Investigate Body Systems

OVERVIEW

Students will investigate how aspects of their bodies function (digestive, circulatory, respiratory, and motor systems) and compare and contrast these body systems to those of sauropods.

BACKGROUND FOR EDUCATOR

Dinosaurs have intrigued paleontologists since the first fossil finds in the 19th century. Now other scientists, such as animal nutritionists and medical physiologists, are also shedding light on sauropod biology and the conditions that enabled their gigantic size. This exhibition shows how sauropod body systems worked and how they compare to those of humans and other animals.

For a quick overview, read the article, "Living Large: How Did Sauropods Get So Big?" (*Rotunda*, Spring 2011)
amnh.org/join/rotunda/AMNH_RotundaSpring_2011.pdf

BEFORE YOUR VISIT

In these activities, students will explore how their own digestive and circulatory systems work, and predict how they might have worked in sauropods, which ranged in size from almost one ton to ninety.

Discussion: A Day in Your Life
Begin the class by asking students to describe a day in their lives in terms of basic biological functions. Use the questions below as prompts. Divide students into discussion groups of four. Then ask a spokesperson to share some of each group's ideas and record them on the board.

- What do you eat on a typical day? How often?
- When do you move the most?
- How does your heart rate change during the day? How about your breathing?

Circulation Activity: How does movement affect heart rate?
Students will investigate their heart rate during different activities, and reflect the relation between size and circulation.

Materials:
- stop watches or clock with second hand visible to entire class

Ask students to take their heart rate while (1) resting and (2) doing a simple activity (such as walking). Ask: What do you notice about your heart rate? *(Answers will vary.)* Have students do five trials, record their findings on a chart, and calculate the group average. Then write the heart rates of a human newborn baby and an adult on the board (see the chart on the next page). Ask students to compare their numbers with those of a baby and an adult. Have students speculate about the differences. What can they infer about the relationship between heart rate and size? *(Answer: As size of an animal increases, the heart rate decreases.)*

NYS Science Core Curriculum

LE.1.2a: Each system is composed of organs and tissues which perform specific functions and interact with each other, e.g. digestion, gas exchange, excretion, circulation, locomotion, control, coordination, reproduction, and protection from disease.

The Jigsaw Method

These activities use a cooperative learning strategy called Jigsaw. Students form **home groups**; each member joins a different **expert group** to learn about a specific subtopic; home groups then reassemble and members share what they've learned.

- **Before Your Visit:** Divide the class into home groups of four students each. Assign each student in the home group to a different expert group (digestion, respiration, circulation, or locomotion). Distribute copies of the respective worksheets to the expert groups, and review them with students.
- **During Your Visit:** Students work in expert groups to gather evidence about the digestion, respiratory, circulation, and locomotion of sauropods and to begin to reflect on what it means to live large.
- **Back in the Classroom:** Students share what they learned with their home groups; the teacher facilitates discussion of how these systems work together. In addition, the whole class activity uses calculations to infer dinosaur size and stride and understand how scientists study extinct species.

Animal	Average Heart Rate	Make a statement about the relationship between heart rate and size.
Human Newborn Baby	110 beats per minute	
Human Adult	70 beats per minute	

Digestion Activity: How long does it take to chew your food?

Materials:
- bags of baby carrots
- box of unsalted crackers
- stop watches

Crackers: Working in groups of four, have students chew two crackers for two minutes without swallowing. Ask them to think about how both the texture and taste of the crackers change as they chew. Have them record their observations. Then explain to them how the teeth and saliva work together to break down food.

Carrots: Working in pairs, have each student chew two carrots for two minutes without swallowing. Ask each student to think about how the texture and taste change, and to record their observations. Have each partner observe the other's chewed carrots and record his or her observations.

Transition to having students reflect on how many carrots they think they would need to eat in a day to get the calories they need. Ask: If each carrot contains approximately 15 calories and a 13-year-old needs 2,200 calories a day, how many carrots would he or she need to eat to meet this daily requirement? How long would it take? What teeth is he or she using?

Bring the class together and have students share their results. Show a picture of a sauropod (a plant eater) and ask the students to draw upon what they've learned to imagine how chewing and digestion work in sauropods.

Discussion: A Day in the Life of a Sauropod
Have students make predictions about a day in the life of a 13-ton sauropod by reflecting on questions such as: What did they eat? How much did they eat? How many carrots would they need in a day? How did their hearts work? How fast? Students will probably have lots of questions about other body systems. Make sure they record these questions.

Divide the class into home groups of four, and then into four expert groups. Have each expert group write 10 questions about how that body system might function in sauropods.

To build background knowledge, students can read short descriptions of the digestion and circulatory systems. (You can download readings from http://science.nationalgeographic.com/science/health-and-human-body/human-body/)

DURING YOUR VISIT

***The World's Largest Dinosaurs* Exhibition**
4th floor (45 minutes)
Have expert teams use the student worksheets to explore and collect evidence about the four body systems (digestive, circulatory, respiratory, locomotion).

Hall of Saurischian Dinosaurs
4th floor (30 minutes)
Have students examine the *Apatosaurus* skeleton. Ask them to count the number of vertebrae (in the neck, the tail, the body). Using their bodies as a ruler, have them estimate the length of the sauropod's femur bone. Have students write five observations about the animal, and five inferences.

Then, tell students that back in the classroom, each home team will create a story titled "A Day in the Life of a Sauropod" using evidence obtained in *The World's Largest Dinosaurs* exhibition and in this fossil hall. Have students jot down notes, and use this time to decide a plot, the setting, and characters.

BACK IN THE CLASSROOM

Activity: Exhibition Wrap-Up
Have students share their findings in their home groups. Encourage students to make connections to other body systems. Use these questions to facilitate the discussion:

- How much am I like a sauropod? How am I really different?
- How does size affect the way sauropods' bodies work?
- Think about how long it took you to chew a carrot and how much food *Mamenchisaurus* ate in one hour. How does size affect the sauropod digestive system?
- How were sauropods able to extract so much oxygen from every breath?
- How does size affect heart rate?
- How does size affect how animals move, and how much they move?
- How are the body systems that each team member learned about connected?

Then, ask each home group to create a story about a day in the life of a sauropod. Remind them that their story needs to include information they learned at the Museum, along with a detailed drawing of the part of the animal, with important body system parts labeled.

Activity: Locomotion/Skeletal System
Using fossil evidence, studies of living animals, and their knowledge of biomechanics, scientists can make inferences about sauropods and other extinct organisms. In these two activities, students learn how size can be determined by leg length, and stride length can determine distance traveled. They will compare their results to what they learned in the exhibition about sauropod size.

Materials:
- measuring tapes
- yardsticks
- masking tape

First, measure out an area in which students will take their measurements.

1. Calculate Stride

Tell students that stride length is the distance covered in an average step, either from heel to heel or toe to toe. Using a ruler, have students measure each of their stride lengths and calculate the group average. Using that average, ask them to use the equation below to figure out the distance traveled in 5,000 steps.

0.7 (length of stride in cm) x (number of steps) = X (meters) / 1000 (meter in a km) = X km

For example if the average stride is 70 cm:
0.7 (70 cm) x (number of steps) = X (meters) / 1000 (meter in a km) = X km

2. Infer Height from Femur Length

Tell students that the femur is the single large bone that extends from the hip socket to the kneecap. Have them work in pairs, and use a meter stick or measuring tape to determine the approximate length in centimeters of their partner's femur. Use the following equation to estimate height:

(length of femur in cm) x 2.6 + 65 = height in cm

Then have students use a metric ruler to obtain their partner's height in centimeters. (They can convert this metric measurement to inches by dividing by 2.54.)

Finally, have students infer the relationship between stride length and femur length. *(Answer: The longer the legs, the bigger the steps.)*

Circulation: Powerful Hearts

1. Go to the "Beat" section to investigate and gather evidence about sauropods' powerful hearts.

Play the pumping heart interactive. Describe the difference between a human and an elephant heart.

Record different animals' heart rates in this chart.

Animal	Heart Rate (beats per minute)	Make a statement about the relationship between body size and heart rate.
deer mouse		
horse		
African elephant		
human		

What do you think pumping a sauropod's heart would be like?

What evidence suggests that sauropods had a slow heart rate?

Why do scientist think that sauropods had four-chambered hearts?

Sketch the *Mamenchisaurus* heart model and label the parts.

2. Visit the Body Theatre and watch the video.
Listen to the heart rate of sauropods. Record notes about the circulation system.

Respiration: Efficient Lungs

1. Go to the "Lungs and Breathing" section to investigate and gather evidence about the efficient respiratory system of sauropods.

Sketch and label the parts of the sauropod respiratory system.

What is the purpose of the lungs?

Why is the sauropod lung more efficient than the human lung?

2. Visit the Body Theatre and watch the video.

Observe how the lungs and air sacs worked in sauropods. Record notes about the respiratory system.

Digestion: Tough Stomachs

1. Go to the "Teeth" section to investigate and gather evidence about how sauropods ate.
Describe how your teeth compare to sauropod teeth.

Sketch sauropod teeth.

What did their teeth allow sauropods to do?

2. Go to the "Fuel" section to investigate and gather evidence about what sauropods ate.
How many calories did sauropods need to consume every day? How does that compare to you?

How is human digestion different from that of sauropods?

What type of plants did sauropods eat?

Make a chart below of the pros (+) and cons (-) of at least two of these plants, and sketch them.

Plant	Pros (+)	Cons (-)	Sketch the plants

3. Visit the Body Theatre and watch the video.
Record notes about the digestive system and why scientists think sauropods had "fermentation tanks."

Student Worksheet

Skeletal/Locomotion: Necks and legs

1. Go to the "Reach" and "How Big" sections to investigate and gather evidence about how sauropods moved.

Observe and lift the giraffe and sauropod vertebrae.
How are they different? How many vertebrae do giraffes have?
How many do sauropods have?

Sketch and label the structure of the sauropod vertebrae.

What did the long neck allow a sauropod to do?

2. Visit the "Femur station activity" to measure a sauropod femur and your weight if you were a sauropod.

On the other side, measure your femur bone and calculate your height. (Ask a friend to help you.)

Calculate and record your height based on the length of your femur. ____________________

How do scientists predict the height and weight of sauropods?

3. Visit the Body Theatre and watch the video.
Record notes about the sauropod skeleton, in particular its long neck.

Student Worksheet

Grades 6–8

ANSWER KEY

Circulation: Powerful Hearts

1. Go to the "Beat" section to investigate and gather evidence about sauropods' powerful hearts.

Play the pumping heart interactive. Describe the difference between a human and an elephant heart.

(Answer may include: It's easier to pump the human heart. The elephant's heart rate is slow. It takes some effort to get it to beat just once.)

Record different animals' heart rates in this chart.

Animal	Heart Rate (beats per minute)	Make a statement about the relationship between body size and heart rate.
deer mouse	*(Answer: 400)*	*(Answers may include: The bigger the animal, the more powerful the heart has to be. The bigger the animal, the slower the heart rate).*
horse	*(Answer: 38)*	
African elephant	*(Answer:28)*	
human	*(Answer: 72)*	

What do you think pumping a sauropod's heart would be like?

(Answers will vary, but it would be hard because their hearts are big and big hearts take more time to fill and empty.)

What evidence suggests that sauropods had a slow heart rate?

(Answer: It's challenging to circulate blood throughout this massive body. Big hearts take more time to fill and empty.)

Why do scientist think that sauropods had four-chambered hearts?

(Answer: Crocodiles and living dinosaurs like birds have four-chambered hearts. A four-chambered heart holds oxygen longer and absorbs it more efficiently.)

Sketch the *Mamenchisaurus* heart model and label the parts.

2. Visit the Body Theatre and watch the video.
Listen to the heart rate of sauropods. Record notes about the circulation system.

Student Worksheet

Grades 6–8

ANSWER KEY

Respiration: Efficient Lungs

1. Go to the "Lungs and Breathing" section to investigate and gather evidence about the efficient respiratory system of sauropods.

Sketch and label the parts of the sauropod respiratory system.

What is the purpose of the lungs?

(Answers may include: Lungs transfer oxygen from the air to the blood through their thin membranes. The lungs also remove CO_2 from the blood-stream.)

Why is the sauropod lung more efficient than the human lung?

(Answers may include: In addition to lungs, sauropod bodies contained two sacs for holding air. Each breath stayed inside the sauropod's body during a second inhale and exhale, allowing more time for oxygen to be extracted. Oxygenated air is always going through a sauropod lung. Large air-filled pouches would have made the animal a lot lighter.)

2. Visit the Body Theatre and watch the video.
Observe how the lungs and air sacs worked in sauropods. Record notes about the respiratory system.

Student Worksheet

Grades 6–8

ANSWER KEY

Digestion: Tough Stomachs

1. Go to the "Teeth" section to investigate and gather evidence about how sauropods ate.
Describe how your teeth compare to sauropod teeth.

(Answers may include: Humans have different types of teeth for tasks like biting and grinding. Sauropods have only one kind of tooth, which resembles our incisors.)

What did their teeth allow sauropods to do?

(Answers may include: Sauropods could scrape and rake leaves and snap branches. They could eat a great deal of vegetation very fast because they did not take the time to chew.)

Sketch sauropod teeth.

2. Go to the "Fuel" section to investigate and gather evidence about what sauropods ate.
How many calories did sauropods need to consume every day? How does that compare to you?
(Answers may include: A young adult sauropod needed up to 100,000 calories a day. Human teenagers need about 2,400.)

How is human digestion different from that of sauropods?

(Answers may include: Human digestion begins in the mouth and continues in the stomach and intestines. Food passes through our digestive tracts within a few days. Sauropod stomachs functioned as fermentation tanks. Digestion could take as long as two weeks, allowing time for microbes to break down the cell walls of tough plant material.)

What type of plants did sauropods eat?

(Answers may include: Ginkgo, horsetail, monkey puzzle, conifers, cycads, broadleaf trees, and grasses.)

Make a chart below of the pros (+) and cons (-) of at least two of these plants, and sketch them.

Plant	Pros (+)	Cons (-)	Sketch the plants
(Sample answer: Horsetail)	*(Sample answer: Very nutritious, digestible, accessible, plentiful)*	*(Sample answer: Hard to chew)*	
(Sample answer: Monkey puzzle tree)	*(Sample answer: Nutritious, accessible to tall animals, plentiful)*	*(Sample answer: Difficult to digest, low protein content)*	

3. Visit the Body Theatre and watch the video.
Record notes about the digestive system and why scientists think sauropods had "fermentation tanks."

Student Worksheet

ANSWER KEY

Skeletal/Locomotion: Necks and legs

1. Go to the "Reach" and "How Big" sections to investigate and gather evidence about how sauropods moved.

Observe and lift the giraffe and sauropod vertebrae.
How are they different? How many vertebrae do giraffes have?
How many do sauropods have?

(Answers may include: Like most mammals, the giraffe had only 7 vertebrae in its neck. Sauropods usually had between 10 and 19 vertebrae in their necks.)

Sketch and label the structure of the sauropod vertebrae.

What did the long neck allow a sauropod to do?

(Answers may include: Allowed the animal's head to move up and down or side-to-side to access food.)

2. Visit the "Femur station activity" to measure a sauropod femur and your weight if you were a sauropod.

On the other side, measure your femur bone and calculate your height. (Ask a friend to help you.)

Calculate and record your height based on the length of your femur. ______________________________

How do scientists predict the height and weight of sauropods?

(Answers may include: Using both fossil evidence and studies of living animals, scientist have developed several methods to determine how much a dinosaur might have weighed. Scientists measure the length and thickness of the thighbone, as well as use computer models.)

3. Visit the Body Theatre and watch the video.
Record notes about the sauropod skeleton, in particular its long neck.

Middle School																	
Standard	**Major Understandings**	Introduction	The Importance of Size	Meet *Mamenchisaurus*	Eating	Brain	Neck & Biomechanics	Size of Sauropods	Reproduction	Skin	Trackways	Metabolism	Biology Theater	Circulation	Respiration	Dig Pit	Epilogue
LE 4	**3.2c:** Many thousands of layers of sedimentary rock provide evidence for the long history of the earth and for the long history of changing life forms whose remains are found in the rocks. Recently deposited rock layers are more likely to contain fossils resembling existing species.		X		X		X	X			X					X	
	3.1b: Changes in environmental conditions can affect the survival of individual organisms with a particular trait. Small differences between parents and offspring can accumulate in successive generations so that the descendants are very different from their ancestors. Individual organisms with certain traits are more likely to survive and have offspring than individuals without those traits.		X		X		X	X							X		
	1.2a: Each system is composed of organs and tissues which perform specific functions and interact with eachother, e.g., digestion, gas exchange, excretion, circulation, locomotion, control, coordination, reproduction and protection from disease.		X	X	X	X	X	x	X	X	X	X	X	X	X		
	1.1H: Living things are classified by shared characteristics in the cellular and organism level. In classifying organisms, biologists consider details of internal and external structure . Biological classification systems are arranged from general (kingdom) to specific (species).		X		X	X	X	X	X	X	X	X	X	X	X		

High School																	
Standard	**Major Understandings**	Introduction	The Importance of Size	Meet *Mamenchisaurus*	Eating	Brain	Neck & Biomechanics	Size of Sauropods	Reproduction	Skin	Trackways	Metabolism	Biology Theater	Circulation	Respiration	Dig Pit	Epilogue
LE 4	**1.2 a:** Important levels of organization for structure and function include organelles, cells, tissues, organs, organ systems, and whole organisms.				X	X	X	X	X	X	X	X	X	X	X		
	3.1g: Some characteristics give individuals an advantage over others in surviving and reproducing, and the advantaged offspring, in turn, are more likely that others to survive and reproduce. The proportion of individuals that have advantageous characteristics will increase.		X		X		X	X							X		
	1.2 b: Animals are complex organisms. They require multiple systems for digestion, respiration, reproduction, circulation, excretion, movement, coordination, and immunity. The systems interact to perform the life functions. **1.2c:** The components of the animal body, from organ systems to cell organelles, interact to maintain a balanced internal environment. To successfully accomplish this, organisms possess a diversity of control mechanisms that detect deviations and make corrective actions.		X	X	X	X	X	X	X	X	X	X	X	X	X		
	3.1L: Extinction of a species occurs when the environment changes and the adaptive characteristics of a species are insufficient to allow its survival. Fossils indicate that many organisms that lived long ago are extinct. Extinction of a species is common; most of the species that have lived on earth no longer exist.	X															X