Mammalian Anatomy – A Short Practical Introduction

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Practical Mammalian Anatomy
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Students: Medical physicists
Maastricht University UNS50, Room 4.101

10:00 – 10:30h Welcome and Introductiony lecture
Mammalian organ systems
10:30 – 12:00h Practical rat body dissection
1. Body, limbs and skin from the outside
2. The abdominal cavity: the gastrointestinal system

12:00 – 13:00h Lunch break

13:00 – 14:00h Practical rat body dissection
3. The thoracic cavity: cardiovascular and respiratory systems
4. The excretory and reproductive systems

14:00 – 14:30h Coffee break

14:30 – 16:30h Practical sheep brain dissection
1. The brain organization from the outside: meninges, cortex, brain stem, cranial nerves
2. Sagittal section, anatomical drawing: major subdivisions and fiber tracts of the brain
3. Brain dissection, horizontal sections of one hemisphere: ventricular system, structures of the limbic system
4. Brain dissection, coronal sections of the other hemisphere: basal ganglia, thalamus

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Part 1: Rat dissection

Rats for this preactical are experimental animals from the CVA facility of the UM. They were left over from completed experiments and not killed for this practical. Rats are not fixed, they were frozen, stored and thawed over night for the practical.

1. External Features

a) The skin is covered by different kinds of hair, a characteristic of all mammals. Most notably are the whiskers or vibrissae, which are characterised by their length, large and well-innervated hair follicle, and by having an identifiable representation in the somatosensory cortex of the brain.They are specialised for tactile sensing (other types of hair operate as more crude tactile sensors). While rats scurry for food, often in total darkness, the whiskers enable them to maintain contact with walls and other solid objects that will guide their search.

b) Body regions - The rat's body consists of the head, trunk, appendages, and tail. Compare the length of the tail and the rest of the body. The tail is used for balance and support, particularly when the animal is sitting erect and using the forelimbs in a manner more or less similar to the way the arms are used by humans. Notice that the appendages are adapted for walking. How many fingers to you count?

c) Mouth - Within the mouth a distinguishing feature of rodents are pairs of razor-sharp incisors. These incisors have thick layers of enamel only on the front and do not stop growing. Therefore, the animal must continue to wear them down so that they do not reach and pierce the skull. As the incisors grind against each other, the softer dentine on the rear of the teeth wears away, leaving the sharp enamel edge shaped like the blade of a chisel. Also typical for rodents is the split upper lip.

d) Nares - Look for this pair of openings near the tip of the snout. Air can be drawn through them into the respiratory system. While passing through the nasal passages, gaseous substances in the air can stimulate the olfactory receptors.

e) Eyes - Notice where the eyes are placed in the skull. The central area through which light enters the eye is the pupil, surrounded by a circular structure called the iris. In most animals, the iris is pigmented. By its contraction, the iris can regulate the size of the pupil. A characteristic feature is the nictitating membrane (Plica semilunaris) in the corner of the eye. In other vertebrate species (some amphibians, reptiles, camels, seals) this is a transparent third eyelid that can cover the entire cornea.

f) Pinnae - Rats are much more auditorily oriented than humans. Their cartilagenous pinna acts as a reflector dish, eliminating a segment of the frequency spectrum (pinna notch, cf. HRTF). Pinna movements help with sound localization. In the living animal, the pinna can be rotated in the directionsource of a sound source.

g) Anus - The posterior opening of the digestive system is found at the base of the tail. - Determine the sex of your rat. Compare it with one of the opposite sex.

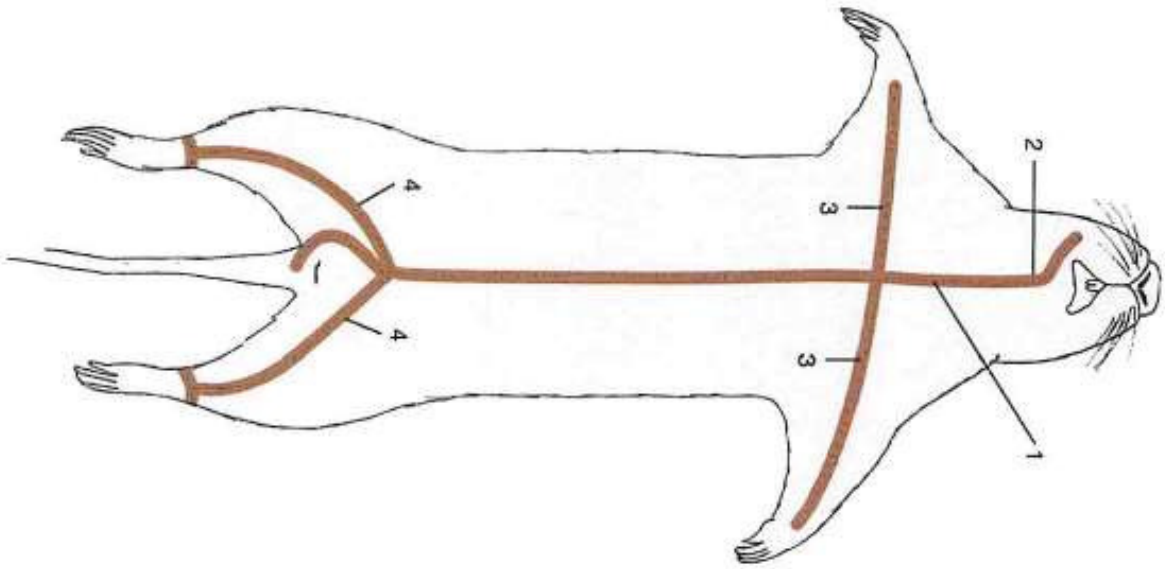
h) Male external reproductive structures and openings: The scrotum containing the testicles is located anterior of the anus, and in front of this the penis with the opening of the urogenital system. In rodents, the testicles descend periodically from the abdominal cavity

along the inguinal canal into the scrotum (spermatogenesis does not occur at internal body temperature). In the mid-ventral line, anterior to the scrotum, there is a small sheath of loose skin, the prepuce. Look for the opening in its apex. During sexual arousal, the penis can be protruded through this opening.

i) Female external reproductive structures and openings: The vaginal opening is visible between the anus, at the base of the tail, and the separate opening of the urethra, which is more ventral. Look for the mammary glands. There are usually six pairs–three in the thoracic region and three in the abdominal region. They will be small and difficult to see in both immature females and in males.

Dissection step I: *Using the scalpel or scissors cut the ventral scin in one medial cut from the lower jaw to the pelvic girdle, at one side from penis/clitoris. Be careful not to damage the underlying layers of muscle. If you have a male rat draw the cut to the posterior end of the scotum. After this cut the skin over the limbs until reaching the middle of the lower arms and legs. Then separate the skin with a scalpel from the muscles.*

j) The integumentary system comprises the skin and its appendages. The skin consists of the tough cutis (epidermis and dermis) and underlying connective tissue (subcutis) with deposits of fat. The tough structure of the dermis is due to collagen.



2. The Abdominal Cavity: Digestive System

Dissection step II *: To open the abdominal cavity make a medioventral cut along the linea alba from the pelvic girdle to the sternum. Pull the muscle layers with forceps and cut tangentially. The organs inside the abdomen should not be damaged. At the posterior margin of the thorax cut the peritoneum (the membrane lining of the abdominal cavity) along the rib cage. At the posterior end of your cut (by the genitals), cut laterally so that you are creating two flaps of skin that will open from the center of the rat. Flap these open and fix them with pins on the sides. The abdomen is separated from the thoracic cavity by the diaphram. You can now identify the following organs:*

a) The Liver is an obvious landmark. It is the large, reddish brown mass that lies immediately posterior to the diaphragm (the muscle dividing the thoracic and abdominal cavities). The liver has a great number of functions, including the storage of carbohydrates (glycogen), fat and protein metabolism and detoxification. Its role in digestion is to produce bile, a substance that emulsifies fats making them easier to digest. In humans, the bile is stored in the gall bladder before being released into the small intestine (*ductus coledochus*). However, the rat lacks a gall bladder. Therefore, the bile is released through a duct directly into the small intestine. Conjugated toxins and hemoglobin breakdown (bilirubin and biliverdin, which give faces its colour) are excreted with the bile.

b) Mesenteries - All the organs of the body cavity, particularly those of the digestive system, are called the viscera. These organs are supported from the dorsal body wall by mesenteries. The liver is situated in the ventral mesentery of the stomach and its lobes protrde into the cavity. The mesenteries contain blood vessels, lymph ducts and nerves.

c) Stomach - The food passes from the esophagus into the stomach. Locate this bean-shaped sac, which is partially covered by the left lateral lobe of the liver. By carefully removing this lobe you may easily observe the entire stomach and esophagus. One function of the stomach is to act as a storage organ so that fewer and larger meals can be consumed. Within the stomach, food is coated with mucus and digestion of proteins begins. The cells lining the stomach secrete the hydrochloric acid and the enzyme pepsin,w hich is active only in an acidic environment. The muscular walls of the stomach churn the food, mixing it with enzymes and helping to fragment it. During this time, circular muscles, called sphincters, located at each end of the stomach, prevent the food from escaping.

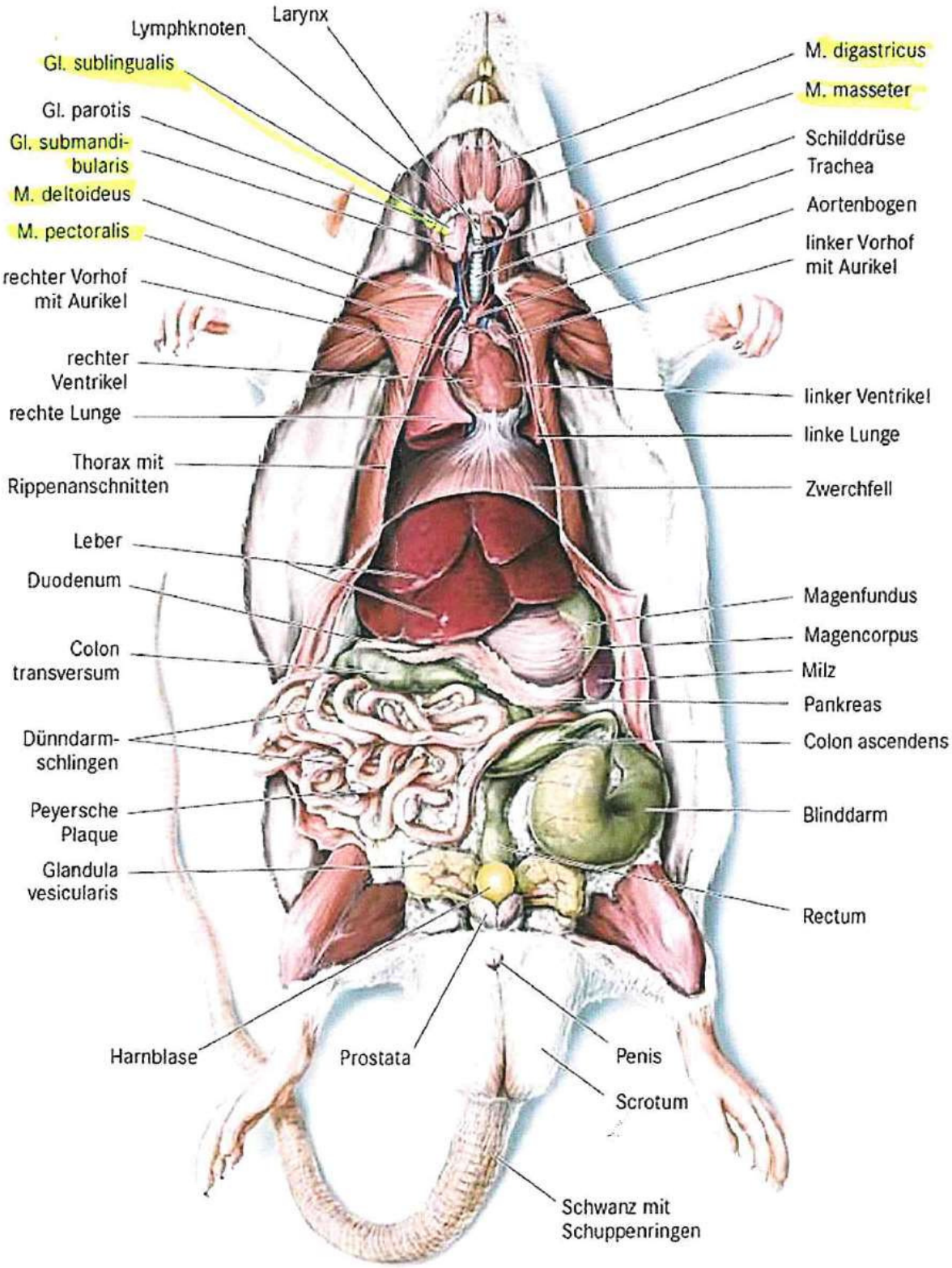
d) Pancreas - The pancreas is an irregular mass of brownish glandular tissue in the mesentery dorsal to the stomach. Secretions of the pancreas enter the small intestine (*ductus pancreaticus* close to the pylorus) and contain enzymes for the breakdown of fats, carbo-hydrates, and proteins. The digestion of fats is aided by bile by emulsifying the fats. The islets of Langerhans in the pancreas are an endocrine organ that produces the hormones insulin (β-cells) and glucagon (α-cells), which pass directly into the circulatory system.

e) Spleen – This is not part of the digestive system. However, it is an obvious structure, and this is a convenient time to locate it. It is a dense, red, elongate structure located on the left side of the rat's body. It is part of the circulatory system where it plays a role in the pro-duction and destruction of blood cells. The spleen also synthesizes antibodies and removes antibody-coated bacteria and blood cells by way of blood and lymphatic circulation. The spleen forms a large reservoir of the body's monocytes, which can move to injured tissue where they differentiate into dendritic cells and macrophages.

f) Small intestine- Locate where the stomach joins with the small intestine. Without tearing the mesentery that binds the coils together, trace the small intestine to its junction with the large intestine. *Do not damage it because you really do not want to release what is inside*. Most of the digestion and the absorption of the products of digestion take place in the small intestine (consisting of ileum, duodenum and jejunum). Glands in the wall of the small intestine secrete enzymes for the breakdown of proteins and carbohydrates. The alkaline environment of the small intestine inactivates the pepsin from the stomach. Enzymes from the small intestine continue the digestion of protein. Epithelial cells lining the small intestine absorb the digested substances and pass them on to the blood capillaries or the lymphatic system for distribution.

g) Caecum - At the junction of the small and large intestine you will find a blind sac, the caecum. This is a place where ingested cellulose is digested by microbial fermentation. Rats and lagomorphs (rabbits, hares) will produce a special feces formed from the caecum product. They will then ingest this feces again, to digest it a second time (why?). This behavior is called coprophagy. Not all mammals have a caecum. Humans do have a short caecum terminating in the appendix. The appendix may serve a function in the immune system, making antibodies. The human caecum provides space for digestion, but does not have the microbes for cellulose fermentation.

h) Large intestine or colon - Running from the caecum, the colon ascends, crosses the abdominal cavity, and descends again. The colon connects posteriorly with the poorly differentiated rectum of the rat connecting the colon and the anus. The primary function of the large intestine is to absorb most of the water of the digestive secretions. In humans, most of the *microbiome* is located in the colon, where bacteria breakdown undigested fibers and other materials thereby contributing to the digestive function. Investigating interactions of the intestinal microbiome with the immune and nervous systems is fashionable right now.


Lymphknoten
Larynx
Gl. sublingualis
Gl. parotis
Gl. submandi-
bularis
M. deltoideus
M. pectoralis
rechter Vorhof
mit Aurikel
rechter
Ventrikel
rechte Lunge
Thorax mit
Rippenanschnitten
Leber
Duodenum
Colon
transversum
Dünndarm-
schlingen
Peyersche
Plaque
Glandula
vesicularis
Harnblase
Prostata
M. digastricus
M. masseter
Schilddrüse
Trachea
Aortenbogen
linker Vorhof
mit Aurikel
linker Ventrikel
linke Lunge
Zwerchfell
Magenfundus
Magencorpus
Milz
Pankreas
Colon ascendens
Blinddarm
Rectum
Penis
Scrotum
Schwanz mit
Schuppenringen

3. The Thoracic Cavity: Cardiovascular and Respiratory Systems

Dissection step III: We now open the thoracic cavity. For this, cut the diaphragm along the ribs without damaging the underlying organs. Using the scissors make a flat cut of the sternum on one side thereby breakin the ribs where they join the sternum. Then, remove the ribs on both sides by cutting them at their dorsal insertion. Cut the rib bones with the points of the scissors always angled slightly upwards, so that you do not damage any internal organs. When the left and right rib cages are no longer joined, carefully open them to expose the thoracic cavity.

a) Trachea - To reach the lungs, air travels through the nose or mouth to the pharynx and then to the trachea. Find the trachea in the neck region. You will notice that it has C-shaped rings of cartilage to prevent it from collapsing as air rushes through it. Note that in the anterior region the cartilaginous bands are replaced by a single, larger housing of cartilage. This initial portion of the trachea is the larynx or voice box, within which lie the vocal cords. The vocal cords are folds of epithelium that vibrate, producing sounds as air passes over them. The trachea branches into the right and left bronchi. The forking of the trachea occurs immediately dorsal to the aorta and cannot be seen at this time. Each bronchus leads to a lung where it branches further into bronchioles.

b) Thyroid - The small brownish glandular mass found on either side of the anterior end of the trachea is the thyroid gland. As an endocrine gland it is not part of the respiratory system. What is the hormone produced here, and what are its functions?

c) Lungs - Identify the lungs and note that there are four lobes on the right lung and only one on the left lung. Within the lungs, the bronchioles carry the air to their endings, tiny air sacs. Inside, these air sacs are further partitioned into chambers called alveoli. This greatly increases the surface area available for gas exchange. In the human, the internal surface area of the lung is equal to about half the area of a tennis court. In fact, our lungs have a greater surface area than our skin. The alveoli are only one cell layer thick and have capillaries immediately outside of them. The gas exchange occurs across these moist surfaces by simple diffusion. The oxygen, being in higher concentration in the inspired air, diffuses across the alveolar and capillary walls and is picked up by the red blood cells of the blood. The concentration of carbon dioxide is higher in the blood that has carried it from the cells, where it was produced by the oxidation of foodstuffs. The carbon dioxide will diffuse into the alveoli and leave the body during exhalation.

d) Diaphragm - Notice that the lungs are located within closed cavities, the thoracic or pleural cavities, which are lined by membranes, called the pleura. The parietal pleura line the wall of the cavity (body wall, diaphragm, and median septum) and visceral pleura line the lungs. Find the diaphragm, a muscular wall separating the thoracic and abdominal cavities. The fact that the lungs lie within closed cavities is critical to the mechanism of breathing. During inspiration, the size of the chest cavity is increased, creating a negative pressure or vacuum that draws air into the lungs. This action is accomplished by the contraction and flattening of the dome-shaped diaphragm and the contraction of the muscles between the ribs. The contraction of the rib muscles raises the ribs, thus increasing the size of the thoracic cavity. Air fills the lungs. During expiration, the diaphragm and rib muscles relax and decrease the size of the chest cavity, forcing the air out. The maintenance of a closed chest cavity is, therefore, essential to the breathing mechanism. This is similar to the way a bicycle pump works. When you pull out the handle, a piston is drawn back inside the cylinder,

increasing its volume and creating a negative pressure that draws air into the pump. Pushing in the handle moves the piston so that the internal volume is lessened and air is forced out of the pump. Obviously, a hole in the side of the pump would prevent it from working.

We will pay more attention to the **heart and the cardiovascular system** later.

5. The Abdominal Cavity: the Urogenital System

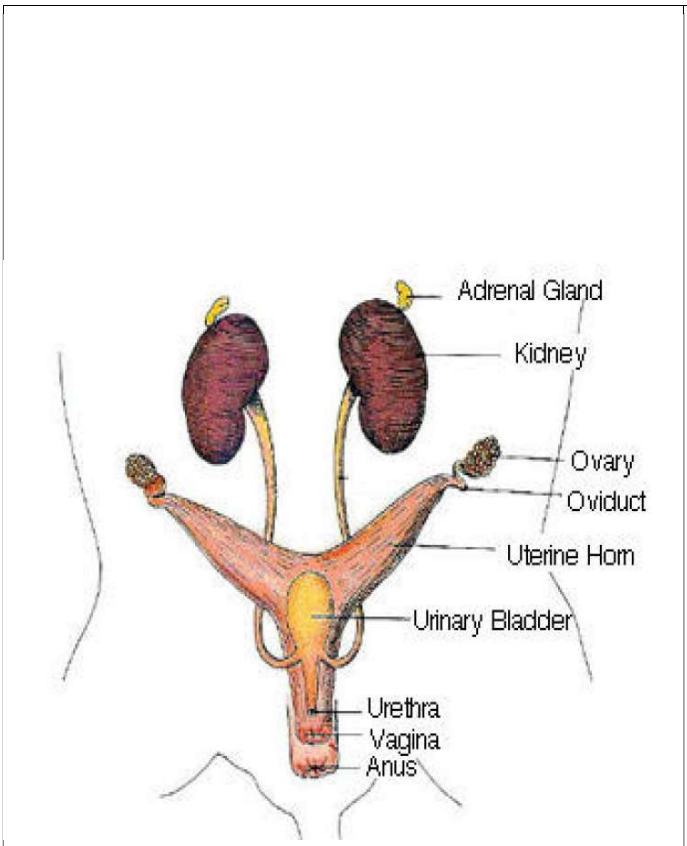
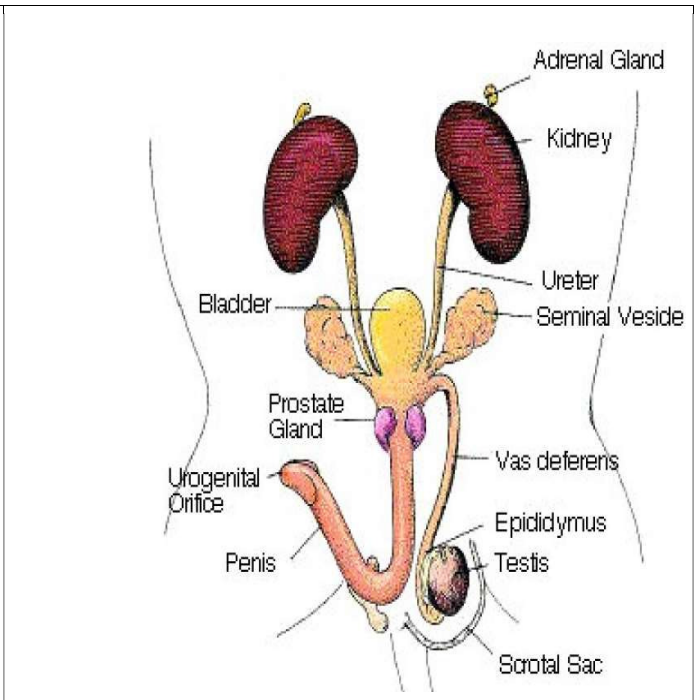
Push the guts aside and look what is underneath (dorsal).

a) Kidneys - Find the pair of bean-shaped kidneys lying against the back muscles on the dorsal side of the animal. These are often embedded in fat. The blood is brought into the kidney for processing and taken out of the kidney via the vessels that can be seen near the medial indentation. The excretory system functions in removing the nitrogenous waste products of cellular metabolism, as well as in removing a number of other materials that may be present in the blood in excess of the body's needs. However, it conserves materials that are not in excess. The material removed from the blood by the kidney is gathered internally in collecting ducts that empty into the larger **ureter** through which the urine leaves the kidney. Locate this duct as it passes from the indentation on the medial side of each kidney close to the blood vessels. The path of the ureter is toward the posterior end of the animal.

b) Adrenal glands - Remove some of the fat from around the kidneys and locate the adrenal glands. These are endocrine glands. The most important hormone of the adrenal medulla is adrenaline (epinephrine), which exerts a variety of effects on the body, preparing it for emergency situations. The cortex of the adrenal glands produces other hormones that can be categorized into three groups: regulators of carbohydrate and protein metabolism, regulators of salt and water balance, and sex hormones.

c) Urinary bladder- This sac stores the urine prior to its passage outside the body. The organ is usually contracted in a preserved specimen and appears as a small pear-shaped muscular sac. Do not pinch the bladder not to spill the rats urine. **Urethra -** The urine flows through this tube as it exits the body. It can be seen if the mesenteries holding the bladder are dissected away and the bladder is displaced dorsally. In the male, the urethra extends through the penis. It will carry sperm from the testes and secretions of reproductive accessory glands as well as the urine. In the female, the urethra opens to the exterior separately from the reproductive system.

Prepare one of the kidneys, removing the fatty tissue. Which blood vessels and what else do you have to dissect the kidney? With the scalpel cut the kidney lengthwise: In the section you can identfy the renal sinus, pyramids in the medulla and renal cortex.

	
male reproductive system	female reproductive system

The male reproductive system:

d) Scrotum - You have already identified the scrotum, the sac housing the testes. In the nonreproductive season, the testes may be withdrawn into the abdominal cavity.

e) Testes - Cut open the scrotum to reveal the testes. Slit one testis open and notice that it contains a mass of tubules. These are the "seminiferous tubules", where the sperm are produced. In addition to sperm, the testis produces male sex hormones.

f) Epididymis - The sperm pass from the seminiferous tubules into this highly coiled tubule. The epididymis covers both ends and the lateral surface of the testis.

g) Vas deferens - This tubule carries the sperm from the epididymis to the urethra. It passes anteriorly and joins the urethra very close to the spot where the latter leaves the urinary bladder. – Close by is the urethra - You have previously identified this tubule.

h) Penis - You have already identified this structure. Its erectile tissue is composed of three cylindrical masses of sponge-like vascular tissue. During sexual excitement, the arteries leading to this tissue become dilated and the veins draining it become constricted to cause the erection. In addition, the rat has a rod of connective tissue called a baculum or “penis bone” enhancing this rigidity.

Accessory glands - The secretions of all the accessory glands form the seminal fluid that

carries the sperm during ejaculation, activates the sperm, provides some nutrients for them, and contains substances that help to neutralize the acidity of the vagina. The products of the coagulating gland probably contribute to the vaginal plug, which is formed in the female rat after copulation. There are several accessory glands.

i) The prostate gland is large and has lobes. Look for it where the urethra and vas deferens join. It usually surrounds the bladder.

j) Seminal vesicles - The vesicular glands and the coagulating glands comprise the *Vesicula seminalis*. They are shaped like wings and are located anterior to the urinary bladder.

k) The Preputial glands are exocrine glandes that are located in the folds fatty tissue of the genitals. They and produce pheromones and lubricants during copulaiton.

The female reproductive system

l) Uterus - Locate this structure in the region posterior to the kidneys. In the rat, the uterus is actually divided into two complete uteri, which open separately into the vagina. The two uterus system is know as the unterine horn. Open the uteri and examine any embryos you find.

m) Ovaries - These are located near the anterior end of the uterus. They are often embedded in fat, which must be carefully dissected away. The ovaries produce the ova, which, if fertilized, will develop into embryos.

n) Oviducts - Each oviduct is a highly coiled tubule found on the surface of an ovary. The ova pass from the ovary into the oviduct, which carries them to the uterus. The ovary is actually surrounded by the funnel-shaped opening of the oviduct, so that the eggs are released directly into this tubule.

6. The Cardiovascular System

Now have a closer look at the heart and the major blood vessels (see figure lastt page).

a) Turn the heart to the right side of the rat to see the right atrium where the **Vena cava posterior, V. cava anterior dextra** and **sinistra** enter, follow the V. cava posterior as it goes through the diaphragm, receives the **Vena hepatica** from the liver and enters into the **right atrium**.

b) Turn the heart to the left side of the rat. You see the **Vv. pulmonales** coming from the lungs, enter into the left atrium- The **aorta** has its origin in the **left ventricle**. Identify the **main arteries that branch off from the aorta**. Which vessels carry the blood to the brain?

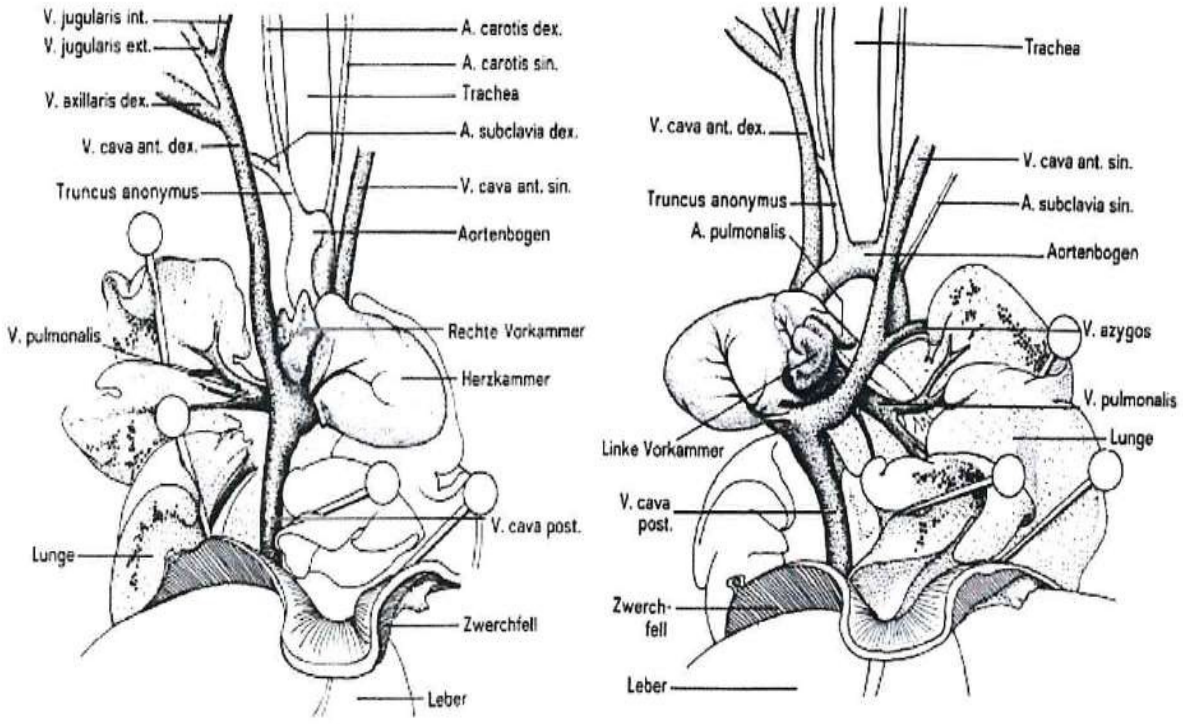
c) *Open the pericardial sack, remove the heart from the thorax and cut it with the scalpel* so that you can see the **two ventricles**. Note the differnt thickness of the myocard of left and right ventricle. Orient the heart so that the thicker-walled left ventricle is on your right. This is the position of the heart when it is exposed from the ventral side of the animal, as your rat's heart is now.

Please review the blood flow through lungs, body and different chambers of the heart.
Valves - The effectiveness of these contractions is increased by the presence of valves that prevent the backflow of blood. Locate the semilunar valves between the aorta and the left ventricle. A similar set of valves is found at the junction of the pulmonary artery and the right ventricle. These valves prevent blood from flowing back into the ventricles from the arteries. Between each atrium and its corresponding ventricle is a set of 'atrioventricular valves'. When the ventricles contract, blood is forced against these valves, forcing them shut and preventing the flow of blood back into the atria. Chordae tendineae prevent the valves from flapping back into the atria, which would permit the backflow of blood.

Sources:

http://bcrc.bio.umass.edu/intro/content/rat-dissection-protocol

Kückenthal, Zoologisches Praktikum, Spektrum Verlag


V. jugularis int.
V. jugularis ext.
V. axillaris dex.
V. cava ant. dex.
Truncus anonymus
V. pulmonalis
Lunge
A. carotis dex.
A. carotis sin.
Trachea
A. subclavia dex.
V. cava ant. sin.
Aortenbogen
Rechte Vorkammer
Herzkammer
V. cava post.
Zwerchfell
Leber
Trachea
V. cava ant. dex.
Truncus anonymus
A. pulmonalis
Linke Vorkammer
V. cava post.
Zwerch-fell
Leber
V. cava ant. sin.
A. subclavia sin.
Aortenbogen
V. azygos
V. pulmonalis
Lunge