



Rat Anatomy Organ Systems Unit Plan

GRADES 5-6



Animal Welfare Institute

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Curriculum Alignment

This unit plan can be used to create classes for Grades 5-6 based on the BC Science Curriculum. Specific Big Ideas covered in this lesson plan include:

Grade 5: Multicellular organisms have organ systems that help them to survive and interact with their environment

Grade 6: Multicellular organisms rely on internal systems to survive, reproduce, and interact with their environment.

We have recommended specific anatomy apps and virtual dissection tools to use to get the most out of this lesson plan. You'll find links to those on page 7.

Learning Objectives

This unit plan is for a summary of rat anatomy and body systems. It can be condensed into one longer summary class, or used to delve deeper into each body system over multiple classes. It is intended for Grade levels 5-6 but can be adapted for other grades depending on the level of detail covered.

By the end of the lesson students should be able to:

- Explain how key anatomical features help rats in their natural environments
- Describe the major body systems of rats and their major organs
- Explain the function of each major organ
- Explain how the major body systems in rats work together to create whole functioning organisms
- Identify key similarities and differences between rats and humans

All About Rats!

Use these notes to inform your class content, no matter what grade you're teaching!

Rats belong to the order *Rodentia*, from the Latin root “rodere” which means “to gnaw.” Rodents make up about 40% of all mammal species and include rats, mice, beavers, chipmunks, squirrels, prairie dogs, porcupines, guinea rats, hamsters, and gerbils, all of which are characterized by their continuously growing upper and lower incisors which are used to gnaw food, create burrows, and defend themselves.

Rats have a varied diet, including seeds and other plant materials, and are often considered commensal organisms, living among humans and scavenging and consuming scraps from waste receptacles and decaying organisms. Intelligent and social animals, many rats live in societies with one another, communicating in complex and varied ways. They have a keen sense of smell and can be trained easily, making them great pets.

Unfortunately, rats are also synonymous with the word “pest” as they are often the cause of disease and habitat destruction. It makes sense that a group of rats is called a “mischief”! A rat's genome is 90% similar to that of a human's and by studying their working anatomy, we can gain insight into our bodies and our relationship to rats as vertebrates.

EXTERNAL ANATOMY

The **nose** is located at the anterior end of the rat and is responsible for smell. Two small holes in the tip of the nose (**nares**) bring air into the nasal passageways for gas exchange when the mouth is closed. The rat has a very keen sense of smell and picks up smells from its surroundings including chemicals such as pheromones. **Vibrissae**, or tactile hairs, (also known as whiskers) are located on the cheeks, chin and eyebrows and are used for sensory reception. Below the nose is the **mouth**, the site where food consumption occurs. Upper and lower **incisors** protrude from the mouth and are used to gnaw through food, assist in burrow excavation, and aid in defense. Two **eyes** situated on either side of the head take in visual stimuli with some ability to distinguish colour, but provide blurry vision and poor depth perception. Each eye is surrounded by an upper and a lower **eyelid** which are responsible for protecting the eye. Rats also have a **nictitating membrane**, found in the inside corner of the eye. This membrane is responsible for wiping debris from the surface of the cornea and to help moisten the eye. On either side of the head above the eyes are two **pinnae**, or external ear flaps, that surround the external auditory membrane. These gather sounds from the environment and focus them into the inner ear to be interpreted by the brain.

Before you get started, it's important to review some anatomical terminology with your students. When studying any organism, scientists use directional terms to identify regions and parts easily. These terms are consistent throughout anatomy studies and are provided in the chart below. Be sure to revisit this chart with your students often.

Posterior	Back	Anterior	Front
Superior	Above	Inferior	Below
Caudal	Toward the bottom or tail	Cranial	Toward the top of the head
Proximal	Toward the trunk (abdomen)	Distal	Away from the trunk (abdomen)
Lateral	Away from the midline	Medial	Toward the midline
Dorsal	Back	Ventral	Front
Superficial	Closer to the surface of the body	Deep	Further from the surface of the body
Internal	On the inside	External	On the outside

Recommended Software and Other Education Tools

[3D Rat Anatomy app](#) by Biosphera
(also available via Google Play)

[Paper rat dissections](#) and worksheets
(These are great fun! We highly recommend trying to get these to your students even if you're teaching online)

[Emantras Virtual Rat Dissection app](#)
(also available via Google Play)

Recommended Hardware/Workbooks

This inventory is for regular in-person classes. For responsible physical distancing use one tablet per student. If teaching online, screen share your own tablet or desktop with the Biosphera 3D Rat Anatomy app installed, and use electronic versions of our Rat Anatomy Workbook.

Six (or more) tablets

Six (or more) constructed rat paper dissections (3 male, 3 female) with blank legends printed out (the legends are part of the rat paper dissection bundle from Getting Nerdy with Mel and Gerdy, linked below) and the relevant numbers highlighted to focus students on the body systems/organs you want to cover. If teaching online we recommend trying to get paper rats to your students somehow, whether you arrange for them to pick them up at the school, mail them, or have them print them at home—their homework can be to cut out their rat and stick it together before class (assembly instructions are included in the bundle from Mel and Gerdy).

Six (or more) printed copies of the Rat Anatomy Workbook (accompanies the 3D Rat Anatomy app)

Grade 5–6 Unit Plan: Rat Body Systems

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The different organ systems of rats and how they help rats thrive in their natural habitat.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major body systems of rats and their major components• Explain the function of each major organ• Explain how the body systems of rats work together to create a whole functioning organism• Identify key similarities and differences between rats and humans
Objectives	After this unit students will state the major rat body systems and the major organs of each system. They will also identify the major differences and similarities between rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy• Various anatomy worksheets (found within this document)
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the various body systems.
Development	Questions to support inquiry-based learning: <ul style="list-style-type: none">• How do body systems interact with one another?• How do a rat's organ systems interact with the environment to meet their basic needs?• How are internal systems necessary for survival?• What do body systems require for survival?
Practice	Going one body system at a time (one system per lesson), students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different organs.

Grade 5–6 Unit Plan Overview

TOPIC	CONTENT
Respiratory	Heart, arteries, veins, capillaries
Circulatory	Trachea, bronchi, bronchioles, alveoli, lungs, diaphragm
Digestive	Esophagus, stomach, small intestine, pancreas, liver, and large intestine
Urogenital	Kidneys, ureters, bladder, urethra, ovaries and oviducts (female), uterus and vagina (female), penis and testes (male), epididymis, vas deferens, and prostate (male)
Nervous & Sensory	Brain, spinal cord, nerves. Eyes, ears, whiskers, taste buds, nasal epithelium
Endocrine	Adrenals, hypothalamus, ovaries, pancreas, pituitary, testes, thyroid
Musculoskeletal	Bones, tendons, ligaments, muscles, fascia

Grade 5–6 Unit Plan Approach

If teaching regular in-person classes:

- Split students into 6 groups.
- Give each group one constructed paper rat dissection model to refer to, and a blank legend with highlighted numbers to indicate which sections to fill out (you'll need to prepare these ahead of time—the legends are part of the rat paper dissection bundle from *Getting Nerdy with Mel and Gerdy*, linked on page 7). The legend corresponds to the paper dissection and the apps will be used to help identify tissues and organs so that students can fill in the blanks. Give three of the groups a female paper rat, the other three groups a male paper rat.
- Give all groups one (or more) tablet(s) with the 3D Rat Anatomy app loaded and ready to use (linked on page 7).
- For each body system, give the students time explore the apps and do self-directed learning to learn about the organs. Ask them to fill in the blanks of their paper dissection legends using the app to help them.
- Every 15 minutes or so, have a 5 minute check-in to make sure the students are sticking to the learning objectives and filling their legends out correctly.
- The Emantras virtual rat dissection app can be used as supplemental material if you wish (linked on page 7).
- Close each lesson with a focused discussion to recap what was learned, to discuss how the major body systems work together, and to make sure you've covered all your learning objectives.

If teaching physically-distanced classes:

- Proceed as above but with one tablet and one paper rat per student.

If teaching online:

- Screen share your own desktop or tablet to guide students through each organ system (one per lesson).
- We recommend using [Kahoot](#) quizzes to create learning games and to keep students engaged.
- Ask students to fill out their paper rat legends as you go along (if doing this you'll need to arrange for students to have access to paper rats ahead of teaching this unit—you can either mail them, arrange for them to be picked up at the school, or ask students to print out their rats at home).

Detailed Lesson Plans and Teaching Notes

Introduction to topic:

Have a brief conversation about why you're choosing to use non-animal teaching methods rather than real animal specimens, and how this aligns with a culture of respect for animals.

Introduce the software and other materials you'll be using to teach rat anatomy. Give the students a roadmap of topics that will be covered: respiratory, circulatory, digestive, urogenital, nervous & sensory, endocrine and musculoskeletal systems, as well as species differences, adaption to habitat and function, etc.

Opening questions to class:

1. What type of animals are rats?

Rodents, mammals

2. Where do rats live?

They are highly adaptive, but tend to live where they can dig, build burrows and build nests.

3. Can anyone think of anything special about rats that helps them adapt to their habitat?

Whiskers, long tail, fur, acute sense of smell.

Encourage students to keep these answers in mind as they go through the rat anatomy lessons.

Lesson 1: Digestive System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat digestive system.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs of the rat digestive system• Explain the function of each major organ• Explain how the major organs work together Identify key similarities and differences between the digestive systems of rats and humans
Objectives	After this lesson students will state the organ in the rat digestive system and explain the function of each organ. They will also identify the major differences and similarities between the digestive systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the digestive system.
Development	The teacher will ask students to explain how the various organs in the rat digestive system work together to help digest food. The teacher will also ask the students how they think rat and human digestive systems are similar and different.
Practice	Going one digestive organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different digestive organs.

Digestive System

Mouth	Digestion begins in the mouth. Rat teeth grow continually so they need to eat hard foods to wear down their teeth. If the teeth are misaligned (a condition called malocclusion) it can cause fatal injury.
Esophagus	After swallowing, food moves through the esophagus. Wave-like muscular contractions along the esophagus, called peristalsis, move the food along through the esophageal sphincter and into the stomach.
Stomach	The stomach uses mechanical and chemical digestion to break down food further. Three layers of muscle contract in different directions to break down food mechanically. Gastric acid (hydrochloric acid) and protein-digesting enzymes are released into the stomach for chemical digestion. Different sections of the stomach = cardiac region, fundus, body, and pylorus.
Small Intestine	Food then passes into the small intestine via the pyloric sphincter. In the upper portion of the small intestine (the duodenum) digestion continues via secretion of pancreatic digestive enzymes from the pancreas (via the pancreatic duct). In the lower portions of the small intestine (the jejunum and ileum), nutrient absorption occurs via intestinal villi which line the inner surface of the intestine. Nutrients pass across the villi wall to surrounding capillaries and into the bloodstream.
Pancreas	Both a digestive and endocrine organ. In its digestive function it releases digestive enzymes into the small intestine that break down carbohydrates and proteins. In its endocrine function it produces insulin, glucagon and glycogen, which together work to regulate blood sugar levels.
Liver	Has four lobes. Produces bile which contains enzymes that break down fats. Also the body's major waste filter—via the hepatic portal system, blood is filtered through special functional cells called hepatocytes.
Large intestine	Has a special area called the caecum which specializes in breaking down plant material. Primarily responsible for absorption of water.

Digestive System

During check in:

Highlight key differences between rats and other species, especially humans:

Rats have no gallbladder! Why do you think that might be? There are three reasons rats do not have gallbladders.

- *Their diet is primarily made of plant matter, meaning they require less bile to break down their food than if they consumed more proteins that require large amounts of bile.*
- *Rats are constantly eating, meaning that the bile produced by the liver is frequently used and rarely needs to be stored.*
- *The bile produced by the rat's liver is more concentrated than the bile produced by many other species. As the gallbladder is where most animals concentrate their bile after it leaves the liver, this function of the gallbladder is unnecessary in rats. Rat liver also have four lobes (humans have two, pigs have five).*

Highlight key similarities between rats and other species, especially humans:

Same major organs, apart from lack of gallbladder.

Development question:

- How does the digestive system interact with the circulatory system so that nutrients are absorbed into the bloodstream?
- How does the digestive system interact with the circulatory system to filter the blood of waste products?
- How does the digestive system help the rat meet its own basic needs?

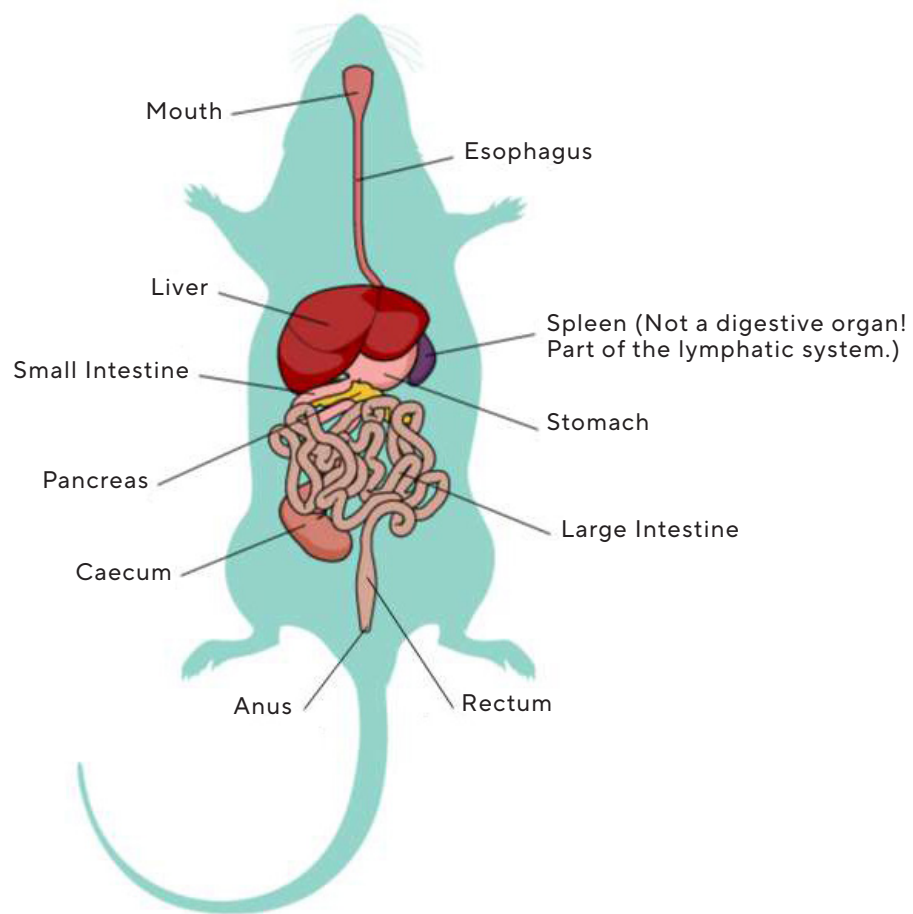
Digestive System

Food enters the rat digestive system through the **mouth**. It is clipped by the upper and lower incisors, chewed by molars, and transported to the pouch-like stomach via the **esophagus** using peristaltic contractions. Food undergoes mechanical and chemical digestion in the **stomach** until it is a mushy substance called chyme. It is stored in the stomach until it is ready to be released into the **small intestine**. The small intestine is divided into three main sections: the **duodenum** (beginning) which receives enzymes via ducts from the digestive glands, liver and pancreas, the **jejunum** (middle), and **ileum** (end). It is responsible for the chemical digestion of food and the absorption of nutrients through millions of tiny finger-like projections lining the small intestine called villi. It is wound tightly upon itself in the abdominal cavity with the help of the intestinal mesentery, a membrane that not only holds the intestines together, but also holds various blood vessels that supply nutrients to and from the intestines. At the junction of the small intestine and the large intestine is the **caecum**, a large pouch-like structure that houses bacteria necessary for the digestion of plant materials in the rat's diet. The **large intestine** functions in the reabsorption of water out of the remaining undigested food before it is passed to the **rectum** to be stored until it is excreted from the body through the **anus**.

Accessory organs in the digestive system are necessary components of the digestive process. The **liver** serves as a filter for removing toxic substances from the blood and creates muricholic acid, a bile acid that helps break down plant cholesterol. Unlike humans, rats do not have a gall bladder, so the muricholic acid is directly secreted into the small intestine. The granular looking **pancreas**, located below the stomach and duodenum, makes a variety of digestive enzymes, including insulin to regulate blood sugar as well as others that aid in breaking food down even further. The smooth **spleen**, also located near the digestive organs, functions in the destruction of old red blood cells.

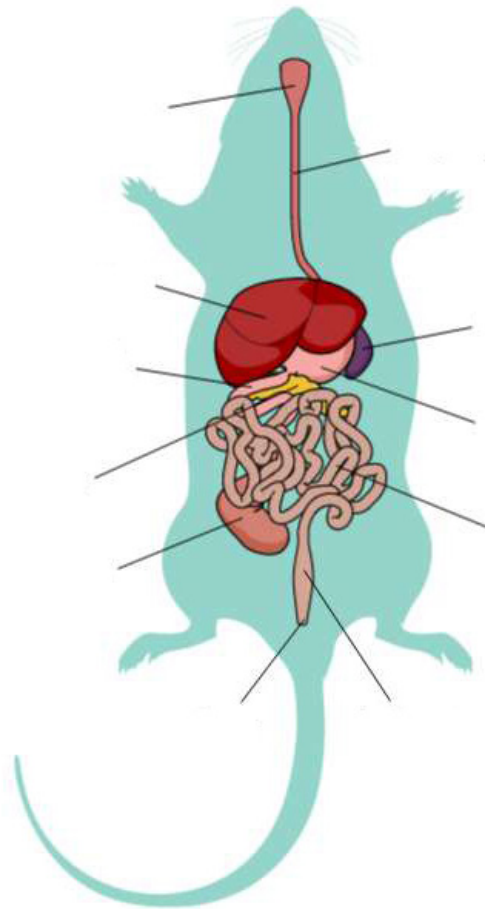
Digestive System (teacher copy)

Ask the students to label the major organs in the rat digestive system. They can either do this as a learning exercise using the 3D Rat Anatomy app or as a post-learning evaluation. There's a blank diagram on the next page to print and use.



Digestive System

Label all the major parts of the rat digestive system.



Lesson 2: Musculoskeletal System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat musculoskeletal system..

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat musculoskeletal system• Explain the function of each major organ/tissue• Explain how the major organs/tissues work together• Identify key similarities and differences between the musculoskeletal systems of rats and humans
Objectives	After this lesson students will state the organs/tissues in the rat musculoskeletal system and explain the function of each. They will also identify the major differences and similarities between the musculoskeletal systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the musculoskeletal system.
Development	The teacher will ask students to explain how the various organs in the rat musculoskeletal system work together to help with body stability and movement. The teacher will also ask the students how they think rat and human musculoskeletal systems are similar and different.
Practice	Going one organ/tissue at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different musculoskeletal organs/tissues.

Musculoskeletal System

Bones	The major functions of the bones are body support, facilitation of movement, protection of internal organs, the production of red blood cells.
Tendons	A fibrous connective tissue which attaches muscle to bone.
Ligaments	A fibrous connective tissue which attaches bone to bone.
Muscles	Muscles allow rats to move, vocalize and chew. They control heartbeat, breathing, and digestion. Other seemingly unrelated functions, including vision, also rely on the muscular system. There are three types of muscles: skeletal (consciously controlled), smooth (lines blood vessels and organs) and cardiac (located only in the heart).
Fascia	Connective tissue that surrounds muscles, groups of muscles, blood vessels, and nerves, binding some structures together, while permitting others to slide smoothly over each other.

During check in:

Highlight key similarities between rats and other species, especially humans:
Same major components and functions.

Highlight key differences between rats and other species, especially humans:
No major differences.

Development question:

- How does the musculoskeletal system work with the nervous system to make sure there is coordination between muscles and nerves?
- How does the musculoskeletal system work with the circulatory system to make sure muscles get the oxygen they need to function effectively?

Musculoskeletal System

Despite their four-legged lifestyle, rats have all the same bones as humans, which is not surprising since they share the characteristics of being both vertebrates and mammals. One striking difference, however, is that rats have anywhere from 58-60 vertebrae (humans have 33). Seven cervical **vertebrae** attach to the skull and support the head of the rat. These are followed by 13 thoracic vertebrae to which the ribs attach. There are 13 **ribs** that make up the rib cage. The **sternum** is the central meeting point of the ribs which serves as an attachment point for many back and abdominal muscles. A bony structure that protrudes caudally is called the **xiphoid process** and provides an additional attachment point for major abdominal muscles. Ribs that attach directly to the sternum are called **true ribs**.

Ribs that attach to the intercostal cartilage before reaching the sternum are considered **false ribs**. The intercostal cartilage provides flexibility to the rib cage so that it can expand and contract with each inhalation and exhalation. Ribs that do not attach to the sternum at all are called floating ribs. Six lumbar vertebrae follow in the lower back/abdominal area and attach to the pelvic girdle which protects some of the digestive organs and reproductive organs as well as provides the point of attachment for the hind limbs. Four sacral vertebrae make up the dorsal (back) portion of the pelvic girdle and lead into 28-30 caudal vertebrae which make up the tail. Each vertebra has several processes (bumps), facets (flat spots) and/or foramen (holes) on the surface of it. These all play different roles in providing the body with places for muscles to attach, bones to touch, and nutrients to be supplied to the cells of the bones.

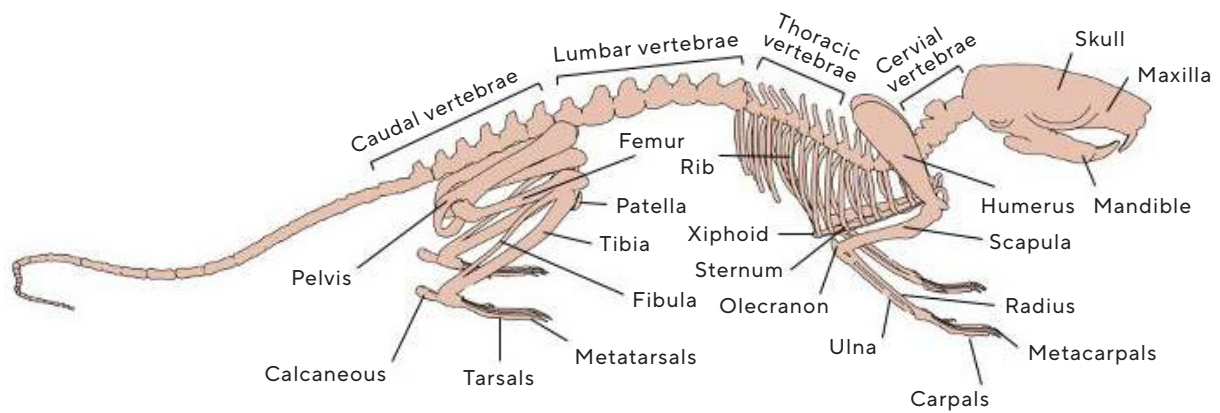
The musculature of rats is attached to bones via tendons. There are three types of muscle tissue: **cardiac** (heart), **skeletal** (used to move the body) and **smooth** (lines organs and vessels).

The skeletal muscles identified in the rat all function in a directional movement of the organism. Here are some major muscles of the cervical, thoracic and abdominal regions:

- *Pectoralis major*: adducts, or moves the forelimb toward the chest
- *Pectoralis minor*: deep to *Pectoralis major*, moves forelimb toward and away from chest
- *Latissimus dorsi*: adducts and rotates shoulder
- *External oblique*: contracts and twists abdomen
- *Rectus abdominus*: contracts and adducts abdomen
- *Sternomastoideus*: contracts and twists neck
- *Clavotrapezius*: contracts and twists neck

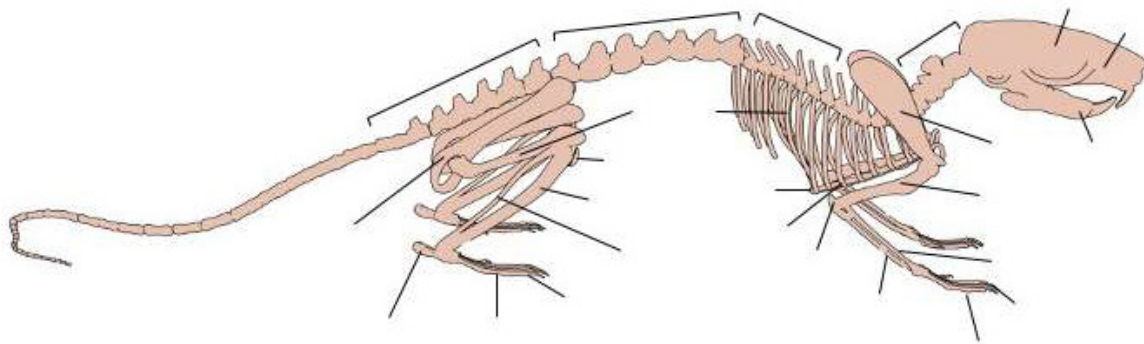
Major Bones (teacher copy)

Ask the students to label the major bones in the rat skeleton - they can either do this as a learning exercise using the 3D Rat Anatomy app or as a post-learning evaluation. There's a blank diagram on the next page to print and use.



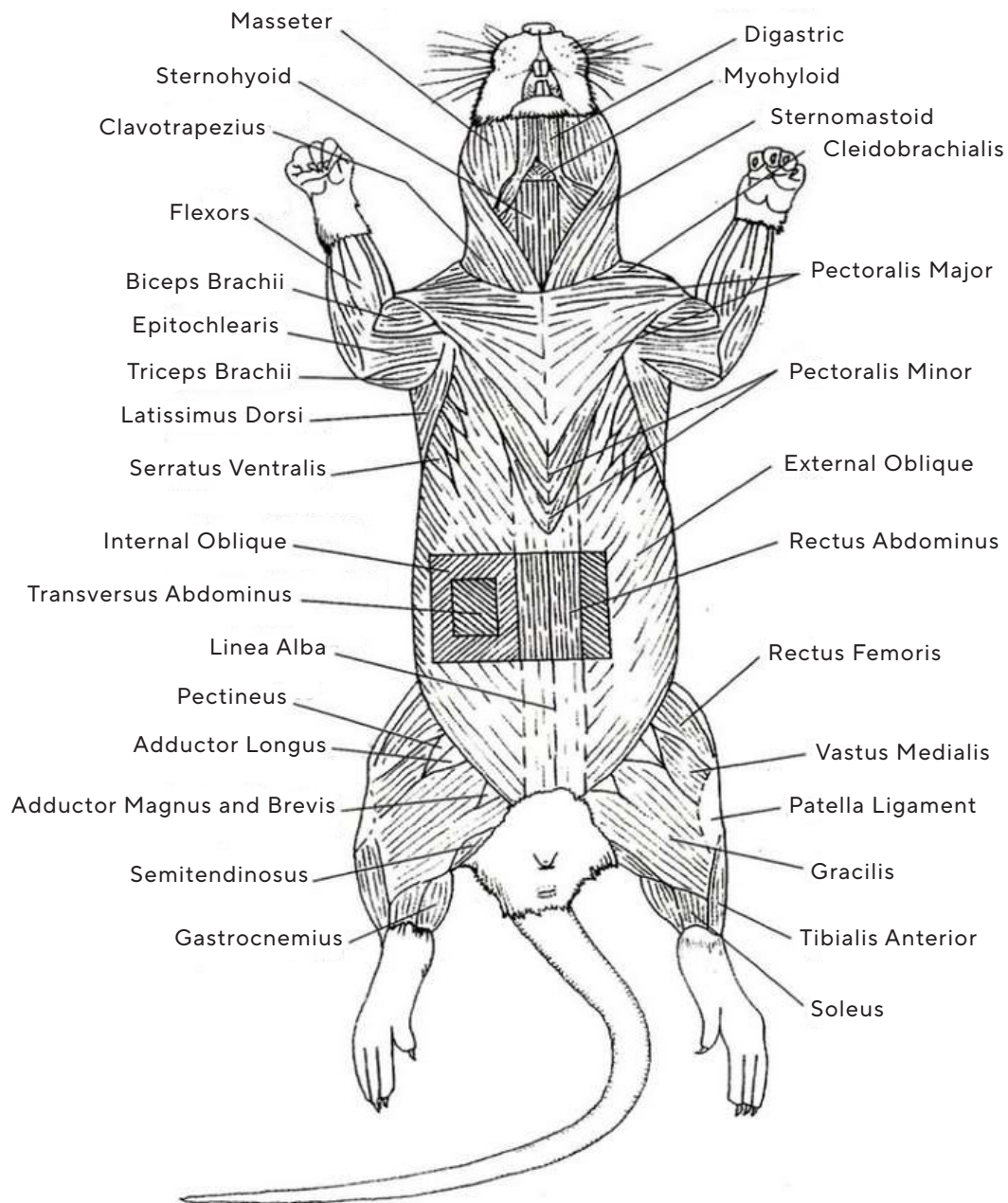
Major Bones

Label the major bones of the rat skeleton

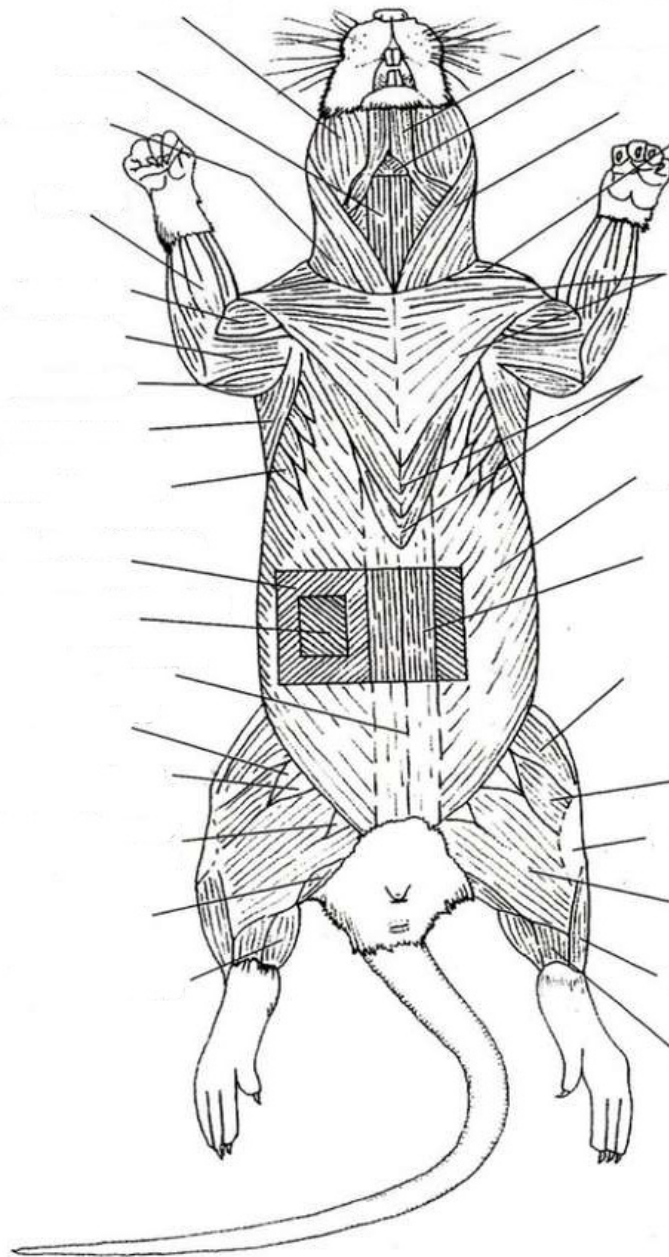


Major muscles (teacher copy)

Ask the students to label the major muscles of the rat. They can either do this as a learning exercise using the 3D Rat Anatomy app or as a post-learning evaluation. There's a blank diagram on the next page to print and use.



Major muscles



Lesson 3: Respiratory System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat respiratory system.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat respiratory system• Explain the function of each major organ• Explain how the major organs work together• Identify key similarities and differences between the respiratory systems of rats and humans
Objectives	After this lesson students will state the organs in the rat respiratory system and explain the function of each. They will also identify the major differences and similarities between the respiratory systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the respiratory system.
Development	The teacher will ask students to explain how the various organs in the rat respiratory system work together with the circulatory system to result in effective respiration. The teacher will also ask the students how they think rat and human respiratory systems are similar and different.
Practice	Going one organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different respiratory organs.

Respiratory System

Trachea	A cartilaginous tube that connects the larynx to the bronchi of the lungs, allowing the passage of air.
Bronchial tubes (bronchi)	Divides further into smaller branches called bronchioles.
Bronchioles	Small branched tubes that carry air to terminal air sacs called alveoli.
Alveoli	Air sacs that are located at the end of the bronchioles. Just one cell wall thick, the alveoli are surrounded by tiny blood vessels called capillaries, so they are the site of gas exchange in the lungs (i.e. where oxygen passes into the bloodstream, and carbon dioxide passes out).
Lungs	Major respiratory organs that expand and fill with air on an inhale, and deflate and empty of air on an exhale. one lobe on left, four on right.
Diaphragm	Major breathing muscle. Contracts and pulls down on an inhale causing air to rush into the lungs (negative pressure space). Relaxes and moves up on an exhale pushing air out of the lungs against the negative pressure gradient.

During check in:

Highlight key similarities between rats and other species, especially humans:

Most of the same major organs (trachea, bronchi, bronchioles, alveoli = lungs, and diaphragm).

Highlight key differences between rats and other species, especially humans:

Rats have different arrangement of lobes in their lungs (although same overall total lobes as humans)—one on the left, four on the right (humans have two on left, three on right).

Development question:

- How does the respiratory system work together with the circulatory system to make sure that oxygen reaches all the parts of the body, and that carbon dioxide is expelled?
- How does the respiratory system help the rat meet its own basic needs?
- How does the respiratory system interact with the rat's environment to help it survive?

Respiratory System

If the purpose of the **heart** is to move blood around the body, then the purpose of the respiratory system is to make that blood useful by removing waste products like CO_2 from the blood and supplying it with O_2 . This begins with the process of inhalation and exhalation.

When a rat inhales, air containing oxygen and other trace elements is pulled in through the **nares** and **mouth** using contractions of the muscular **diaphragm**. The air travels through the **glottis** and down a cartilage-ringed tube called the **trachea**. Along the way, air gets passed over the **larynx**, or voice box, which resides on the anterior surface of the trachea and gives the rat the ability to make sounds for communication, etc. The trachea is divided into two branches called **bronchi** (singular: **bronchus**). Each bronchus carries air to a **lung**, the main structure responsible for gas exchange. Inside each lung, each bronchus is further divided into smaller tubes called **bronchioles**. The bronchioles terminate, or end, in small sac-like structures called **alveoli** (singular: **alveolus**). It is in the alveoli that gas exchange occurs. Each alveolus is wrapped in a network of capillaries from the pulmonary arteries and veins.

Blood cells in the **pulmonary veins** drop off carbon dioxide waste that is released from body cells to be exhaled by the lungs in the next breath. The blood cells in the **pulmonary arteries** pick up the inhaled oxygen that diffuses across the alveolar cells and carries it back to the heart to be pumped out to the rest of the body.

Lesson 4: Circulatory System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat circulatory system.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat circulatory system• Explain the function of each major organ• Explain how the major organs work together• Identify key similarities and differences between the circulatory systems of rats and humans
Objectives	After this lesson students will state the organs in the rat circulatory system and explain the function of each. They will also identify the major differences and similarities between the circulatory systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the circulatory system.
Development	The teacher will ask students to explain how the various organs in the rat circulatory system work together with other body systems to result in effective functioning. The teacher will also ask the students how they think rat and human circulatory systems are similar and different.
Practice	Going one organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different circulatory organs.

Circulatory System

Heart	<p>Like humans, rats have four heart chambers: two atria, two ventricles.</p> <ul style="list-style-type: none">• Blood from the posterior portion of the body enters the right atrium of the heart through the inferior vena cava and the superior vena cava.• Blood flows from the right atrium to the right ventricle via the tricuspid valve.• Blood is then pumped through the pulmonary semilunar valve and into the pulmonary trunk where blood travels to the lungs.• Blood then flows through the pulmonary arteries to the lungs where it is oxygenated and then returns from the lungs to enter the left atrium via four pulmonary veins.• Blood goes from the left atrium to the left ventricle via the bicuspid (or mitral) valve.• Blood leaves the left ventricle of the heart through the aortic semilunar valve and enters the aorta, where it is then distributed to the rest of the body.
Veins	<p>Veins <i>always</i> carry blood towards the heart, and usually carry deoxygenated blood. The only vein that carries oxygenated blood is the pulmonary vein which carries blood from the lungs towards the heart. Major vein = vena cava.</p>
Bronchioles	<p>Arteries <i>always</i> carry blood away from the heart, and usually carry oxygenated blood. The only vein that carries deoxygenated blood is the pulmonary artery that carries deoxygenated blood away from the heart to the lungs. Major artery = aorta.</p>
Capillaries	<p>Capillaries are tiny blood vessels that are just one cell wall thick. This means that various substances like gases, nutrients, waste products, hormones, etc. can pass across the cell wall of capillaries.</p>
Aorta	<p>Major artery that receives blood straight from the heart. Four aortic regions: 1) ascending aorta—the upper part of the vessel that starts at the atrium, 2) aortic arch—the place where the aorta bends to the left, 3) descending aorta—after the bend, the aorta can be traced toward the diaphragm, 4) abdominal aorta—the aorta passes through the diaphragm and supplies blood to the lower extremities.</p>

During check in:

Highlight key similarities between rats and other species, especially humans:
The same major organs (heart, veins, arteries, capillaries).

Highlight key differences between rats and other species, especially humans:
No major differences, all the same organs and vessels.

Development question:

- How does the circulatory system work together with the respiratory system to get oxygen into the body?
- How does the circulatory system work together with the digestive system to get nutrients into the bloodstream?

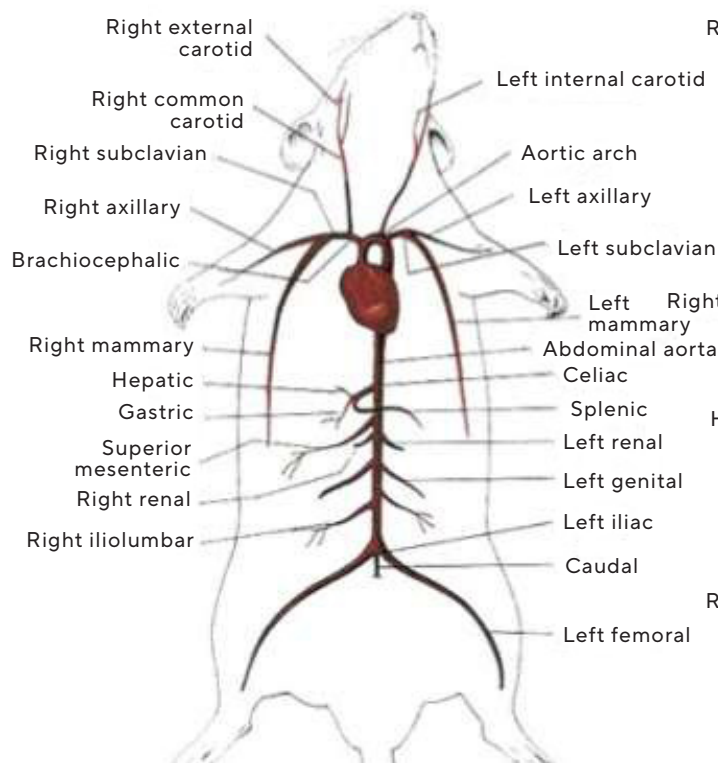
Circulatory System

<p>Tracing the branches of the aortic arch</p>	<ol style="list-style-type: none"> 1. Coronary arteries are located on top of the heart and supply the heart itself with blood. 2. The first visible branch from the aorta is the brachiocephalic artery, it divides into the right common carotid artery, which supplies the right side of the neck, and the right subclavian artery, which supplies the right shoulder and arm. 3. At the most anterior part of the bend in the aortic arch is the left common carotid artery, which supplies blood up the left side of the neck. The common carotid artery branches into the internal and external carotid. 4. Immediately to the left of the left common carotid artery is the left subclavian artery, which supplies blood to the left shoulder and arm. The subclavian artery becomes the axillary artery as it enters the forearm.
<p>Tracing the branches of the abdominal aorta</p>	<ol style="list-style-type: none"> 1. The first arterial branch from the abdominal aorta (below the diaphragm) is the celiac artery which branches to arteries that supply the stomach (gastric artery), liver (hepatic artery), spleen and pancreas (splenic artery). 2. The second artery arising from the abdominal artery is the superior mesenteric artery, which is larger than the celiac, and delivers blood directly to the small intestine. 3. The renal arteries are short and lead directly to the kidneys. 4. Just posterior to the renal arteries are the genital arteries, which lead to the testes or the ovaries. 5. Farther along the abdominal aorta, you can find the iliolumbar arteries which lead to the dorsal muscles of the back. 6. Next, the inferior mesenteric artery leads to the intestinal mesenteries. 7. The abdominal aorta gives rise to the caudal artery, which goes on into the tail. 8. The abdominal aorta finally divides to form the iliac arteries, which deliver blood to the pelvis and hind legs. 9. The iliac arteries lead to the femoral artery in the leg.
<p>Tracing the systemic veins</p>	<ol style="list-style-type: none"> 1. The left and right superior vena cava conduct blood from the upper part of the body into the right atrium. Trace these veins from the atrium until you find the small internal jugular vein, which continues as the subclavian vein. 2. The subclavian vein divides into the external jugular vein and the axillary vein. 3. The inferior vena cava carries blood from the lower part of the body to the right atrium. The hepatic vein drains the liver and enters the inferior vena cava near the diaphragm. 4. Renal veins drain the kidneys. 5. Genital veins lead from the gonads and enter the inferior vena cava. 6. The iliac and femoral veins drain the legs. 7. The caudal vein drains the tail.

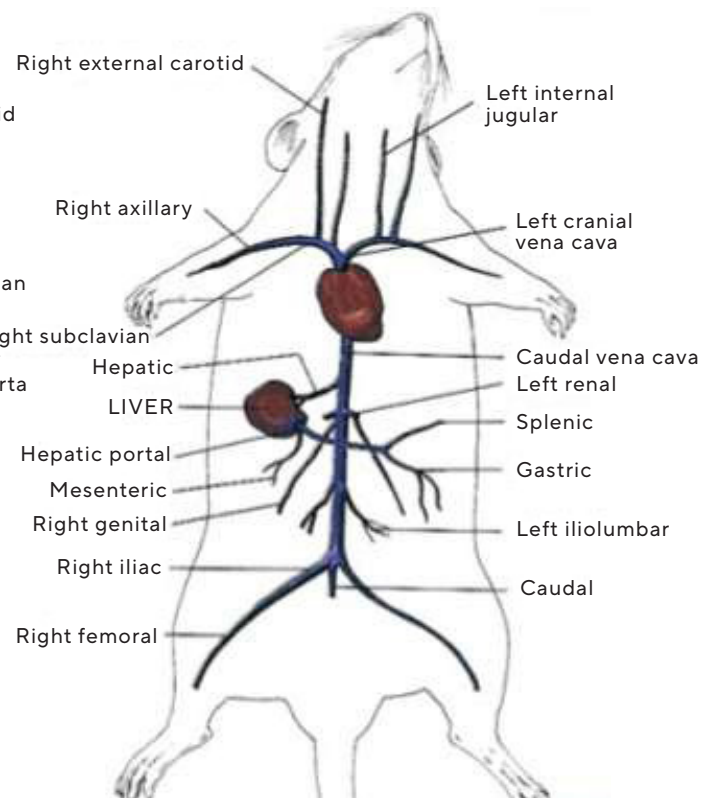
Circulatory System (teacher copy)

Ask the students to label the major blood vessels of the rat. They can either do this as a learning exercise using the 3D Rat Anatomy app or as a post-learning evaluation. There's a blank diagram on the next page to print and use.

Rat Arterial System

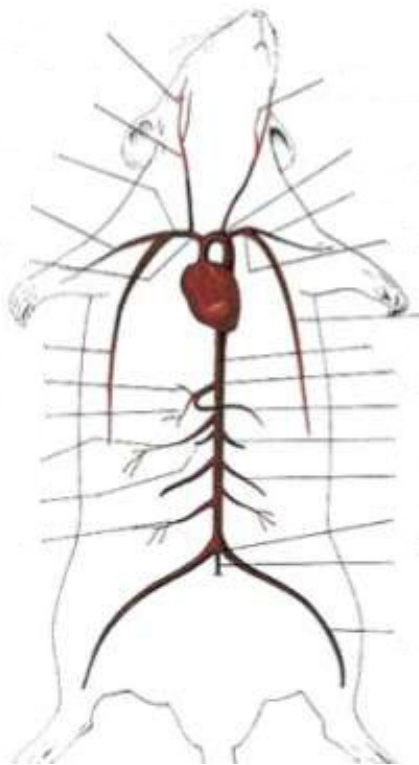


Rat Venous System

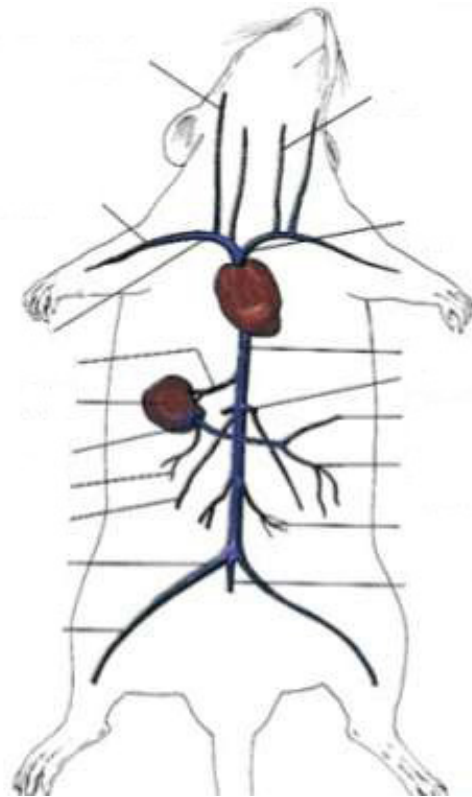


Circulatory System

Rat Arterial System



Rat Venous System



Lesson 5: Urogenital System (Excretory & Reproductive)

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat urogenital system.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat urogenital system• Explain the function of each major organ• Explain how the major organs work together• Identify key similarities and differences between the urogenital systems of rats and humans
Objectives	After this lesson students will state the organs in the rat urogenital system and explain the function of each. They will also identify the major differences and similarities between the urogenital systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the urogenital system.
Development	The teacher will ask students to explain how the various organs in the rat urogenital system work together with other body systems to result in effective functioning. The teacher will also ask the students how they think rat and human urogenital systems are similar and different.
Practice	Going one organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different urogenital organs.

Urogenital System

Kidneys	A pair of organs that filter blood and produce urine. Functional unit = nephrons, which are responsible for blood filtration, reabsorption of water and other important substances, and secretion of urine.
Ureters	A pair of tubes that connect the kidneys and bladder. The urine produced by the kidneys travels along these tubes for storage in the bladder.
Bladder	Stores urine.
Urethra	Urine travels along this tube to exit the body.
Testes	Pair of oval-shaped structures that produce sperm.
Epididymis	Stores sperm produced by the testes.
Vas deferens	Tube that sperm travels down to reach the penis.
Prostate, bulbourethral glands	Produce a fluid that nourishes and protects sperm.
Penis	Pushes urine and semen through the urethra and out of the body.
Ovaries	Paired structures that produce eggs.
Oviducts	Ducts that connect the ovaries and uterus.
Uterus	Receives eggs and supports the development of growing embryos until birth. Rats have a duplex uterus that consists of two separate uterine horns.
Vagina	Serves as a birth canal and also is the orifice that accepts sperm during mating.

During check in:

Question to the class (if using paper dissections):

Looking at your paper rat dissections, do you have a male or a female rat? How do you know? Compare your paper rat with another group that has a different sex. If teaching online and using the paper dissections, you can use the breakout room feature of your online teaching software to allow students to discuss their paper rats.

Highlight key similarities between rats and other species, especially humans:

Same major organs.

Highlight key differences between rats and other species, especially humans:

Uterine horns (humans have pear-shaped uterus). Rats give birth to litters of pups.

How does this arrangement fit their reproductive strategy?

They are more r-selected than humans, but more k-selected than frogs. They are good mothers with strong maternal care, but only invest resources into offspring until weaning.

Development question:

- Looking at your paper rat dissections, do you have a male or a female rat? How do you know? Compare your paper rat with another group that has a different sex.
- How does the urogenital system interact with other body systems?

Urogenital System

The urinary system provides the function of filtering the blood of wastes, excess fluids, and urea, and then eliminating them from the body. It does this using two bean-shaped **kidneys** located below the diaphragm along the dorsal side of the body. Each kidney receives blood from the heart through the **renal artery** which branches from the **descending aorta**. The blood then travels inside the kidney through tiny structures called **nephrons** which filter the blood of waste. The waste is collected and then transported through two tubes called **ureters** which attach to a muscular sac called the **bladder**. The smooth muscle-lined bladder stores the urine and remains relaxed until it becomes full, at which point the brain signals the muscle cells to contract and release the contents through another tube called the **urethra**.

In male rats, the urethra serves as both an exit for the urinary system as well as the reproductive system. This common exit is called the **urinary aperture** and is found at the tip of the reproductive structure in males, called a **penis**. In females, the urethra (anterior) and vaginal orifice (posterior) are separate.

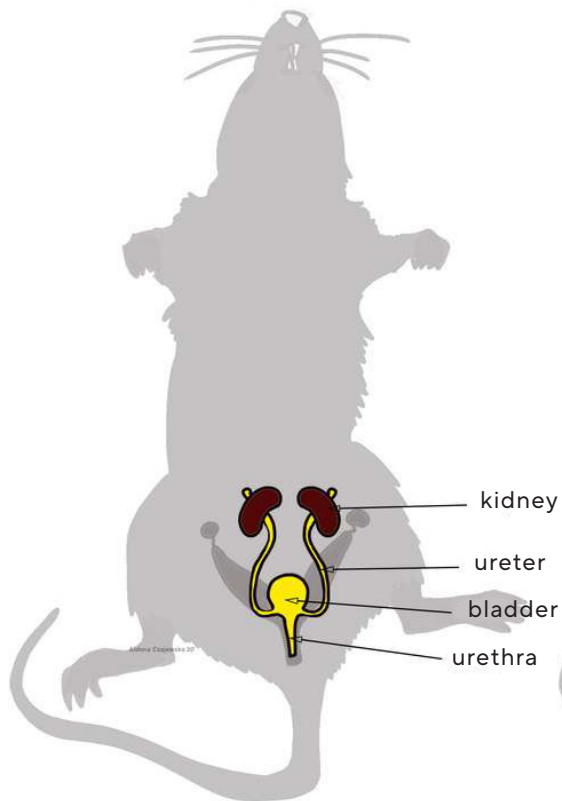
The **testes**, which are housed in the scrotal sac once they descend out of the abdominal cavity, are responsible for making sperm. The **epididymis** collects the sperm and stores it until it is ready to be activated and released from the body. It then travels through the **vas deferens**, which connects the epididymis to the urethra. The **prostate gland** and **seminal glands** located on either side of the penis add seminal fluid to the ejaculate before it is released from the body through the urinary aperture.

In females, eggs are made and stored in the **ovaries**. A tube called an **oviduct** attaches to each ovary and provides the site where fertilization takes place. Fertilized and unfertilized eggs are passed down the oviduct to the **uterine horns**. The bicornuate **uterus** allows rats to have multiple embryos develop at once. Fertilized eggs will become implanted in the uterine horns and begin developing into fetuses. Rats do not show any signs of fertility and do not menstruate. The uterine horns fuse to form the **vagina**, or the birth canal. Viable eggs that become babies will be passed through the vagina and out the vaginal orifice during the birthing process.

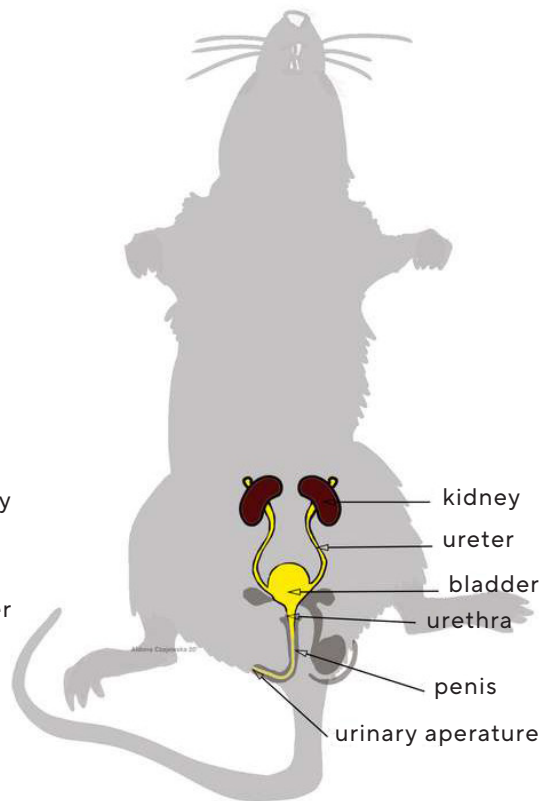
Urinary System Quiz (teacher copy)

Label the major organs.

Female Rat



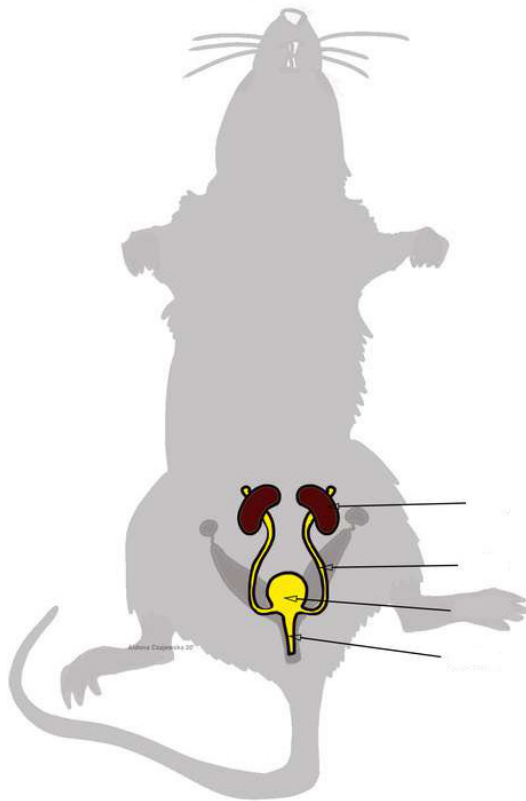
Male Rat



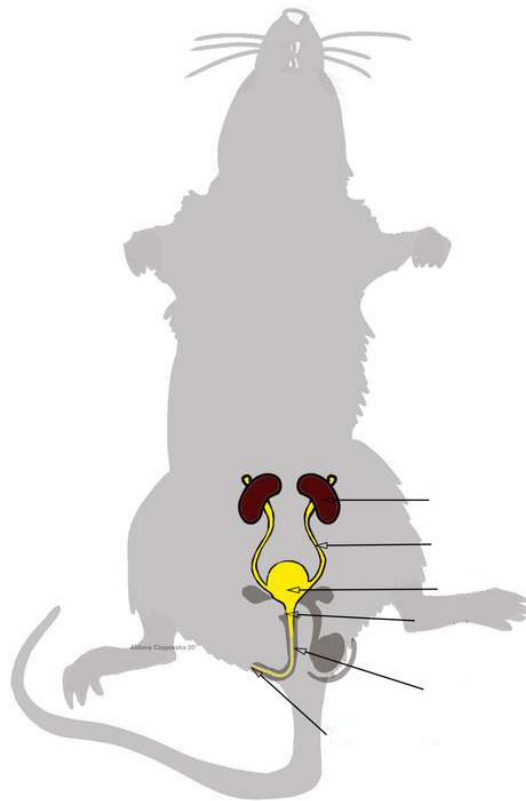
Urinary System Quiz

Label the major organs.

Female Rat

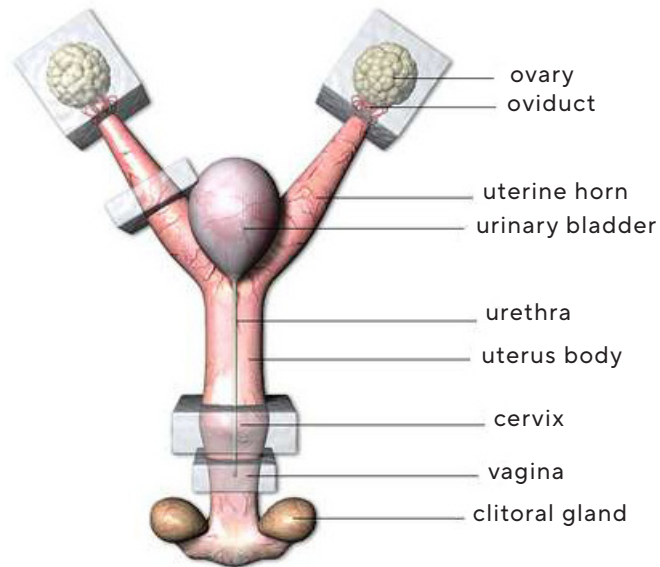


Male Rat

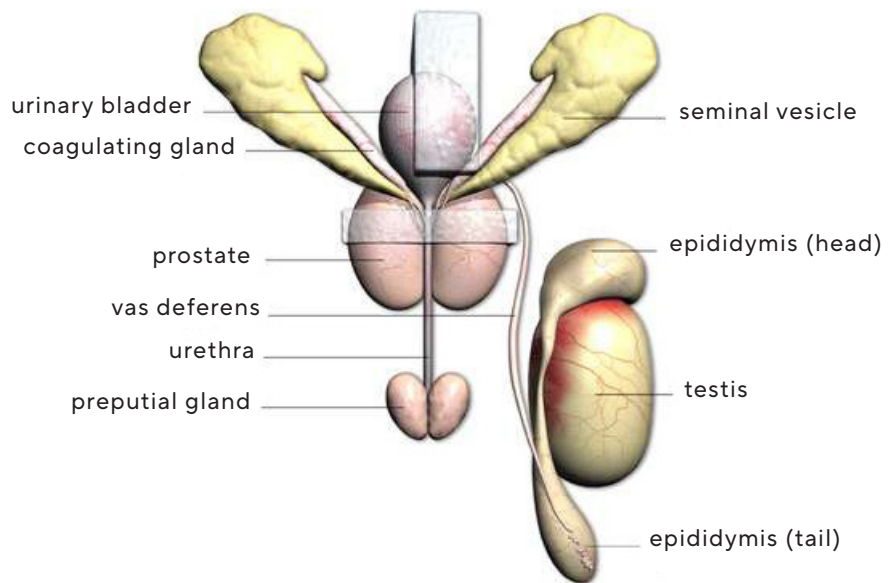


Urogenital System

Female Reproductive



Male Reproductive



Lesson 6: Endocrine (Hormonal) System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat endocrine system.

Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat endocrine system• Explain the function of each major organ• Explain how the major organs work together• Identify key similarities and differences between the endocrine systems of rats and humans
Objectives	After this lesson students will state the organs in the rat endocrine system and explain the function of each. They will also identify the major differences and similarities between the endocrine systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the endocrine system.
Development	The teacher will ask students to explain how the various organs in the rat endocrine system impact with other body systems. The teacher will also ask the students how they think rat and human endocrine systems are similar and different.
Practice	Going one organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different endocrine organs.

Endocrine System

Adrenals	Produce adrenaline and corticosterone (the stress hormone—called cortisol in humans).
Hypothalamus	The hypothalamus produces a variety of hormones that are responsible for body temperature, hunger, moods and the release of hormones from other glands; and also controls thirst and sleep.
Ovaries	Produce estrogen and progesterone—female sex hormones.
Pancreas	Produces insulin (which reduces blood sugar) and glucagon (which increases blood sugar).
Pituitary	The pituitary gland controls the function of most other endocrine glands and is therefore sometimes called the master gland. It produces a wide variety of different hormones that influence other endocrine glands.
Testes	Produce testosterone—male sex hormone.
Thyroid	The thyroid gland produces hormones that regulate the body's metabolic rate controlling heart, muscle and digestive function, brain development and bone maintenance.

During check in:

Highlight key similarities between rats and other species, especially humans:

Same major endocrine glands and function.

Highlight key differences between rats and other species, especially humans:

No major differences.

Development question:

- How does the endocrine system interact with other body systems?
- How does the endocrine system help a rat meet its own basic needs?
- How does the endocrine system interact with the rat's environment to help it survive?

Lesson 7: Nervous and Sensory System

TOPIC: Multicellular organisms have organ systems that help them to survive and interact with their environment.

CONTENT: The rat nervous and sensory system.

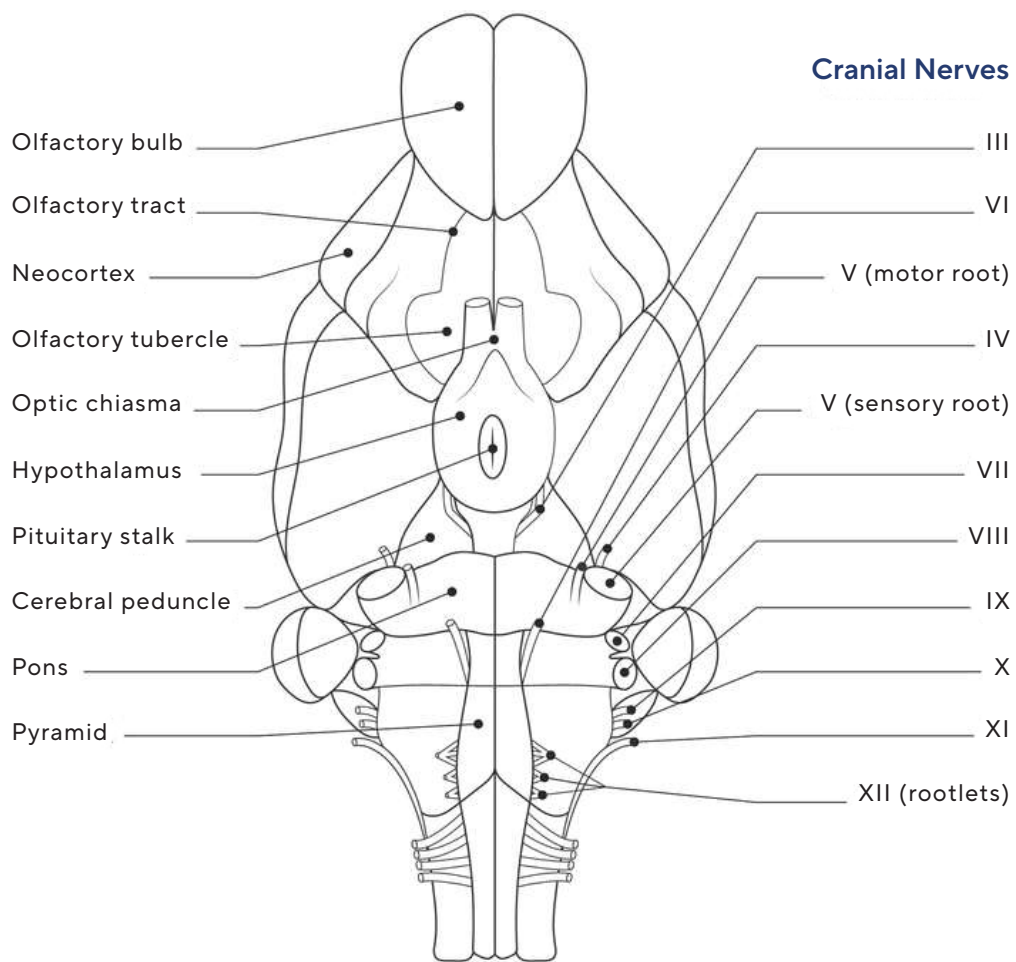
Goals	Students will be able to: <ul style="list-style-type: none">• Identify the major organs and tissues of the rat nervous & sensory system• Explain the function of each major organ• Explain how the major organs work together• Identify key similarities and differences between the nervous & sensory systems of rats and humans
Objectives	After this lesson students will state the organs in the rat nervous and sensory system and explain the function of each. They will also identify the major differences and similarities between the nervous and sensory systems of rats and humans.
Materials	<ul style="list-style-type: none">• 3D Rat Anatomy app by Biosphera• Rat Anatomy Workbook (to accompany 3D Rat Anatomy app)• Paper rat dissection by Getting Nerdy with Mel and Gerdy
Introduction	Using the 3D Rat Anatomy app and the paper rat dissections, the teacher will introduce the nervous and sensory system.
Development	The teacher will ask students to explain how the various organs in the rat nervous & sensory system interact with other body systems, particularly the nervous system. The teacher will also ask the students how they think rat and human nervous & sensory systems are similar and different.
Practice	Going one organ at a time students will work independently or in pairs to fill out the legend of their paper rat dissection by using the 3D Rat Anatomy app to help them identify the different nervous and sensory organs.

Nervous and Sensory System

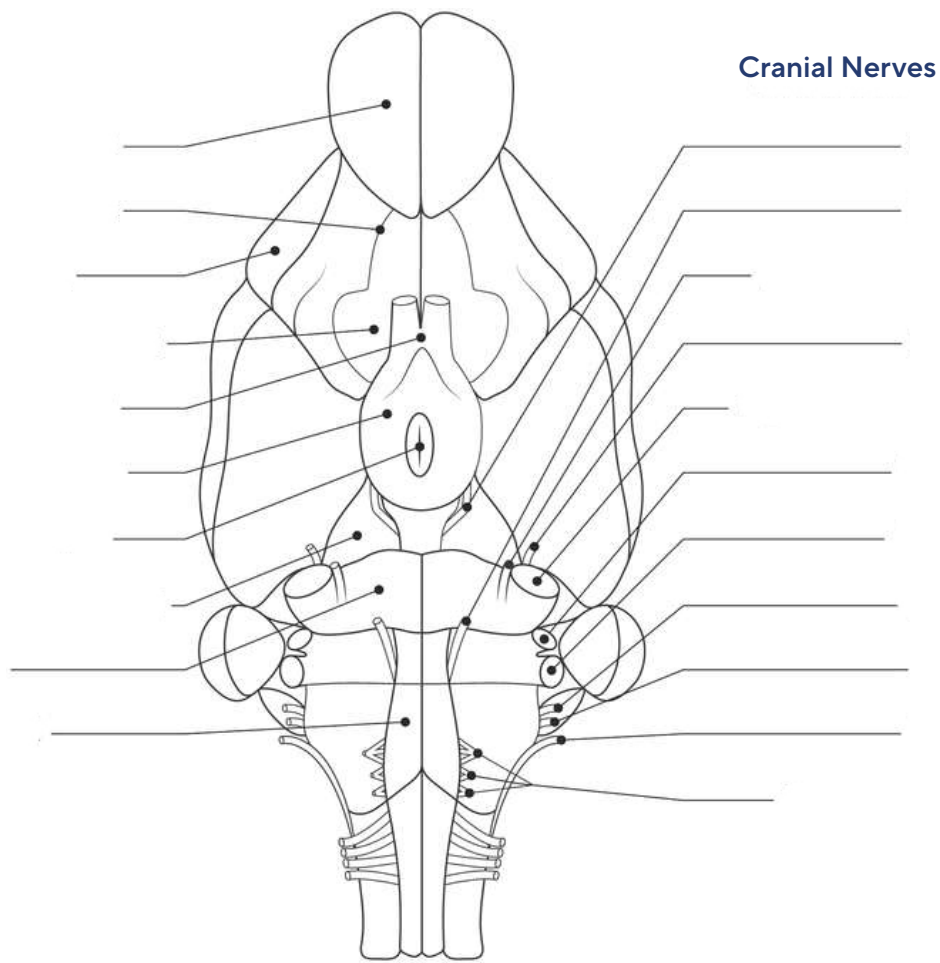
Brain	<p>Part of the central nervous system (CNS), the brain is the primary organ that controls movement, muscular contraction, respiration, digestion, and interprets sensory input. Major parts of the rat brain include:</p> <ul style="list-style-type: none"> • Cerebral hemispheres: separated by a deep fissure and associated with integration. Olfactory bulb: lie anterior to the cerebral hemispheres and caudal to the nasal bones. Associated with the sense of smell. • Cerebellum: lies posterior to the cerebral hemispheres. Has three lobes, two lateral hemispheres and the medial vermis. Responsible for motor coordination and equilibrium. • Medulla oblongata: lies between the cerebellum and the spinal cord. Regulates heart rate, blood pressure, respiration and hormonal secretions.
Neurons	The basic working unit of the brain (CNS). Transmits information to other nerve cells.
Spinal cord	The main pathway to and from the brain. Part of the CNS. Spinal nerves branch off at each region of the spinal cord.
Nerves	Part of the peripheral nervous system (PNS)—specialized fibre bundles that transmit electrical impulses. Rats have twelve pairs of cranial nerves which pass information from the outside directly to the brain.
Eyes	Like humans, rats have eyes that contain receptors that are stimulated by light, and send nerve impulses to the brain that are processed as visual information. However, human retinas contain three types of receptors, whereas rats only contain two. So rats can perceive light and dark, but no colour.
Ears	Like humans, rats have external ears that capture sound vibrations and channel them to a set of inner ear bones. These inner bones vibrate and stimulate small hairs (cilia) that transmit nerve impulse to the brain. However, a rat's hearing is way more sensitive than a human's, and they can hear in the ultrasonic range.
Whiskers	Long, sensitive hairs that grow from the rat's cheeks, chin and eyebrows. A rat perceives its immediate surroundings through its whiskers.
Nasal epithelium	Like humans, rats use their two nostrils (nares) to sample odours in the air. However, a rat's sense of smell is way better than a human's, and they have a larger brain region dedicated to their sense of smell (the olfactory bulbs).

Rat Brain Activity (teacher copy)

Ask the students to label the major parts of the rat brain. They can either do this as a learning exercise using the 3D Rat Anatomy app or as a post-learning evaluation. There's a blank diagram on the next page to print and use.



Rat Brain Activity



Nervous and Sensory System

Dendrite	The branched extensions of a nerve cell that propagate the electrochemical stimulation received from other neural cells to the cell body.
Nucleus	An oval shaped membrane-bound structure found in the soma or body of the neuron. It contains the nucleolus and chromosomes, necessary for the coded production of proteins within the cell.
Cell body	The cell body is the spherical part of the neuron that contains the nucleus and connects to the dendrites, which bring information into the neuron, and the axon, which sends information to other neurons. The job of the cell body is to control all of the functions of the cell.
Axon	An axon, or nerve fibre, is a long slender projection that typically conducts electrical impulses known as action potentials away from the nerve cell body. The axon transmits information to different neurons, muscles and glands.
Schwann Cell	There are two types of Schwann cells: myelinating and non-myelinating. Myelinating Schwann cells wrap around axons of motor and sensory neurons to form a myelin sheath. The myelin sheath is not continuous and acts as an insulator. Myelin is a fatty white substance that surrounds the axon of some nerve cells forming an electrically insulating layer. It is essential for the proper functioning of the nervous system.
Node of Ranvier	Nodes of Ranvier, also known as myelin sheath gap, occur along a myelinated axon. The electric impulse, known as the action potential, "jumps" from one node to another along the nerve axon.
Axon terminal	The distal termination of the branches of an axon.
Synapse	A small gap connecting two nerve cells across which electrochemical signals and neurotransmitter chemicals are transmitted from one neuron to the next.

During check in:

Highlight key similarities between rats and other species, especially humans:
Same major nervous and sensory system components.

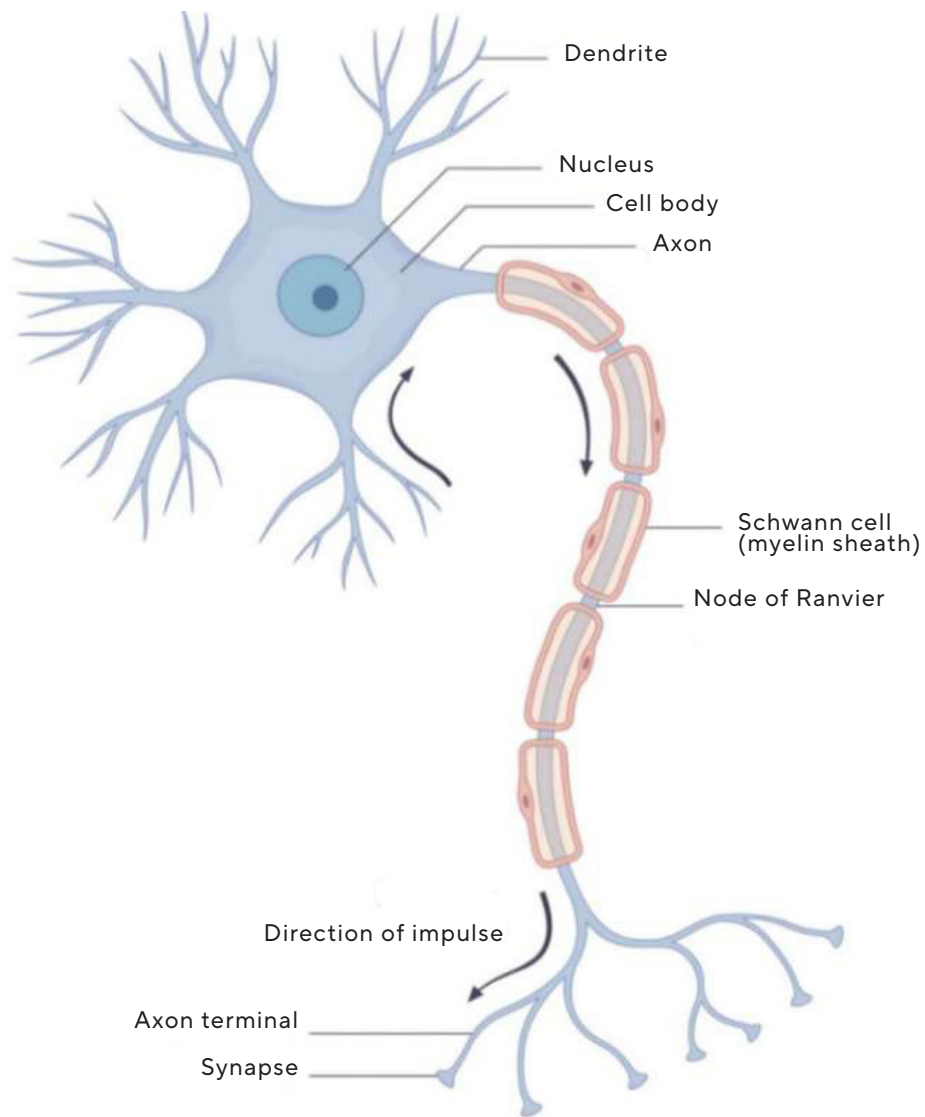
Highlight key differences between rats and other species, especially humans:
Smaller brain, larger olfactory lobe in brain.

Development question:

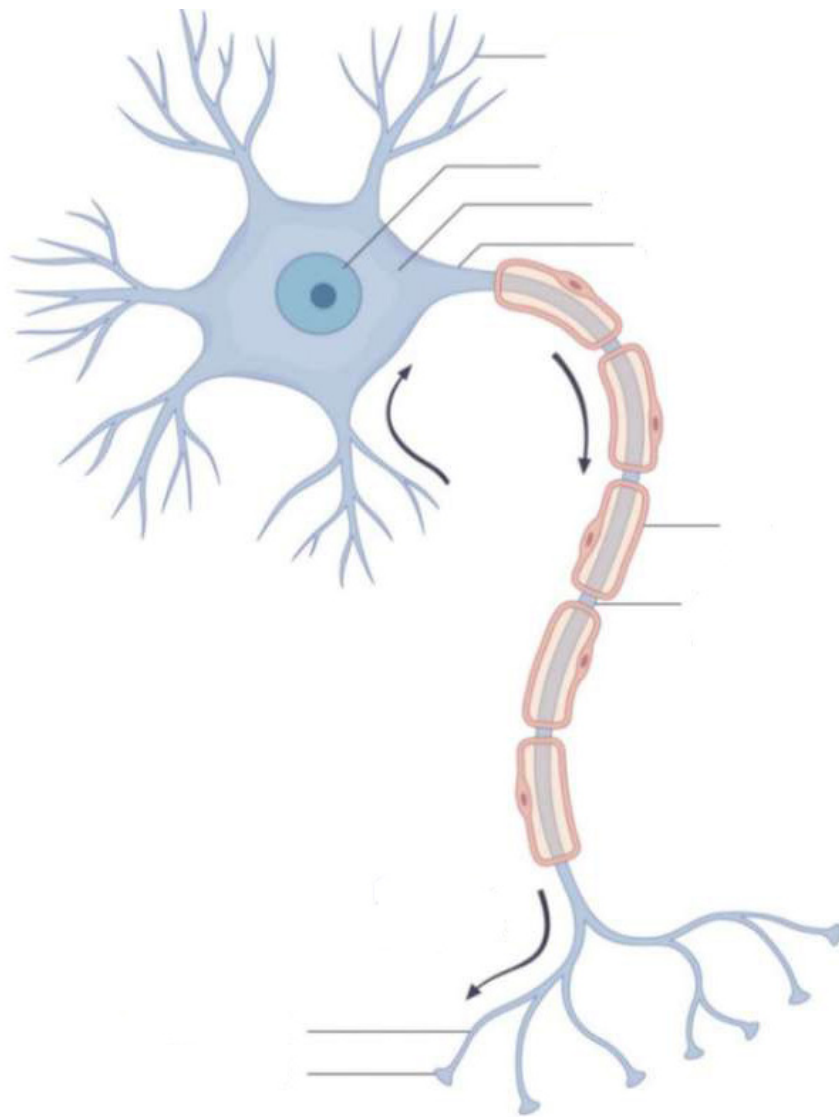
- How does the nervous system interact with other body systems?
- How does the nervous system help a rat meet its own basic needs?
- How does the nervous system interact with a rat's environment to help it survive?

Neuron Anatomy Activity (teacher copy)

Ask the students to label the major parts of a neuron.



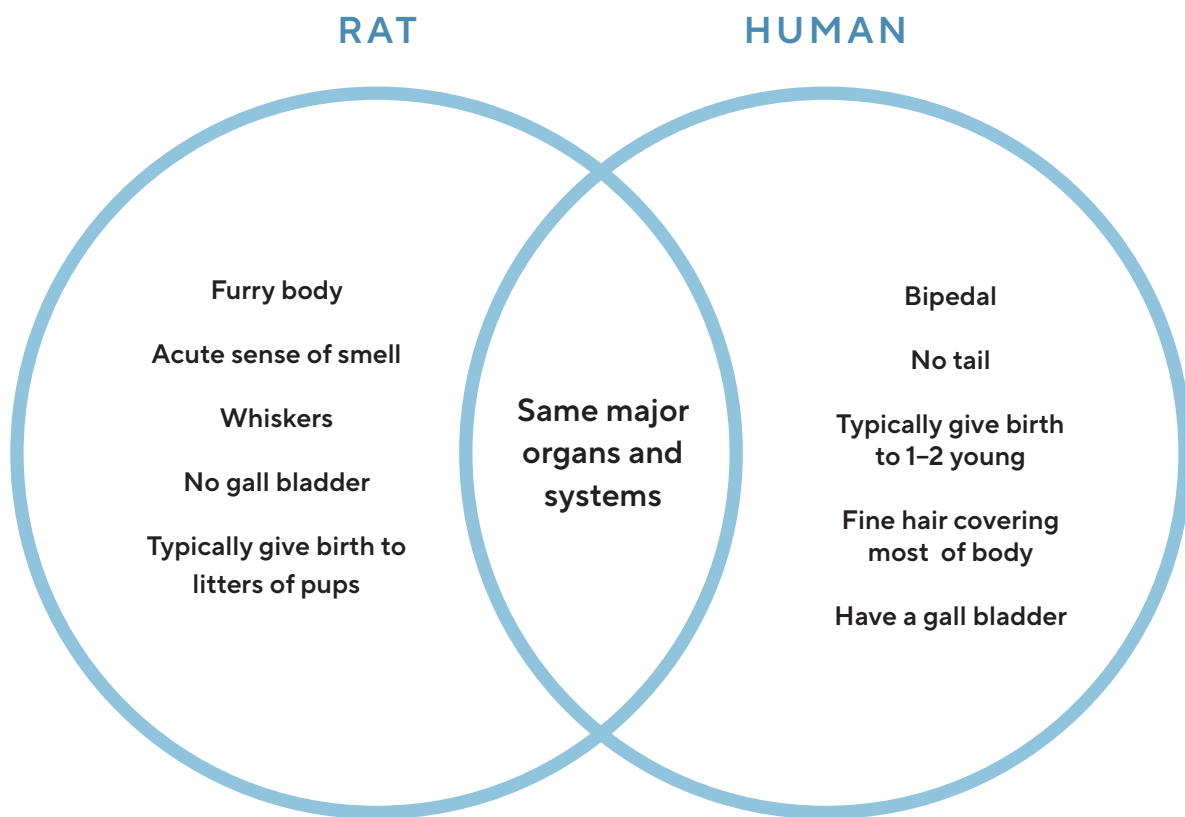
Neuron Anatomy Activity



Similarities and Differences Between Rats and Humans (teacher copy)

ACTIVITY:

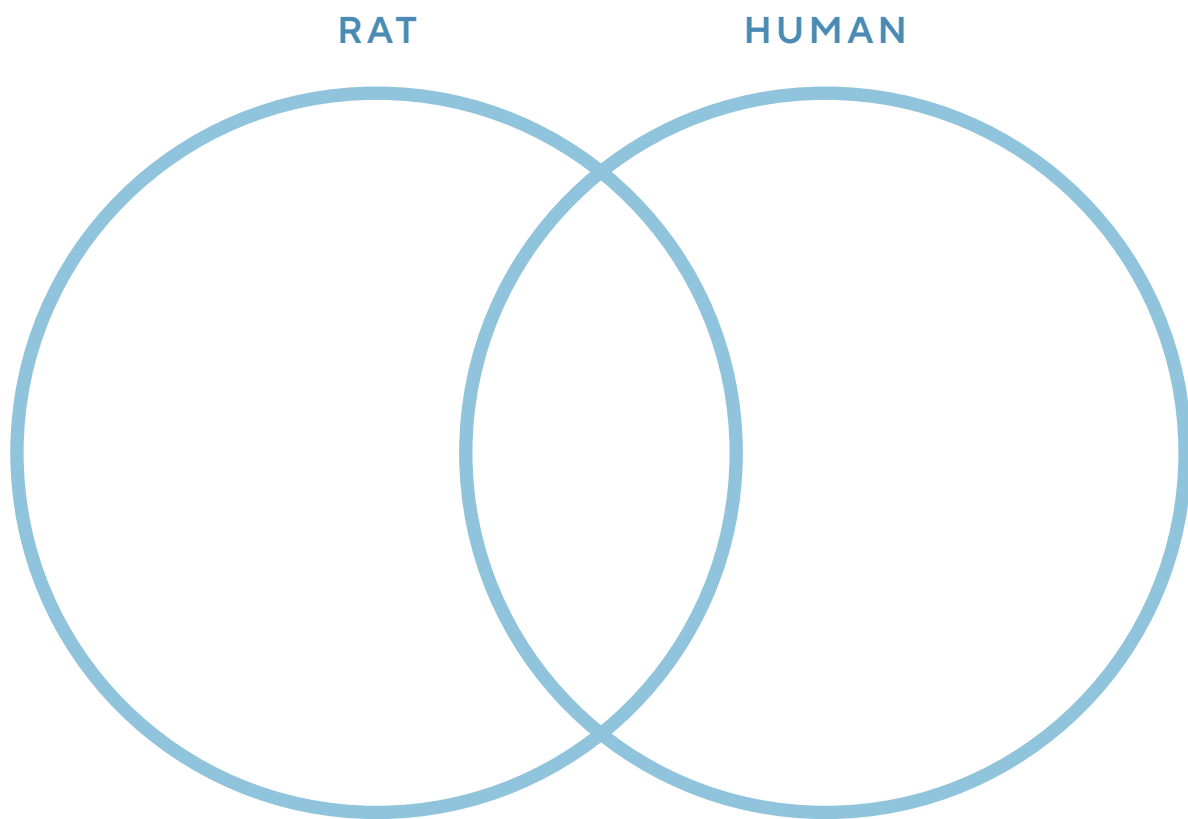
Ask the students to get into pairs, reflect on what they've learned about rat adaptations and organ systems, and fill out the Venn diagram below (some examples are given below but this is not a complete list—blank student copy is on next page).



KEY DISCUSSION POINT AFTER THE ACTIVITY:

While there are some important differences between rats and humans because we are adapted to different natural habitats, there are also many similarities. We both have hearts, lungs, a digestive system, nerves, muscles, bones, blood vessels, etc. *We are more alike than we are different* once you look inside our bodies! So, it's important that we respect rats and avoid causing them harm, especially in science where they are commonly used as 'animal models'.

Similarities and Differences Between Rats and Humans



How Do Organ Systems Work Together?

Ask students how they think the major organ systems work together.

SPECIFIC QUESTIONS CAN INCLUDE:

1. How does oxygen get into the bloodstream? How do the respiratory and circulatory systems connect with each other?

Gas exchange in the alveoli of the lungs—the respiratory and circulatory systems are linked via the capillary network that surrounds the alveoli.

2. How do nutrients from the rat's food get into the bloodstream? How do the digestive and circulatory systems connect with each other?

Nutrient exchange between small intestine and bloodstream—links the digestive and circulatory systems via the capillary network that surrounds the villi in the small intestine.

3. How are harmful substances filtered from the blood? How do the circulatory and digestive/urinary systems connect with each other?

Hepatic portal system of the liver— links digestive and circulatory systems.

Blood filtration in the kidneys—links urinary and circulatory systems.

4. How do hormones interact with other body systems?

Adrenaline/cortisol from adrenal glands increase blood glucose and provide energy to muscles. Insulin and glucagon from pancreas regulate blood sugar levels.

5. How do the nervous and musculoskeletal systems interact with each other?

Nerve impulses travel from the brain, down the spinal cord to the peripheral nerves. Peripheral nerves send signals to muscles so they contract. The opposite also happens, so when we touch something, nerve impulses travel along our peripheral nerves, along our spinal cord, to our brain where the sensory information is processed. Reflexes don't need any brain activity—for example, when we touch something very hot, we react and pull our hand away without even thinking about it. In that case the nerve impulse travels from nerves in our fingers to our spinal cord and straight back to our muscles so that we pull our hand away from the hot surface.

Example Evaluation Questions and Activities

RAT ADAPTATIONS

List three ways in which the anatomy of rats helps them adapt to their natural environment.

(good examples)

1. They have a large, strong tail that helps them with balance and thermoregulation.
2. They have fur to help keep them warm.
3. They have whiskers and a keen sense of smell to help them navigate their environment.

ORGAN SYSTEMS ACTIVITY

Give students both a male and female paper rat dissection and ask them to (1) find the number labels that correspond to the major organs of each body system (you can be specific with this list; for example, ask them which of the numbered labels on the paper dissections correspond to heart, liver, kidneys etc.), and (2) identify which paper rat is male and which is female.

RESPIRATORY SYSTEM

What is the correct order of airflow for rats when they inhale?

- Bronchial Tube > Trachea > Bronchioles > Alveoli
- Trachea > Bronchioles > Bronchial Tube > Alveoli
- Trachea > Bronchial Tube > Bronchioles > Alveoli
- Bronchioles > Trachea > Bronchial Tube > Alveoli

Explain how gas exchange happens in the lungs:

Air flows into the alveoli and oxygen molecules pass across the cell wall of the alveoli, across the cell wall of the surrounding capillaries, and into the blood stream. Carbon dioxide passes in the opposite direction (from the bloodstream to the alveoli) so that it can be breathed out.

True or False: The diaphragm contracts on an exhale.

False.

CIRCULATORY SYSTEM

True or False: Pulmonary veins carry oxygenated blood from the lungs to the left atrium.

True.

Which of the following is correct?

- Atrium contracts, sending oxygenated blood to the brain from the left ventricle. Blood flows through the pulmonary arteries to reach the head.
- Ventricle contracts, sending deoxygenate blood to the brain from the right ventricle. Blood flows through carotid arteries to reach the head.
- Ventricle contracts, sending deoxygenated blood to the lungs from the left atrium. Blood flows through the pulmonary arteries to reach the head.
- Ventricle contracts, sending oxygenated blood to the brain from the left atrium. Blood flows through carotid arteries to reach the head.

DIGESTIVE SYSTEM

Which of the following make up the alimentary canal?

- Mouth, Esophagus, Stomach, Small Intestine, Large Intestine.
- Gastric glands, Liver, Pancreas, Intestinal glands.

Write a detailed summary of the major body parts and organs that a rat's food passes through, from the moment it enters the mouth, to the moment it is pooped out.

Mouth → esophagus → stomach (chemical and mechanical digestion) → pancreas (secretes pancreatic juices and enzymes to help with food breakdown) → small intestine (chemical digestion and food absorption via villi in SI walls) → liver (filters digestive products from blood) → large intestine (water and food absorption)

How many lobes does a rat's liver have?

- 2
- 3
- 4
- 5

UROGENITAL SYSTEM

Which of these are correct? (check all that apply)

- Kidney: filters blood and produces urine
- Kidney: stores urine
- Urinary bladder: expels urine, faeces, sperm, and eggs
- Urinary bladder: stores urine

What is the name of the duct in *male* rats that transports urine from the kidneys to the bladder, and sperm from the testes?

Ureter/urogenital duct/Wolffian duct

HOW DO THE BODY SYSTEMS CONNECT?

How do the respiratory system and circulatory system connect and work together in a fully functioning rat?

Gas exchange between lungs and bloodstream across the walls of alveoli and capillaries.

How do the digestive system and circulatory system connect and work together in a fully functioning rat?

Via the liver and hepatic portal system:

1. Small intestine absorbs products of digestion
2. Nutrient molecules travel in hepatic portal vein to liver
3. Liver monitors blood content
4. Blood enters general circulation by way of hepatic vein

How do the urogenital system, digestive system and circulatory system connect and work together in a fully functioning rat?

Via the kidneys and the renal portal system:

1. Nutrient and waste molecules in the bloodstream travel in renal portal vein to the kidneys.
2. Kidneys filter out harmful substances like urea and carbon dioxide, which are passed outside as urine.