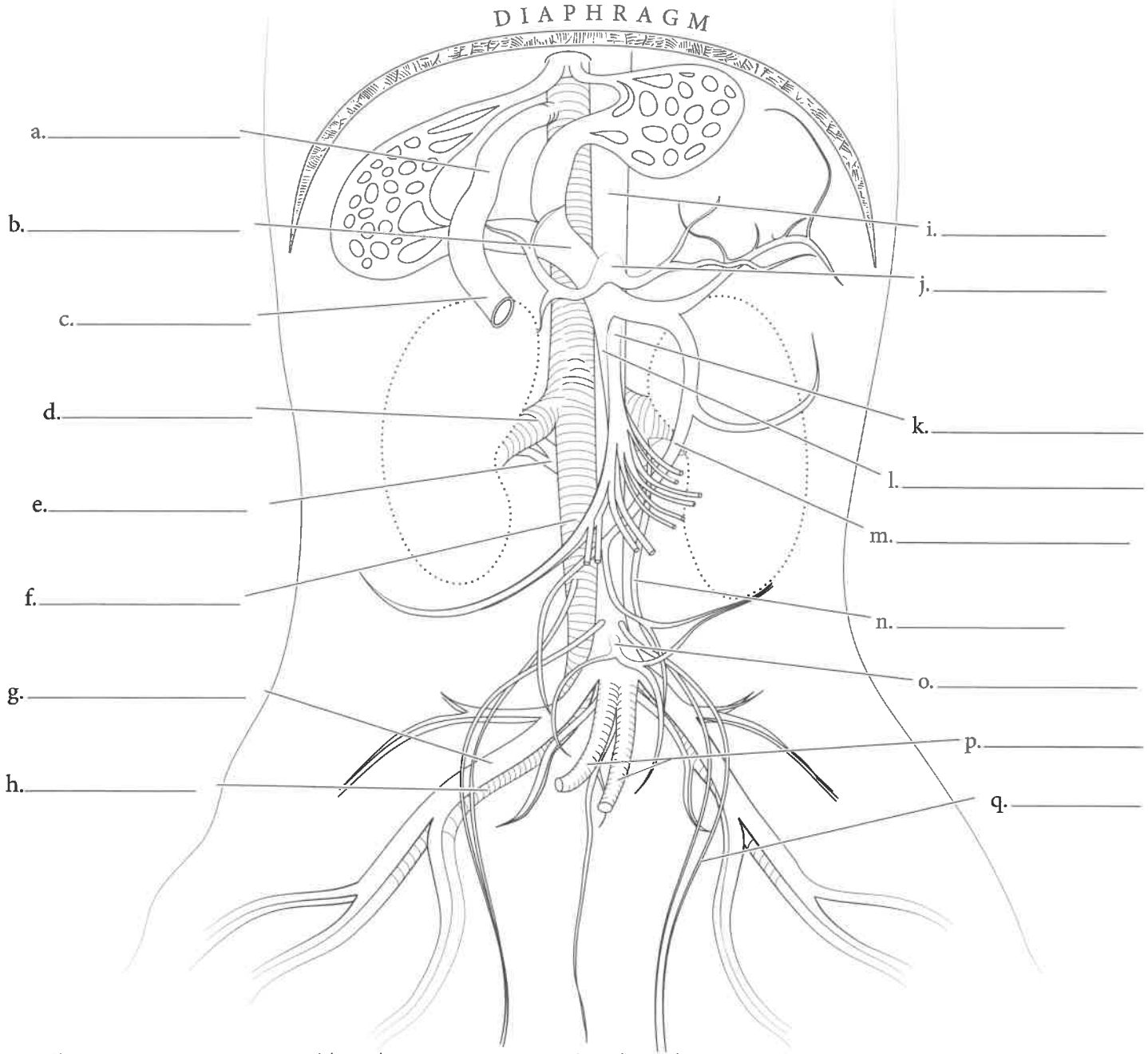
Answer Key:

a. Liver
b. Common hepatic artery
c. Celiac trunk
d. Cranial mesenteric artery
e. Small intestine
f. Stomach
g. Gastric arteries
h. Splenic artery
i. Aorta
j. Spiral colon
k. Caudal mesenteric artery
l. Rectum

VENTRAL ABDOMINAL AORTA AND CAUDAL VENA CAVA

The abdominal organs are supplied with blood from the aorta as it passes dorsally through the abdominal region. In each organ, blood passes through capillaries, where oxygen and nutrient exchange takes place, and is collected again into veins. These veins then enter the caudal vena cava which carries the blood back to the right side of the heart. Select an artery; name it and color it (and its counterpart on the other side, if one of a pair); then, find the vein that completes the circuit back to the vena cava, name it, and color it.

A pair of **renal arteries** supplies the kidneys, while a pair of **renal veins** returns the blood to the vena cava. More caudally, **gonadal arteries** and **veins** supply the gonads, while the **external iliacs** supply the hind limbs. The abdominal aorta terminates in the fetus by dividing into a pair of umbilical arteries that supply blood to the placenta. Although the mesenteric arteries supply blood to digestive organs, mesenteric veins do not return the blood to the vena cava. Instead, they carry this nutrient-rich blood to the hepatic portal vein which carries it to the liver before it returns to the heart.

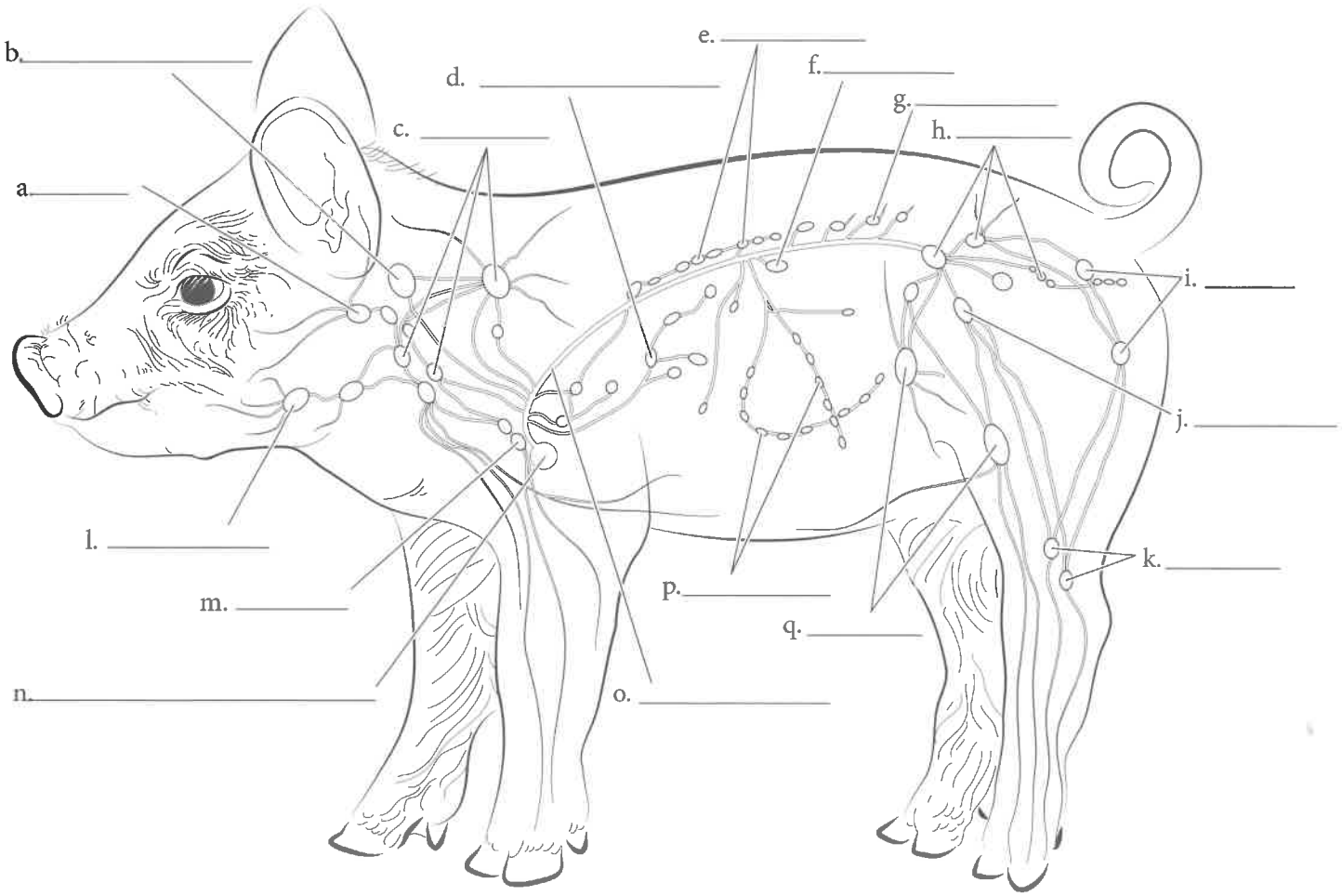


Answer Key:

a. Ductus venosus
b. Hepatic portal vein
c. Umbilical vein
d. Right renal vein
e. Right renal artery
f. Caudal vena cava
g. External iliac artery
h. External iliac vein
i. Aorta
j. Celiac trunk
k. Cranial mesenteric artery
l. Cranial mesenteric vein
m. Caudal mesenteric vein
n. Left gonadal vein
o. Caudal mesenteric artery
p. Umbilical arteries
q. Left gonadal artery

Although the circulatory system is a closed system, and blood always flows within vessels, some of the plasma fluid filters through the capillary walls and bathes the cells as interstitial fluid. While a small amount of this fluid filters back into the capillaries, the remainder is captured and returned to the circulation by the lymphatic system. The fluid enters **lymph capillaries**, which have highly permeable walls, and passes into progressively larger lymphatic vessels containing one-way valves to allow the fluid to move only toward the heart. The skeletal muscles through which the vessels pass exert a pressure that pushes the lymph along its way, and the largest vessels empty into veins on each side of the neck.

The lymphatic system plays a crucial role in immune reactions. Lymph fluid must pass through **lymph nodes** where microbial agents are filtered out. You can see here that lymph nodes are located where lymph collected from every part of the body must pass before returning to the heart. They are particularly prevalent in regions that drain lymph from the lungs, digestive tract, and skin—tissues with exposure to the external world and, therefore, with potential to be contaminated by bacteria and other foreign matter. Note that the names for many of the lymph nodes are derived from their location near various organs or structures in the body. As you color the lymph vessels and the nodes through which the lymph must pass, learn the names of the nodes while recognizing the structures for which they are named.



Answer Key:

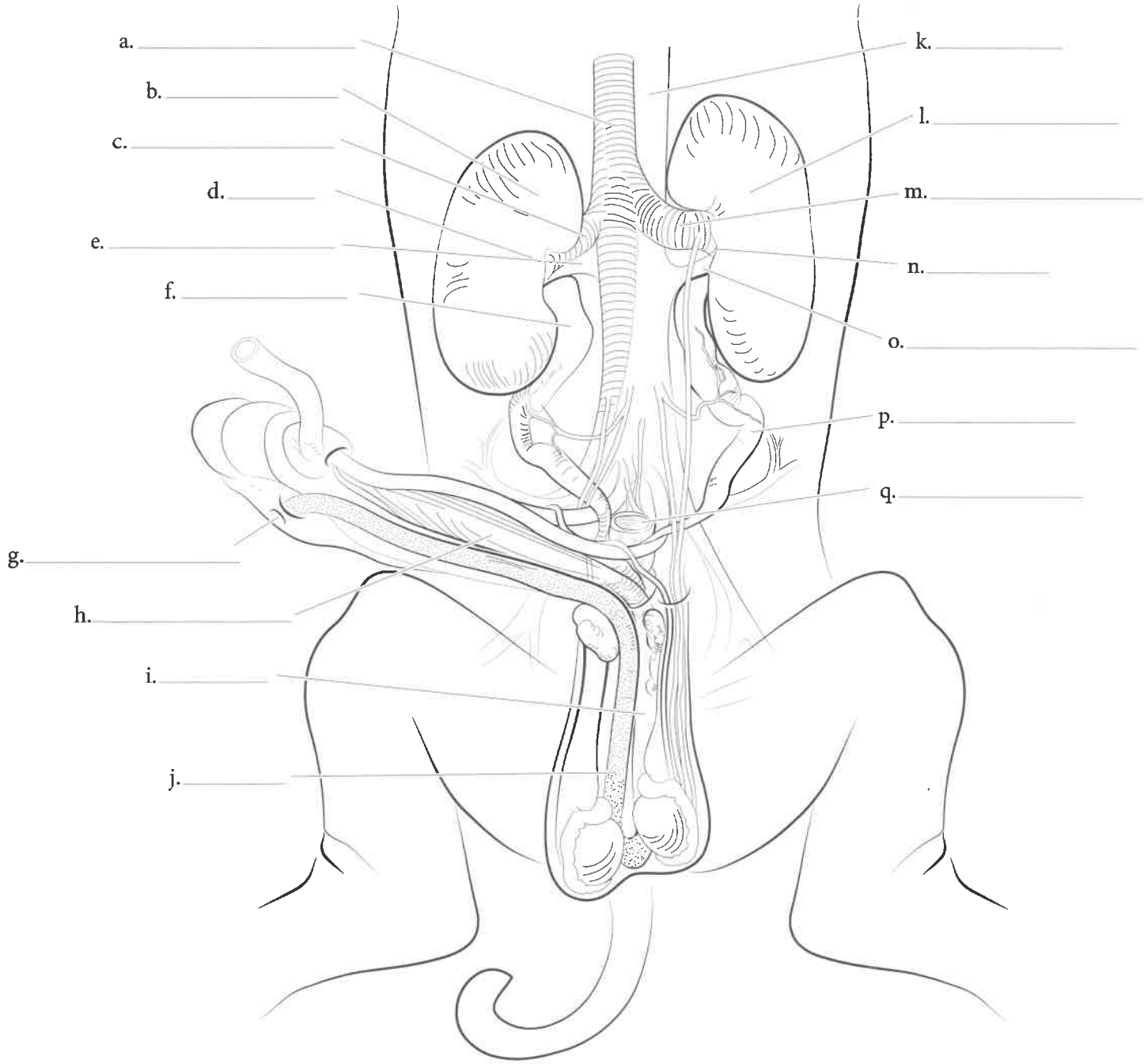
a. Parotid
b. Retropharyngeal
c. Cervical
d. Tracheobronchial
e. Aortic
f. Renal
g. Lumbar
h. Iliosaacral
i. Ischial
j. Iliofemoral
k. Popliteal
l. Mandibular
m. Axillary
n. Left brachiocephalic vein
o. Thoracic duct
p. Mesenteric
q. Inguinal

UROGENITAL SYSTEM, MALE

The urogenital system includes the kidneys and urinary bladder, as well as reproductive organs. As such, they differ significantly in male and female pigs. The reproductive organs have not matured enough in the fetal pigs to be functional, but all of the relevant organs have already formed.

The urinary system removes nitrogenous waste materials from the body. Note the pair of **kidneys** that are located in the dorsal abdominal wall, and the **ureters** that carry urine to the bladder which is located just under the skin on the ventral side of the abdomen. Urine from the bladder is carried to the exterior through the **urethra**. In the male, the urethra passes through the penis and also carries the products from the male sex glands. The penis parallels the bladder and emerges through the urogenital opening just caudal to the umbilical cord.

Use a different color for organs of the reproductive system than you use to color the organs that are part of the urinary system.



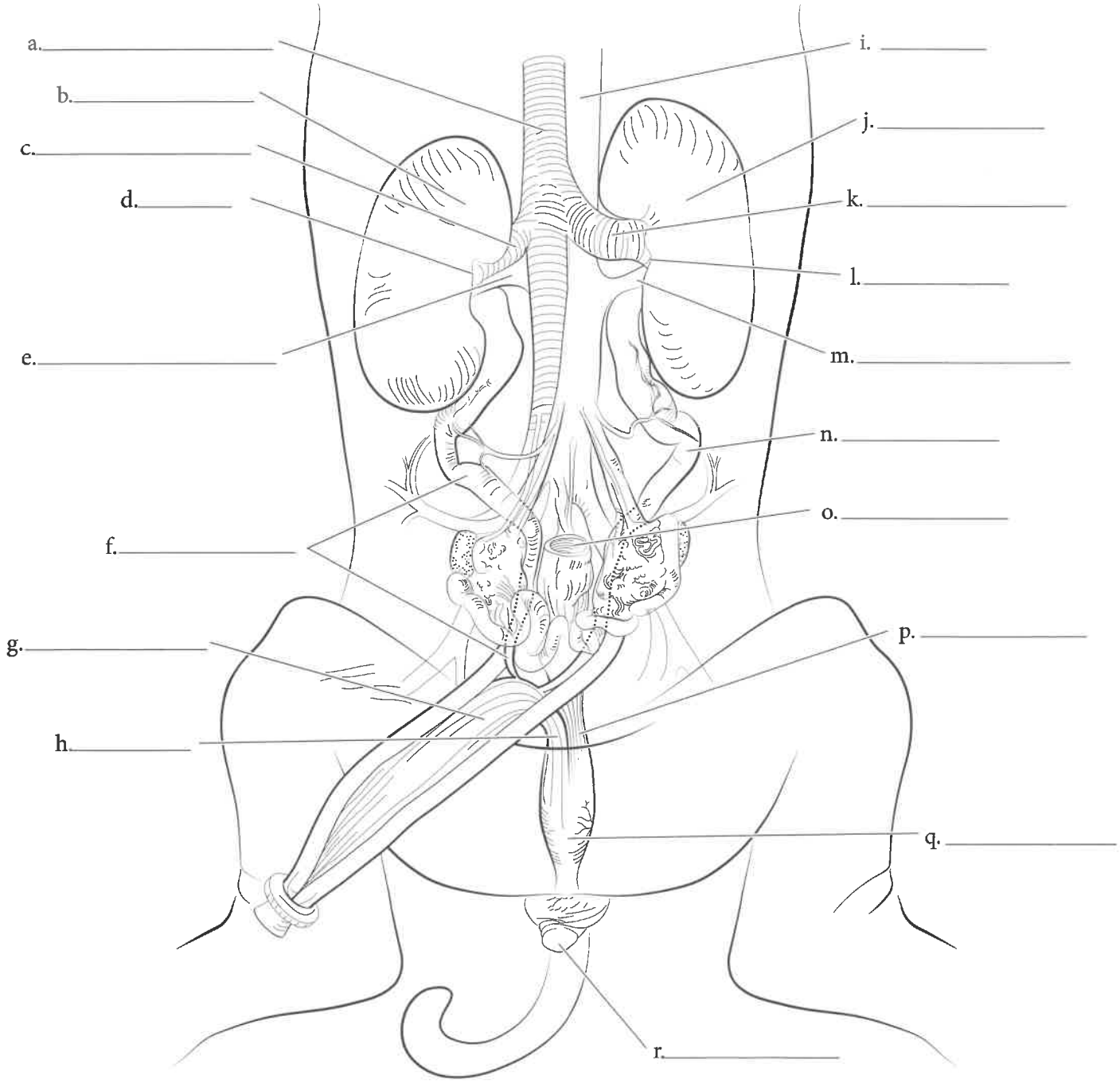
Answer Key:

a. Caudal vena cava
b. Right kidney
c. Right renal vein
d. Hilum
e. Right renal artery
f. Right ureter
g. Urogenital opening
h. Urinary bladder
i. Urethra
j. Penis
k. Aorta
l. Left kidney
m. Left renal vein
n. Hilus
o. Left renal artery
p. Left ureter
q. Colon (cut)

UROGENITAL SYSTEM, FEMALE

There is no difference between males and females in the function or location of the kidneys, ureters, and bladder. However, in the female, the urethra empties into the **urogenital sinus** which then passes wastes to the outside through the **urogenital orifice** located in the urogenital papilla. The **vagina** extends from the **uterus** openings and also enters the urogenital sinus.

Use the same colors for the female urinary organs as you used for the male, but use a different color for those organs that are part of the female reproductive system.



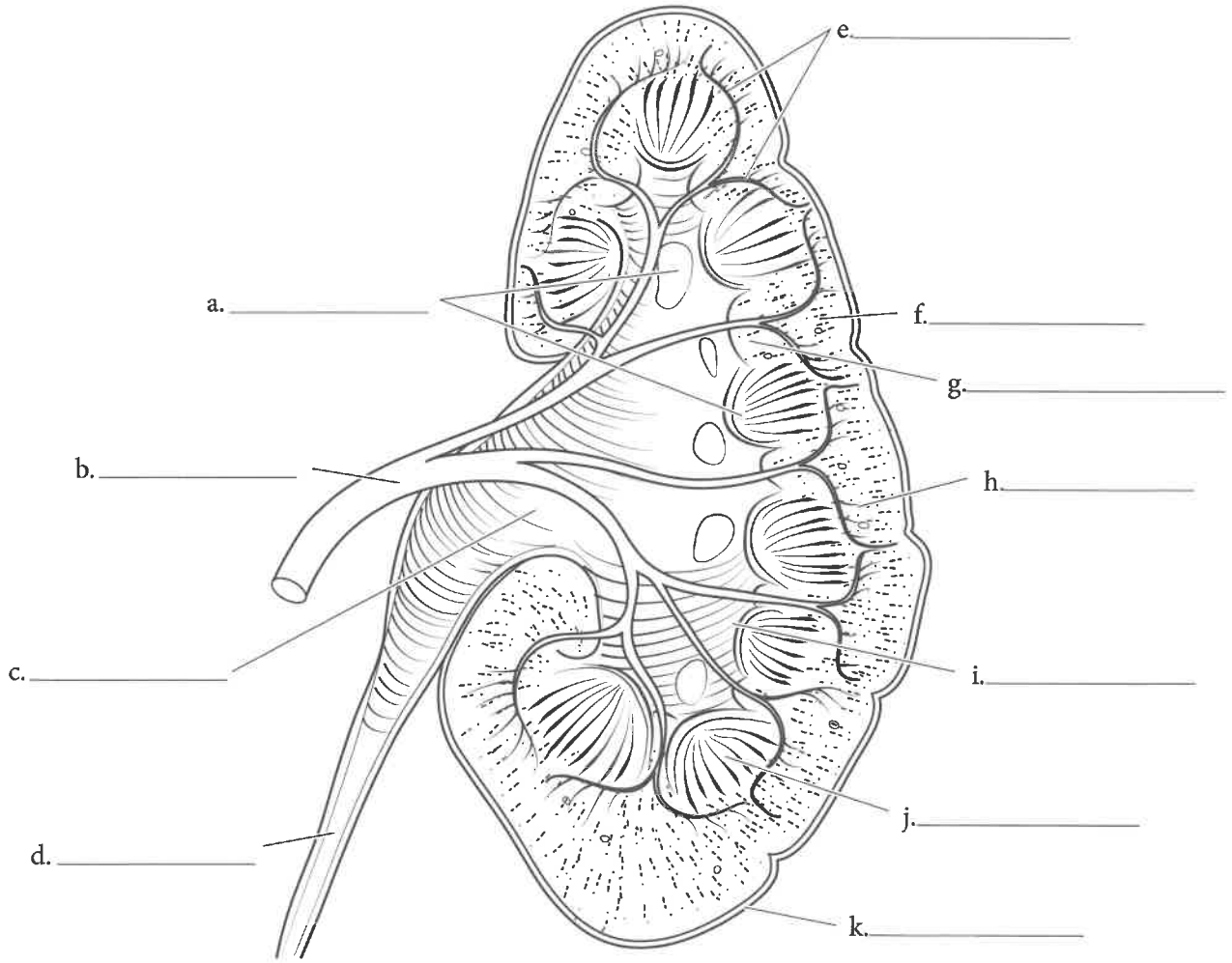
Answer Key:

a. Caudal vena cava
b. Right kidney
c. Right renal vein
d. Hilum
e. Right renal artery
f. Right ureter
g. Urinary bladder
h. Urethra
i. Aorta
j. Left kidney
k. Left renal vein
l. Hilus
m. Left renal artery
n. Left ureter
o. Colon (cut)
p. Vagina
q. Urogenital sinus
r. Urogenital papilla

KIDNEY

The kidneys function in filtering the blood to remove excess water, remove nitrogenous wastes in the form of urea, adjust blood pH by selectively removing hydrogen ions, and maintain blood electrolyte levels by adjusting sodium or chloride ion levels. The urine produced by the kidneys travels through the ureter to the urinary bladder until it is voided to the environment through the urethra. Looking at the interior of the kidney shows that it has several regions; under the protective capsule is the **cortex**; deep to the cortex is the **medulla** which is arranged into **renal pyramids**; and the urine that is formed drains from the medulla into a collecting region known as the **calyx**. From there, urine passes through the ureter to be stored in the bladder. Blood enters the kidney through the renal artery which divides into several smaller **interlobular arteries** that turn perpendicularly to form the **arcuate** vessels that pass at the interface between the cortex and medulla. From here, blood wastes are filtered out in the **nephrons** which are the functional units of the kidney's ability to produce urine.

Use different colors to designate the cortex, medulla, and calyx regions.



Answer Key:

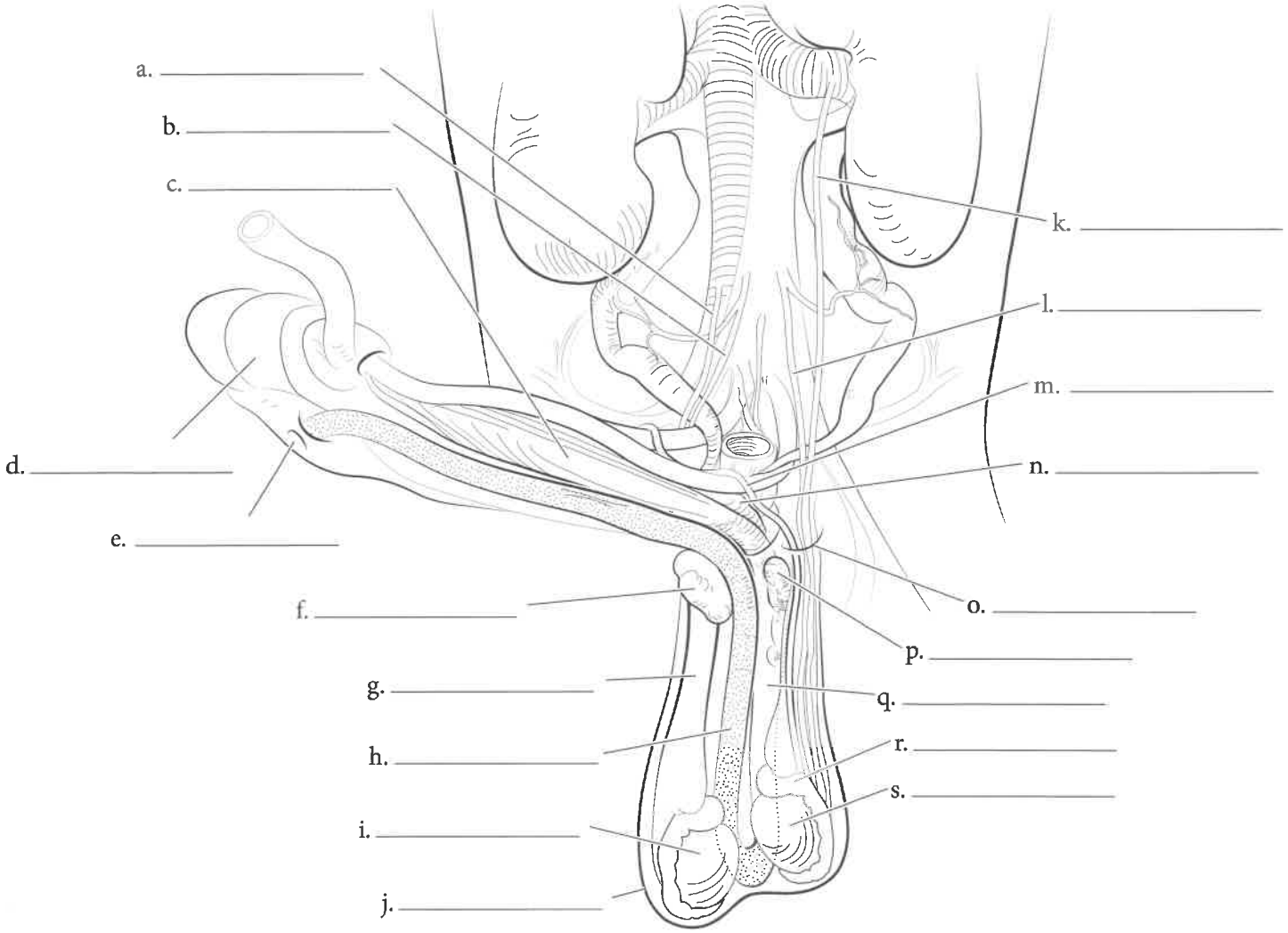
a. Renal papillae
b. Renal artery
c. Renal pelvis
d. Ureter
e. Arcuate vessels
f. Renal cortex
g. Renal column
h. Interlobular vessel
i. Renal calyx
j. Renal pyramid (medulla)
k. Fibrous capsule

REPRODUCTIVE SYSTEM—MALE

The male **testes** develop dorsal to the coelomic cavity, near the kidneys, but migrate during development to lie in an external pouch, the scrotum, ventral to the anus, where the temperature is several degrees cooler than the animal's internal body temperature. In the early fetus, the testes have not yet descended, but in the larger fetal pigs usually studied, they have already migrated to the scrotum. The **testicular artery** and **vein** along with nerves pass into the scrotum through an opening in the body wall called the **inguinal canal**. After the animal reaches sexual maturity, sperm is formed in the testes and passes through or is stored in the **epididymis** which extends alongside the testes and continues into the **ductus deferens**. The ductus deferens from each testis then passes through the inguinal canal and enters the urethra prior to the point where it enters the penis.

In the pig, the penis is very long and lies in a sheath embedded in the ventral body wall, surrounded by erectile tissue. A retractor muscle pulls the penis back into its sheath after an erection. Accessory glands that are also found in the male reproductive tract include the **prostate**, **seminal vesicles**, and **bulbourethral glands**, all of which secrete part of the seminal fluid which carries and nourishes the sperm.

Begin by coloring the urinary system structures as you did before. Name and color the structures in the reproductive system beginning with the testes and continuing in the order in which the sperm pass through the structures. This sequence will help you in remembering the names and functions.



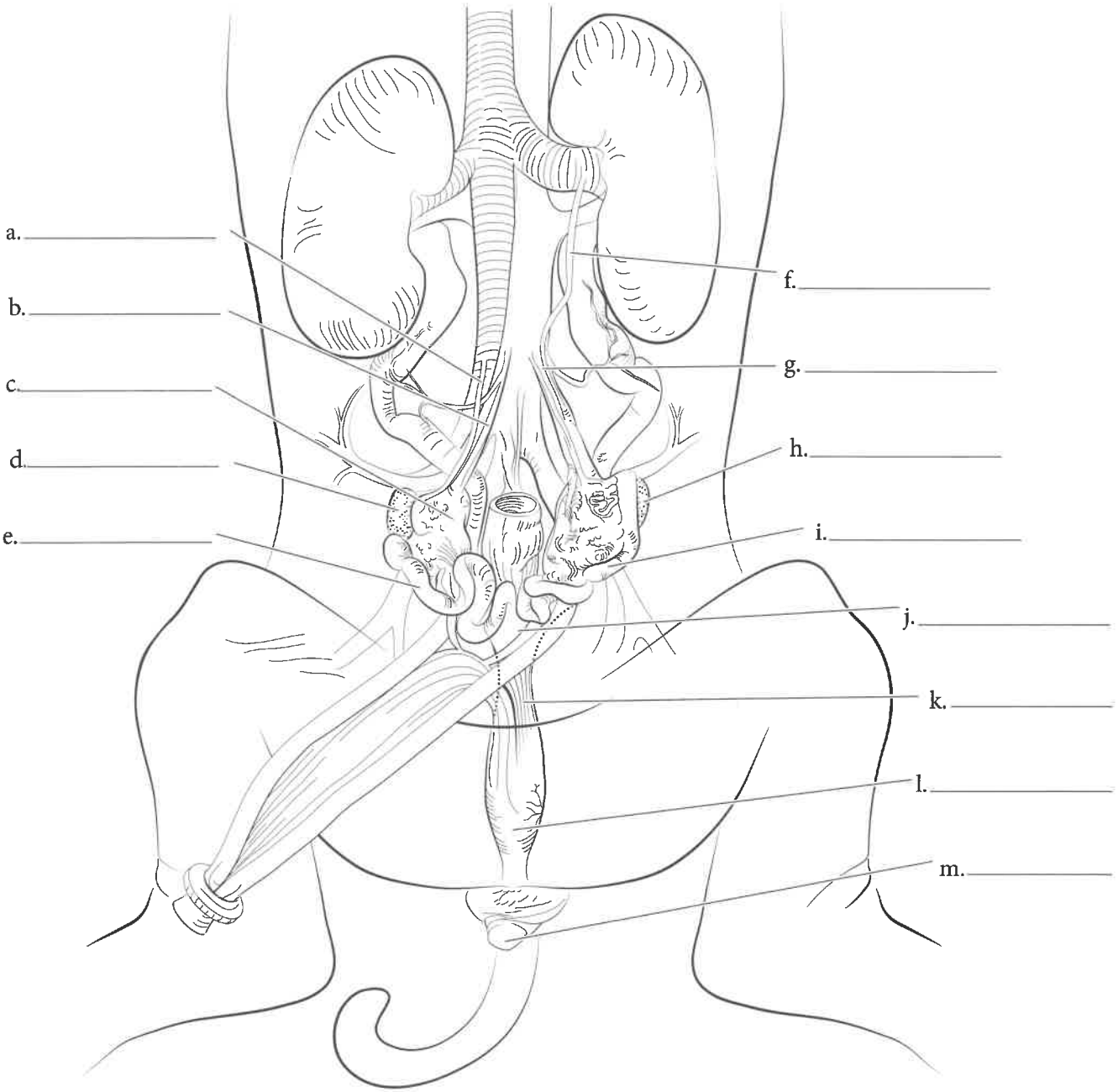
Answer Key:

a. Right testicular vein
b. Right testicular artery
c. Urinary bladder
d. Umbilical cord
e. Urogenital opening
f. Preputial gland
g. Spermatic cord
h. Penis
i. Right testis
j. Scrotum
k. Left testicular vein
l. Left testicular artery
m. Ductus deferens (Vas deferens)
n. Seminal vesicle
o. Inguinal canal
p. Bulbourethral gland
q. Urethra
r. Epididymis
s. Left testis

REPRODUCTIVE SYSTEM—FEMALE

The female reproductive tract includes two **ovaries** which produce eggs that pass through the **fallopian tubes** to the uterus. The fetal ovaries are small, oval organs lying near the dorsal wall of the abdomen, caudal to the kidneys. The mesosalpinx is part of the broad ligament of the uterus which encloses the fallopian tube. In the pig, there is a small **uterine body** with long, convoluted **uterine horns** which are the site of embryo implantation after the eggs are fertilized. In contrast, the human female has no uterine horns but a large uterine body where implantation occurs. The uterus of the pig leads into the vagina which unites with the urethra to form a **urogenital canal** leading to the body surface. In the human, the vagina and urethra open independently on the surface.

Begin by coloring the urinary system structures as you did before. Name and color the structures of the reproductive system beginning with the ovary and continuing in the order in which the egg or developing offspring pass through the structures. This sequence will help you in remembering both the names and functions of each.



Answer Key:

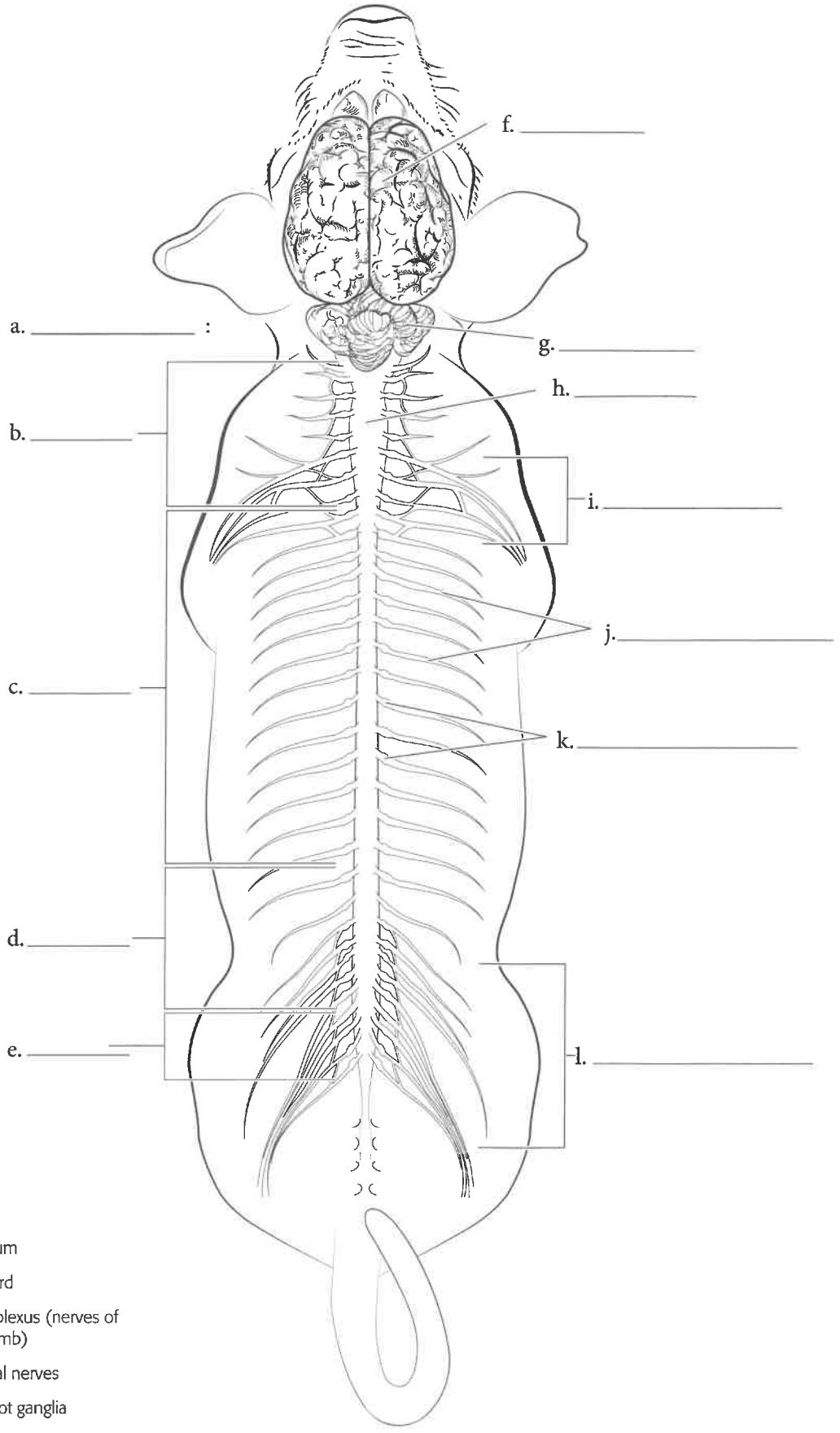
a. Right ovarian vein
b. Right ovarian artery
c. Mesosalpinx
d. Right ovary
e. Right horn of uterus
f. Left ovarian vein
g. Left ovarian artery
h. Left ovary
i. Left horn of uterus
j. Uterus
k. Vagina
l. Urogenital sinus
m. Urogenital papilla

NERVOUS SYSTEM, DORSAL VIEW

The nervous system functions to sense and respond to the external environment, to sense and respond to changes in the internal environment, and to communicate messages between parts of the body. In order to accomplish this, the nervous system includes sense organs (eye, ear), other sensory tissues (taste buds, olfactory tissue, pressure sensors), both sensory and motor neurons to conduct impulses, and the central nervous system.

The central nervous system includes the **brain** and **spinal cord,** which function to integrate and coordinate activities throughout the body. The brain is located inside the cranium and is continuous with the spinal cord stretching along the dorsal midline of the body. **Cranial nerves** from the head region enter the brain directly, while communication with the rest of the body depends upon **spinal nerves** entering the spinal cord. These neurons located outside the central nervous system are called the peripheral nervous system and can be divided into sensory or motor neurons, depending upon whether they convey information toward or away from the central nervous system. Many nerves are mixed in nature—including both sensory and motor nerve fibers.

Motor neurons of the peripheral nervous system may be divided into somatic motor neurons controlling voluntary muscles and autonomic motor neurons which regulate smooth muscle, cardiac muscle, and glands. The autonomic neurons may be further divided into the sympathetic and parasympathetic systems, which often provide organs with compensatory signals. For example, sympathetic stimulation is responsible for dilating the pupil of the eye in low light, while parasympathetic stimulation will constrict the pupil when light levels are higher.

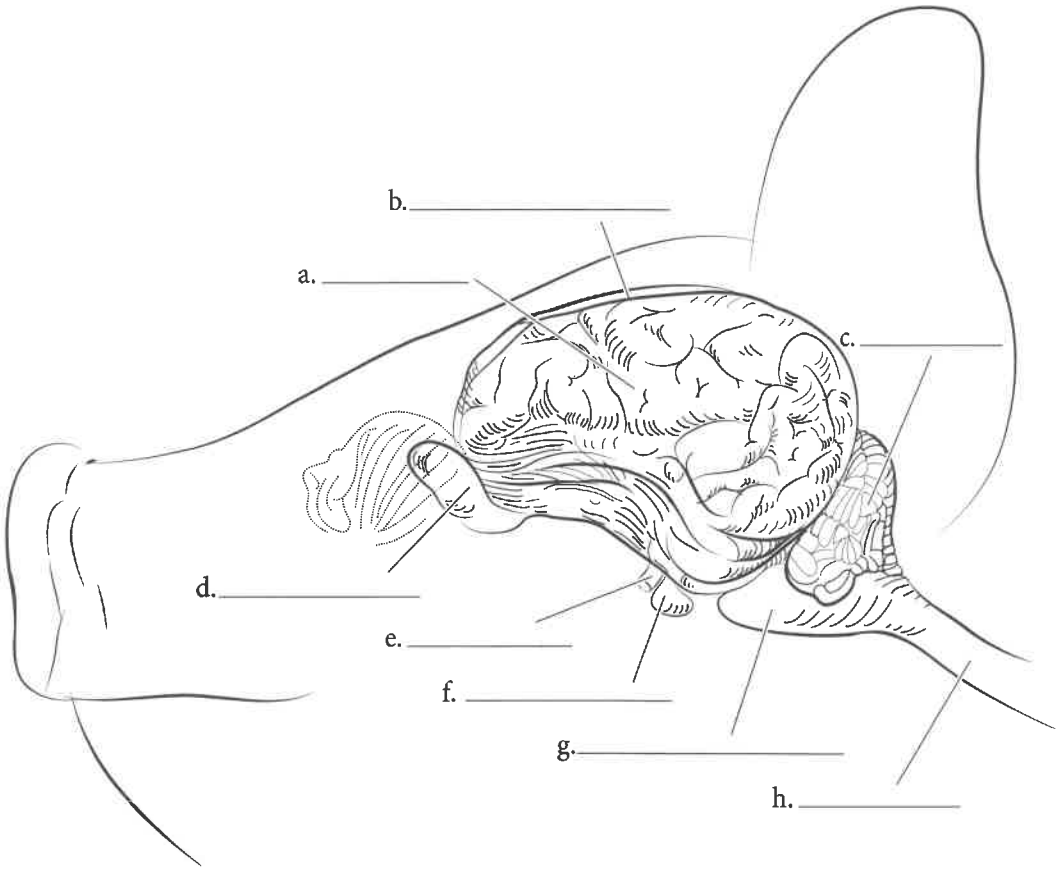


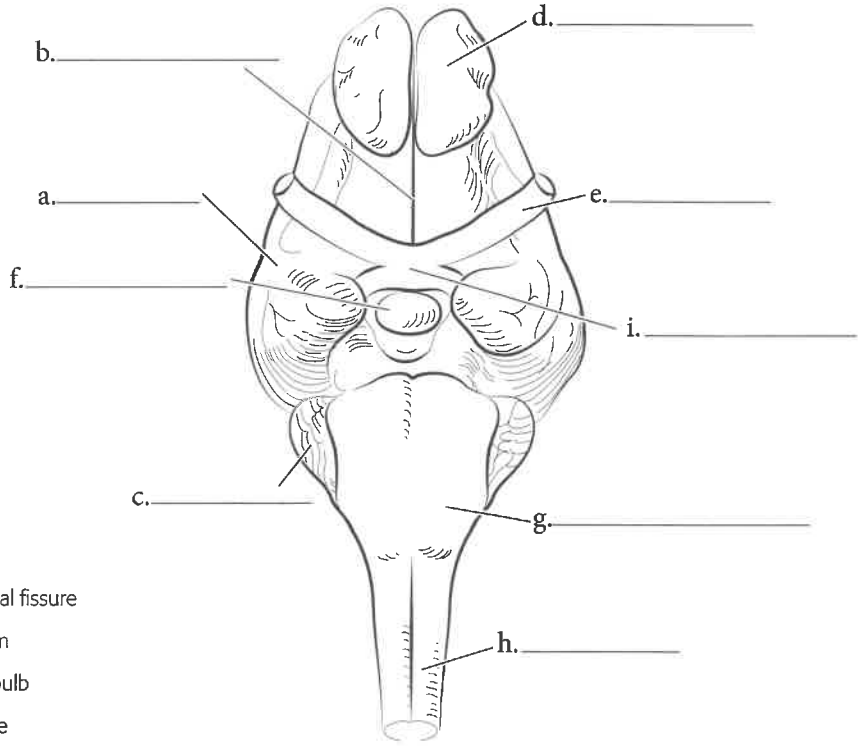
Answer Key:

a. Spinal nerves
b. Cervical nerves
c. Thoracic nerves
d. Lumbar nerves
e. Sacral nerves
f. Cerebrum
g. Cerebellum
h. Spinal cord
i. Brachial plexus (nerves of the forelimb)
j. Intercostal nerves
k. Dorsal root ganglia
l. Lumbar and sacral plexuses (nerves of the hindlimb)

LATERAL BRAIN, VENTRAL BRAIN

The brain is located inside the cranium, and derives from the enlarged anterior portion of the dorsal hollow nerve cord as in all vertebrates. Similar to other mammals, the **cerebrum** is the largest section (although not as large as in humans). Cranial nerves from the head region enter the brain directly, including the **optic nerve** shown entering the ventral side of the brain. Anteriorly, the olfactory bulb is close to its source of stimulation—the nasal conchae containing smell receptors. The **pituitary gland** on the ventral aspect of the brain secretes hormones which control the other endocrine glands and influence growth, metabolism, and maturation. Posterior to the cerebrum is the **cerebellum**, which functions largely in muscular coordination, and the **medulla oblongata**, which controls many involuntary activities such as heart beat, blood pressure, salivation, swallowing, and breathing.



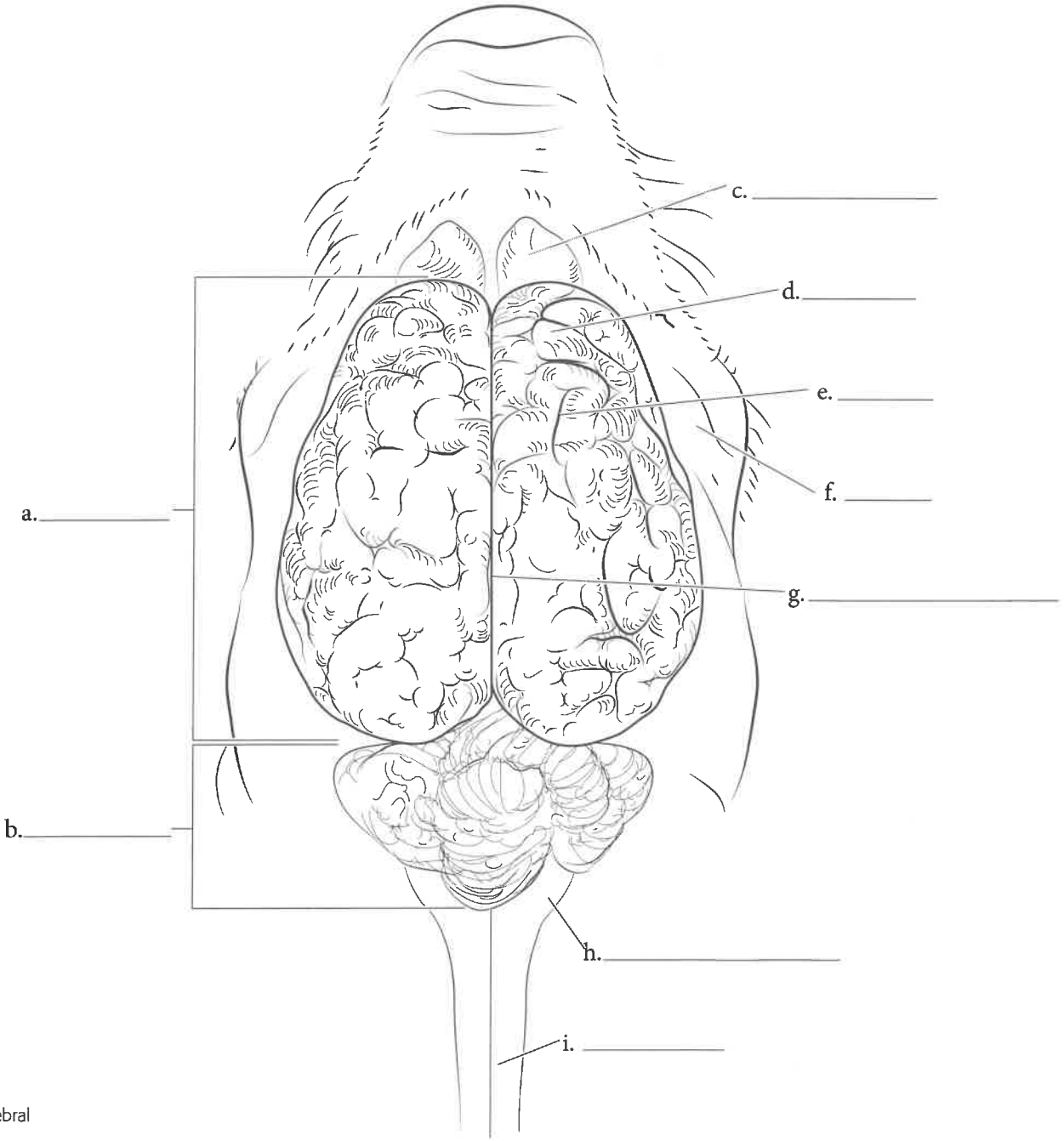


Answer Key:

a. Cerebrum
b. Longitudinal fissure
c. Cerebellum
d. Olfactory bulb
e. Optic nerve
f. Pituitary gland
g. Medulla oblongata
h. Spinal cord
i. Optic chiasm

DORSAL BRAIN

The surface of the cerebral cortex is highly convoluted and densely packed with nerve cells; its area is increased by having a series of ridges called **gyri** and creases called sulci. The cerebrum is divided into left and right halves by the **longitudinal cerebral fissure**. Each region of the cerebral cortex has specific functions that may be sensory, motor, or associative in nature. Within these regions, each point may control or receive input from a specific part of the body.



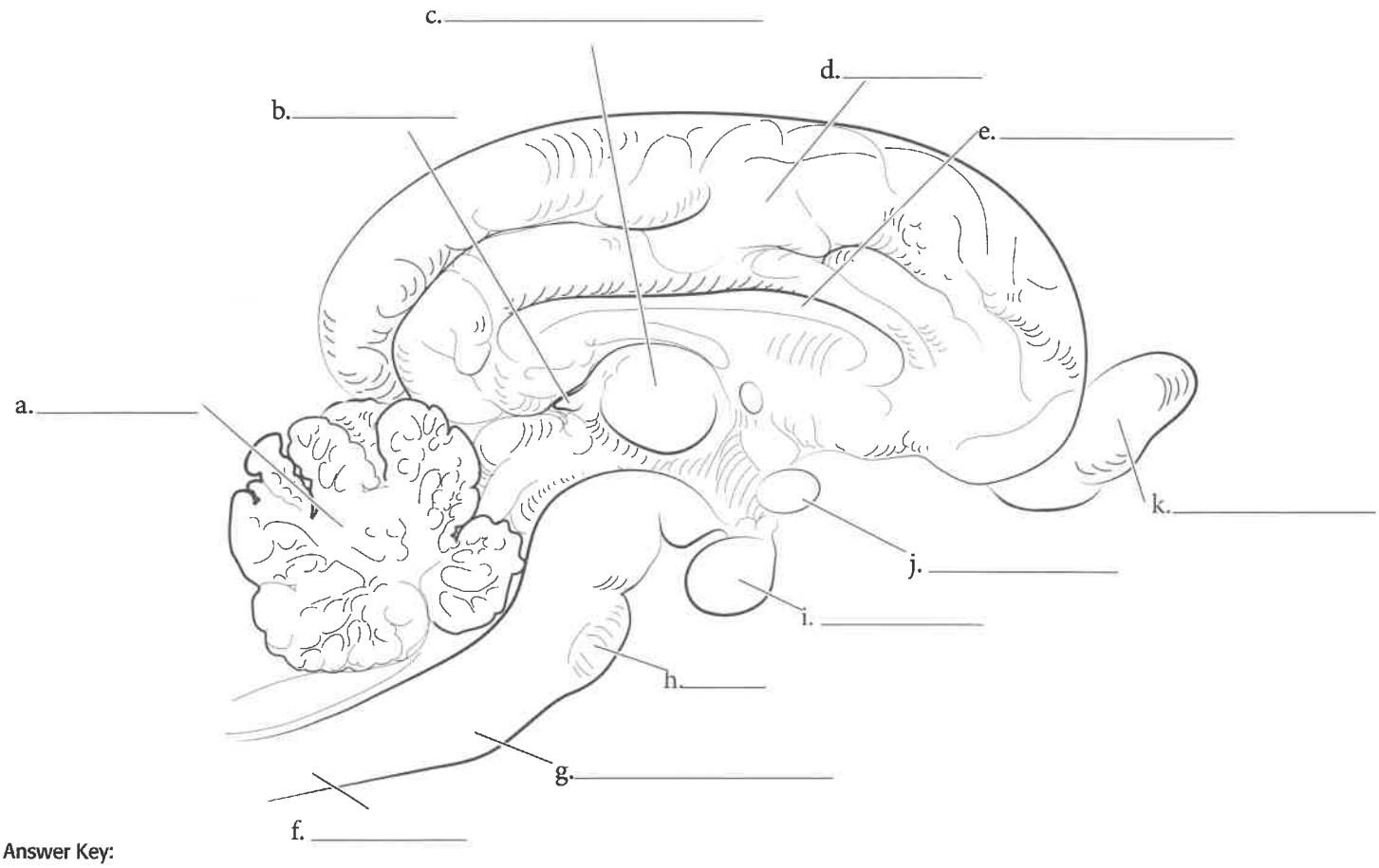
Answer Key:

a. Cerebrum
b. Cerebellum
c. Olfactory bulb
d. Gyrus
e. Sulcus
f. Eye
g. Longitudinal cerebral fissure
h. Medulla oblongata
i. Spinal cord

SAGITTAL BRAIN

A midsagittal view of the brain shows structures deep within the brain that are not obvious from the surface. The **corpus callosum** is a region with bundles of nerve fibers on the base of the longitudinal fissure that function in connecting the two hemispheres of the cerebrum. The **pineal body** is a stalked gland that releases the hormone melatonin during darkness; this is thought to influence rhythms of activity. The **interthalamic adhesion** consists of tissue that contacts the medial surfaces of the thalamus regions on both sides of the brain. The **optic chiasma** is the point where the two optic nerves cross before entering the brain—visual information from the right eye enters the left side of the brain and vice versa.

In the region of the brain just anterior to the spinal cord and medulla oblongata lies the pons, which contains fibers that connect the two hemispheres of the cerebellum. Loosely attached at the base of the brain is the pituitary gland; the posterior pituitary secretes hormones made in the hypothalamus (oxytocin and antidiuretic hormone) while the anterior pituitary makes and secretes a number of hormones, including growth hormone, thyroid-stimulating hormone, and follicle-stimulating hormone.



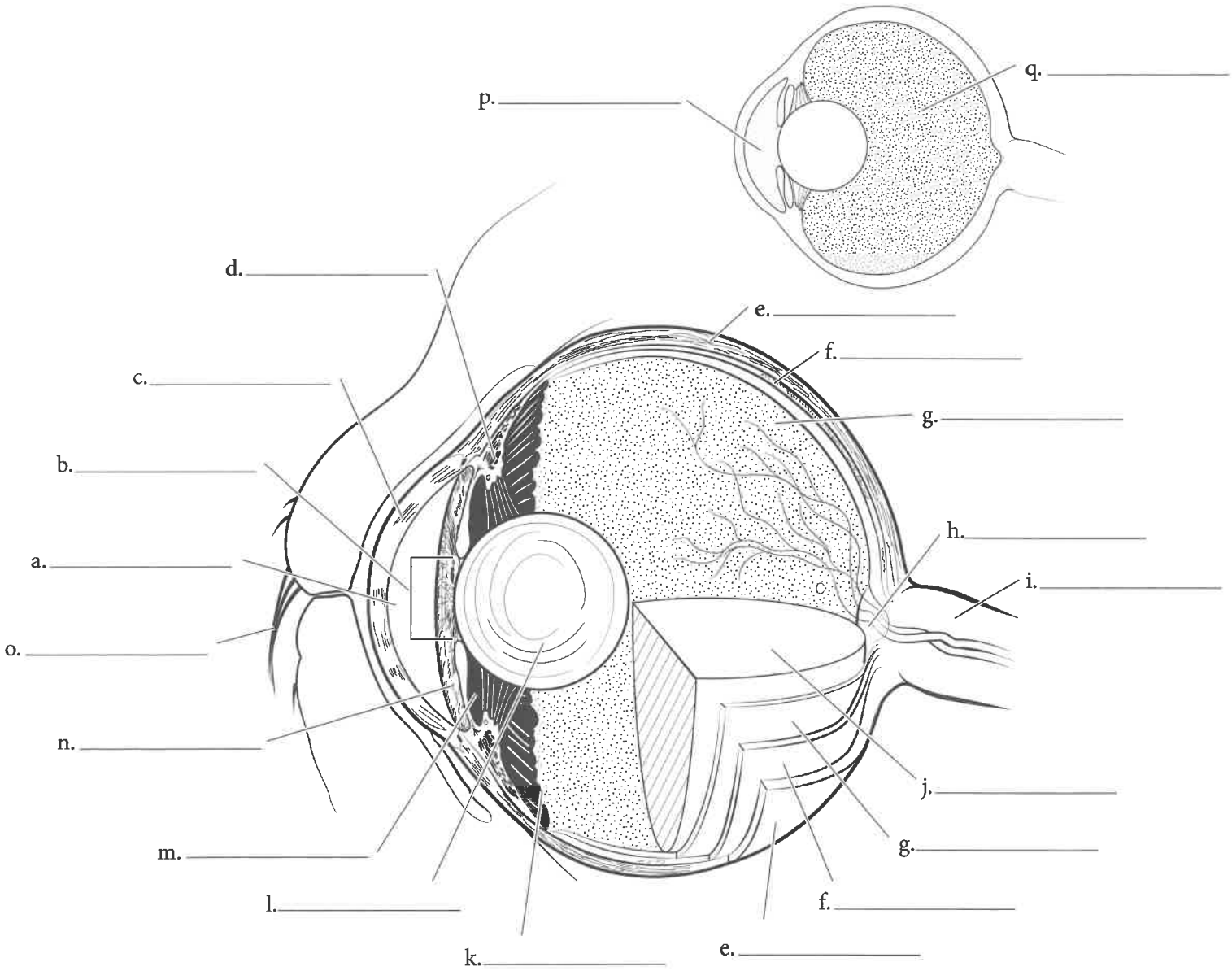
Answer Key:

a. Cerebellum
b. Pineal body
c. Interthalamic adhesion
d. Cerebrum
e. Corpus callosum
f. Spinal cord
g. Medulla oblongata
h. Pons
i. Pituitary gland
j. Optic chiasma
k. Olfactory bulb

EYE

The path of light entering the mammalian eye begins with passage through the clear **cornea** and enters the posterior chamber through a hole in the **iris** called the **pupil**. Light then passes through the **lens** which inverts and focuses the image on the sensory cells of the **retina**, which is complex and multilayered. When a photon activates a retinal cell, an impulse is generated and sent to the brain through the optic nerve. At the opening to the optic nerve, called the optic disc, there are no light receptors.

The lens is held in place, and its shape changed to focus the image, by a muscular **ciliary body located** just behind the iris. The irregular junction of the ciliary body with the complex layers of the retina is a zone called the **ora serrata**. The eyeball wall consists of the outer tough, white **sclera** (which is clear in front to form the cornea), the black **choroid**, and the internal, complex, sensory retina. The cavity posterior to the lens is filled with **vitreous humor**, a clear, gelatinous material that fills the eyeball to maintain its shape while allowing light to pass.

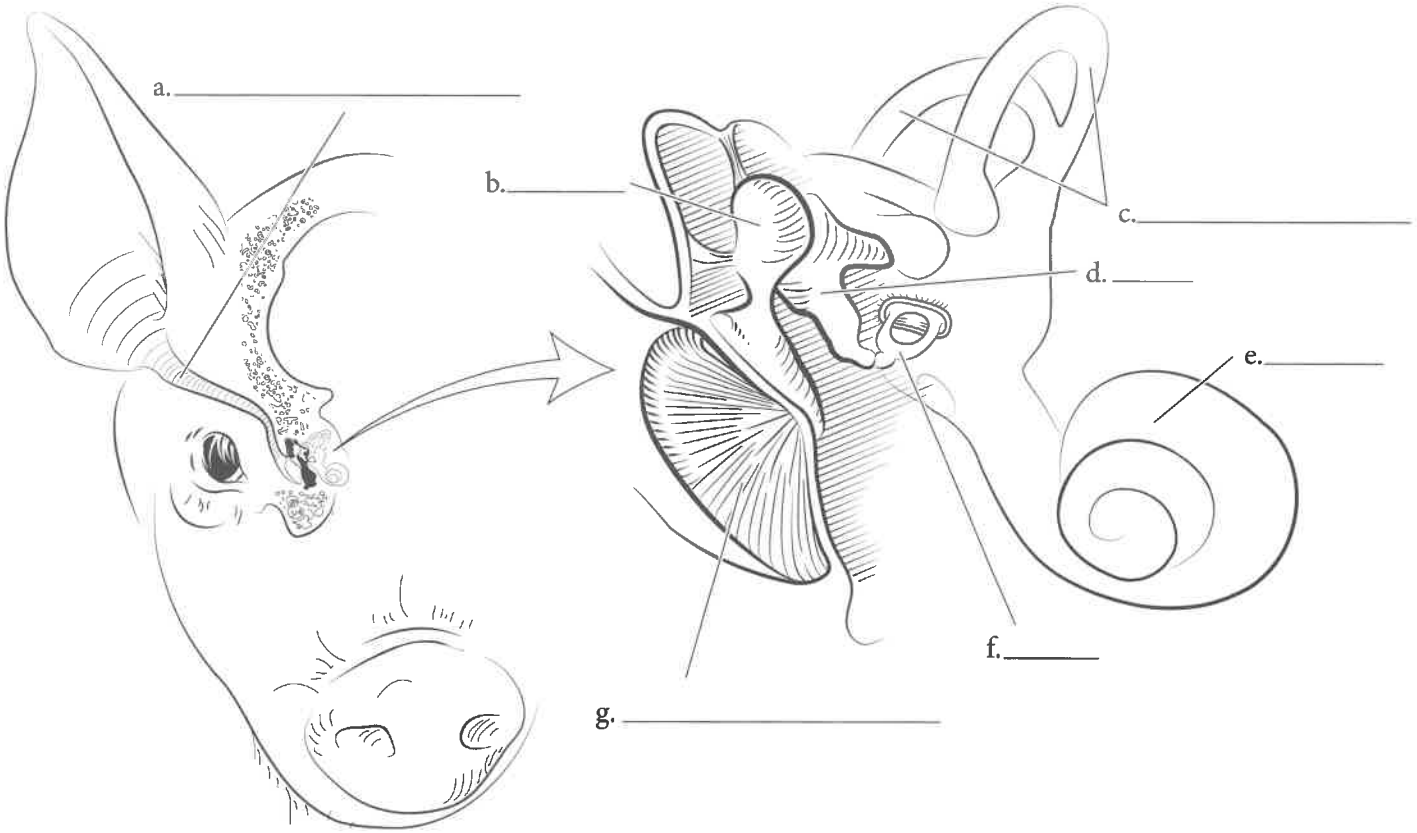


Answer Key:

a. Anterior chamber
b. Pupil
c. Cornea
d. Ciliary body
e. Sclera
f. Choroid
g. Retina
h. Optic disk
i. Optic nerve
j. Vitreous humor
k. Ora serrata
l. Lens
m. Posterior chamber (behind iris)
n. Iris
o. Eyelash
p. Anterior cavity
q. Posterior cavity

EAR

The **external auditory** canal leads from the external ear, or pinna, into the inner ear. At the end of the auditory canal is the **tympanic membrane**, which vibrates when sound waves impact it. The vibration of the tympanic membrane is transmitted sequentially through a series of three small bones: the **malleus**, **incus**, and **stapes**. Vibration of the stapes, in turn, vibrates the oval window of the **cochlea**; fluid in the cochlea then vibrates certain sensory cells in the organ of Corti to send auditory sensory messages to the brain via the auditory nerve. Another part of the inner ear consists of the semicircular ducts, a set of three fluid-filled canals set approximately perpendicular to each other in three separate planes; movement of the fluid in these ducts provides information crucial to balance.



Answer Key:

a. External auditory canal
b. Malleus
c. Semicircular ducts
d. Incus
e. Cochlea
f. Stapes
g. Tympanic membrane

Many metabolic functions are coordinated throughout the body using blood-borne chemicals on a slower time scale than possible with the electrical impulses of the nervous system. This system, called the endocrine system, relies on sensing the internal environment and subsequent release of chemical messengers called **hormones** into the bloodstream for delivery to target cells at some distance away. Many hormones affect cells throughout the body; others have specific targets in one or more organs.

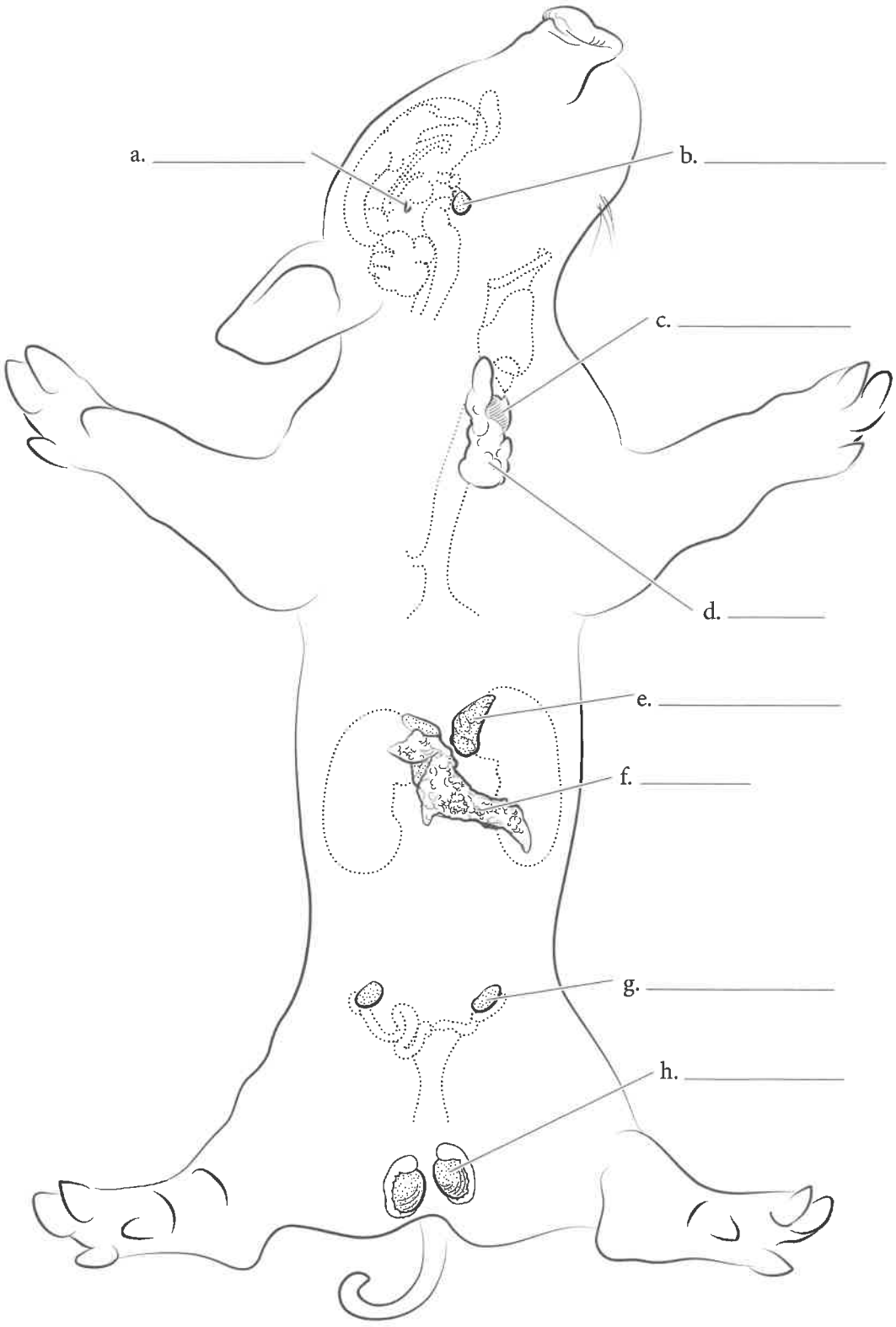
Some hormones are peptides, such as thyroid stimulating hormone (TSH) or adrenocorticotropic hormone (ACTH). Other hormones are steroid molecules, such as estrogen, testosterone, or cortisol. In order for a hormone to affect a cell or tissue, that cell must express receptors for the hormone. The type of receptor is coordinated both to the type of hormone and to the mechanism by which the hormone functions. Peptide hormones that cannot enter cells unassisted will bind to a cell surface receptor that transmits its message across the cell membrane chemically. Steroid hormones, on the other hand, cross the cell membrane easily and bind to intracellular receptors; the hormone receptor complex typically binds to defined stretches of DNA to control transcription of certain genes. Other hormones exhibit other mechanisms of action. In addition to their direct effects on target organs, many hormones provide feedback to the organs that produce them, reducing the hormone production when the effect has been adequate.

Although the brain's control mechanisms are primarily electrical, three regions are also important in chemical control through the endocrine system. The pineal gland secretes melatonin, important in the pig and other mammals (not humans) in controlling the time of year when estrus cycles occur. The pituitary gland affects many organs throughout the body and has two regions. The posterior pituitary releases two hormones produced by the hypothalamus – antidiuretic hormone which controls wanter retention by the kidney, and oxytocin which stimulates milk release during suckling among other effects. The anterior pituitary is an epithelial-derived gland that produces and releases at least seven hormones. Growth hormone stimulates growth of many tissues throughout the body. TSH causes the thyroid gland to secrete thyroxin which stimulates metabolism in all tissues. ACTH induces the adrenal cortex to produce steroid hormones that regulate glucose metabolism, among other things. Lutenizing hormone and follicle-stimulating hormone are involved in functioning of both ovaries and testes. Prolactin stimulates production of milk in mammals. Melanocyte-stimulating hormone has little known effect in mammals, although it may stimulate the production of melanin pigment. While the pituitary gland secretes these many hormones that control many functions throughout the body, it is also controlled in part by hormones – released from the hypothalamus, another instance of chemical regulation by regions of the brain.

The pancreas is an endocrine organ as well as a digestive organ since it provides both digestive enzymes that are transported directly into the small intestine and the hormones insulin and glucagon that regulate glucose metabolism throughout the body. Insulin is released when glucose levels are high in the blood; it induces all cells to take up and metabolize glucose and makes the liver take up excess glucose to store in the form of glycogen. Glucagon has the opposite effect on the liver, inducing glycogen breakdown and release to increase blood levels of glucose.

Sex organs also release hormones. The testes release testosterone in the male, while the ovary produces estrogens and progestins.

The **thyroid gland** in the neck region secretes an iodine-containing hormone that generally increases metabolic activity in all cells. The nearby **parathyroid gland** secretes hormones that regulate calcium uptake or deposition within the bones. The **adrenal glands** are located at the anterior tip of the kidneys, and they secrete several hormones. The adrenal medulla produces epinephrine and norepinephrine (also called adrenaline and noradrenalin) that prepare the body for emergencies—increasing heart rate, blood pressure, and blood glucose levels while diverting blood flow away from the skin and digestive organs. This is known as the "flight or fight" response. The adrenal cortex produces cortisol, a steroid hormone that controls certain aspects of glucose metabolism that are important during fasting or intense exercise. Cortisol also has an anti-inflammatory influence on the immune system. In addition, the adrenal cortex provides a hormone that influences the kidney to reabsorb more sodium to decrease sodium loss in the urine, as well as low levels of several steroid sex hormones.



Answer Key:

a. Pineal gland
b. Pituitary gland
c. Thyroid gland
d. Thymus
e. Adrenal gland
f. Pancreas
g. Ovary (female)
h. Testis (male)