SCIENCE THEATER
EXPLORE 1D LESSON 19

Food and Agriculture Center for Science Education

Science Theater Teacher Directions

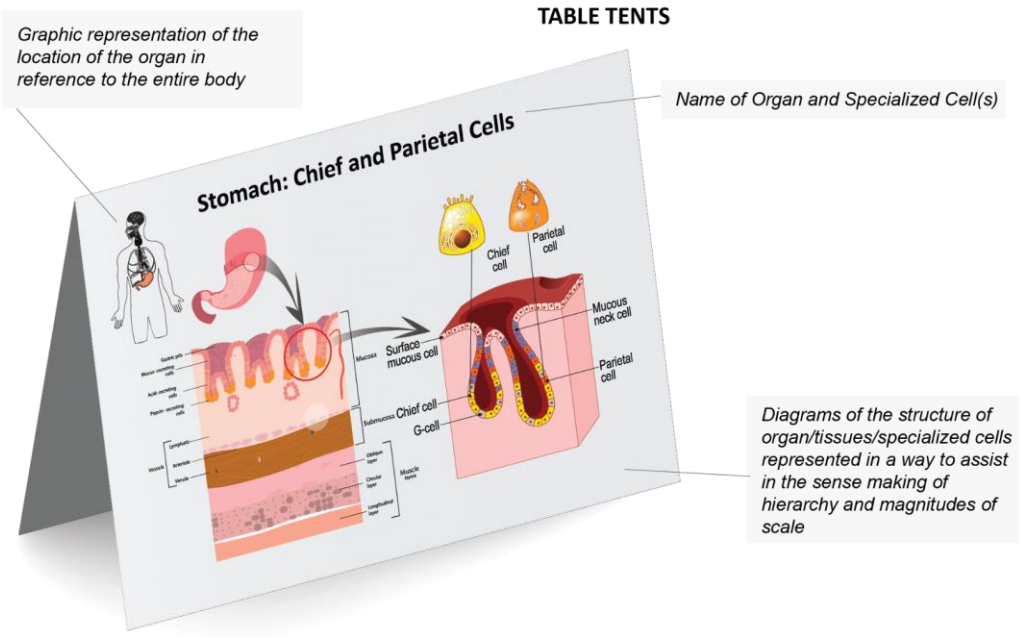
Key Outcomes

- Students experience the model from two points of view: an observer and a participant assigned to the role of an organ and/or specialized cell within an organ.
- Students cooperate to combine information about individual organs and cells to make sense of the pathways and processes that occur to produce energy for exercise in the body via both aerobic and anaerobic pathways.

Materials

The following is a list of the printed materials, which are located in the student handout. There you will find:

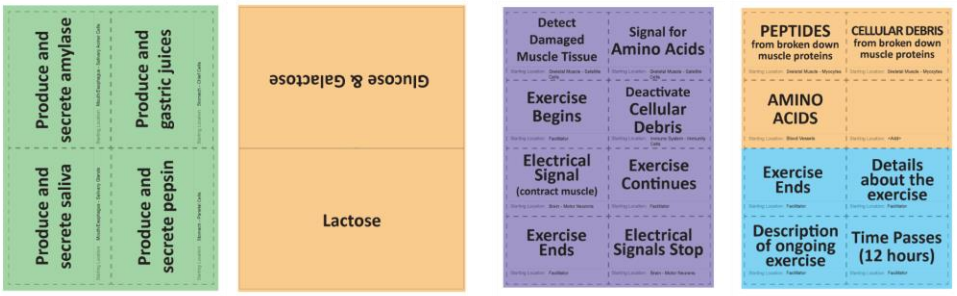
Table Tents for each organ that depict the structure of the organ and the specialized cells it is composed of.



Tokens represent relevant nutrients, stimuli, processes, and responses that occur during the mechanism being modeled.

Note: In Module 1, the tokens for nutrients, water, and electrolytes are intended to be used as name tags or labels that can be flipped over after digestion.

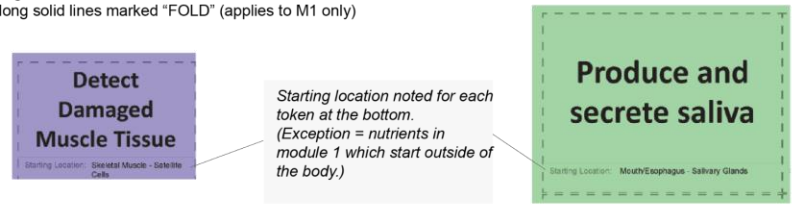
TOKENS



Above are a few examples from various Science Theater models throughout the unit.

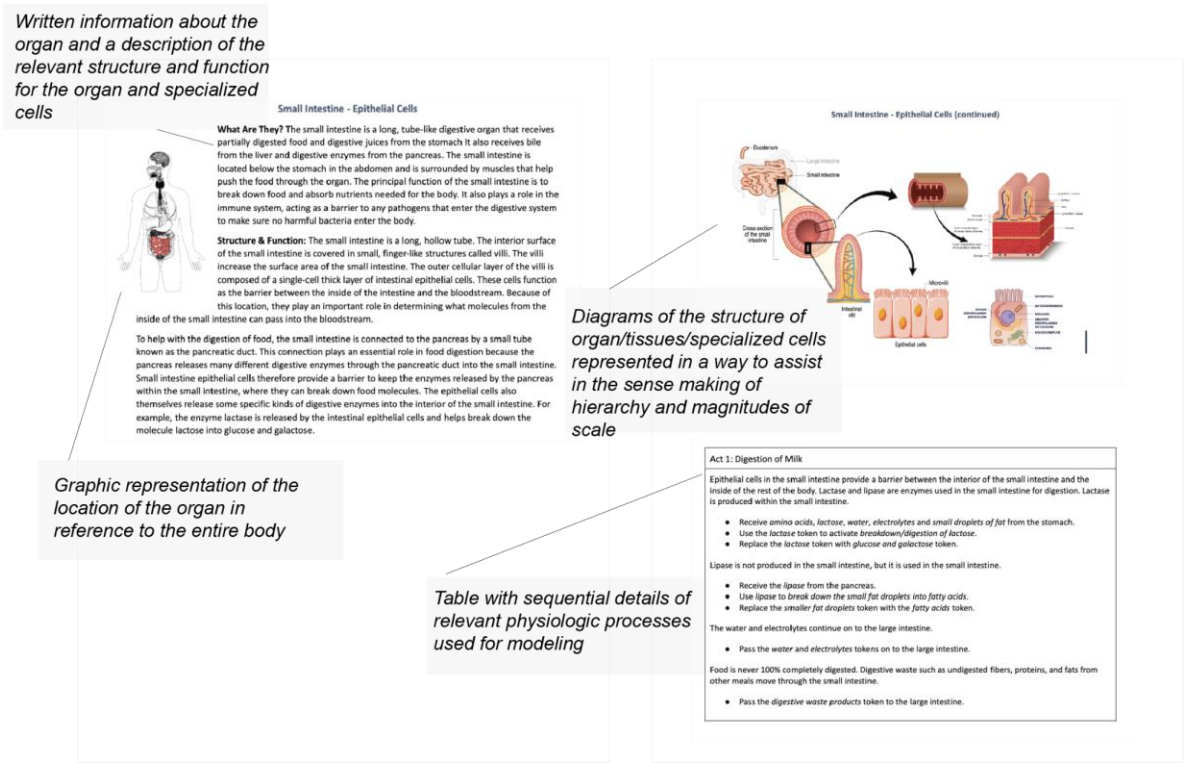
Instructions after printing:

- Multiple tokens are located on a page.
- Cut along dotted lines.
- Fold along solid lines marked "FOLD" (applies to M1 only)



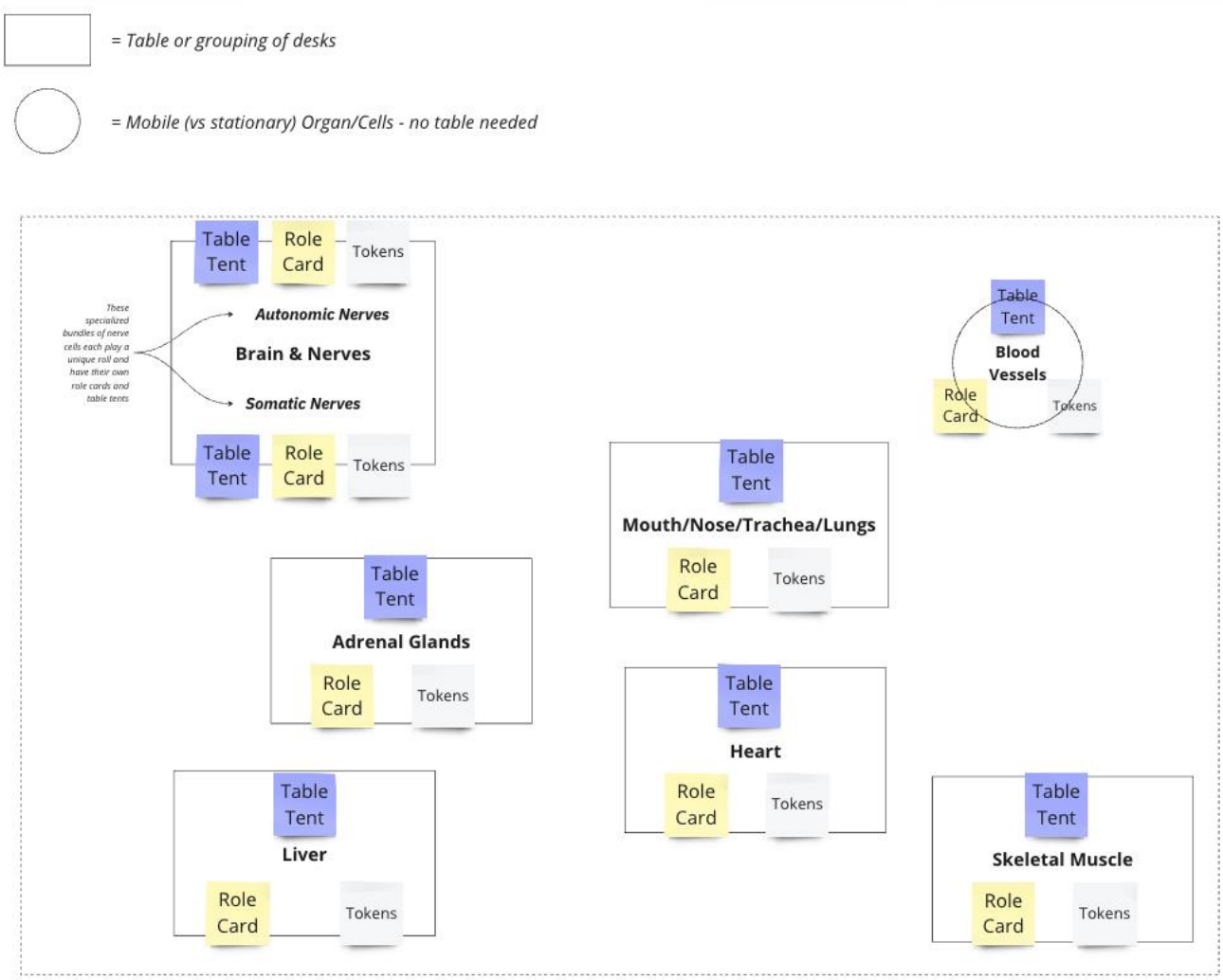
Role Cards for each organ (including any specialized cells) that describe the function of each organ and its specialized cells, as well as instructions for how students will engage in the model.

ROLE CARD



Physical Classroom Setup

Set up and label the classroom layout as shown below so that a table (or grouping of desks) represents each organ. Ensure each organ has the corresponding visual poster where it is visible. Students will stand or sit at each table as they represent the cells of each organ. Molecule cards will be "moving" from one organ to another.



Below is a table listing the initial locations for each token:

Organ	**Tokens**
Autonomic Nervous System	● Electrical signal (similar to fight-or-flight)
Brain & Somatic Nervous System	● Electrical signal to initiate movement ● Electrical pain signal
Mouth/Nose/Trachea/Lungs	● Increased breathing rate ● Oxygen (6 molecules)
Blood Vessels	● Increased blood flow ● (2) Glucose Molecule (1 molecule)
Adrenal Glands	● Produce epinephrine ● (4) Epinephrine
Heart	● Increased heart rate
Liver	● Begin glycogenolysis (breakdown of glycogen into glucose molecules) ● Glycogen (1 molecule) > Glucose (several molecules)
Skeletal Muscle	● Movement ● (2) Glucose (1 molecule) ● (3) Anaerobic cellular respiration ● (3) Lactate (2 molecules) ● (3) H+ ions (2 ions) ● (3) ATP (2 molecules) ● Begin glycogenolysis (breakdown of glycogen into glucose molecules) ● Glycogen (1 molecule) > Glucose (several molecules) ● Decreasing pH ● Detect decreasing pH ● Electrical signal - decreasing pH ● End anaerobic respiration ● Aerobic cellular respiration ● ATP (38 molecules) ● Carbon dioxide (6 molecules) ● Water (6 molecules) ● Slow and stop movement
Facilitator	● Intense exercise begins ● Exercise ends

Science Theater Actions by Organ

- Brain & Autonomic Nervous System
    - Receive input from the sensory nerves at the start of intense exercise, triggering a fight-or-flight response.
    - Send a signal to the adrenal glands to produce epinephrine.
- Brain & Somatic Nervous System
    - Sends electrical signal to initiate movement at the start of exercise.
    - When pH levels in the skeletal muscles drop, the nerves receive an electrical signal from pain receptors in the skeletal muscles.
    - The brain creates a sensation of pain and sends it via electrical signal
- Lungs - Alveoli Epithelial Cells
    - Respond to epinephrine by increasing breathing rate to allow for more oxygen and carbon dioxide exchange across the epithelial cells of the alveoli during intense exercise.
- Blood Vessels - Red Blood Cells
    - Blood vessels transport nutrients, gasses, and hormones to internal organs.
- Adrenal Glands - Chromaffin Cells
    - Work in conjunction with the autonomic nervous system to produce epinephrine to increase metabolic processes in the heart, lungs, skeletal muscles, and liver during intense exercise.
- Heart - Pacemaker Cells & Cardiomyocytes
    - Pumps blood through the blood vessels at an increased rate during intense exercise.
        - Pacemaker cells respond to epinephrine by increasing the rate at which the heart beats.
- Liver - Hepatocytes
    - Responds to epinephrine by breaking down glycogen stores in the hepatocytes and releasing the glucose molecules into the bloodstream to maintain blood glucose levels during intense exercise.
- Skeletal Muscles - Myocytes
    - Receive electrical signals from brain and somatic motor neurons to initiate movement.
    - Respond to epinephrine by breaking down glycogen stores into glucose molecules, which are used by each individual cell to produce ATP by cellular respiration.
        - Anaerobic cellular respiration is a primary energy source in the early stages of an intense workout because the skeletal muscle utilizes the glucose already located in the cell and does not have to wait for adequate oxygen to be delivered. Byproducts of anaerobic cellular respiration include lactate (2 molecules), H+ ions (2 ions), and carbon dioxide (2 molecules).
    - Pain receptors (nociceptors) in the skeletal muscles detect decreasing pH levels in the skeletal muscle and send an electrical signal via the nerves to alert the brain. An electrical signal response from the brain induces a pain/burning sensation in the skeletal muscle in an effort to encourage the body to slow down.

- As muscle glycogen stores become depleted, myocytes utilize aerobic cellular respiration by bringing in glucose and oxygen molecules from the bloodstream.

Science Theater Actions in Sequence

Act 1: Exercise Begins

1. Facilitator: Exercise begins
2. Brain and Somatic Nerves: Send a nerve signal to the myocytes to initiate movement.
3. Myocytes: Receive electrical nerve signal from somatic nerves to initiate movement. Oxygen has not yet been delivered to the muscles. Muscles detect the lack of oxygen and begin anaerobic respiration. Glucose molecules in the myocytes are used to generate two molecules of ATP via anaerobic respiration. This process produces 2 molecules of carbon dioxide, 2 H+ ions, and 2 molecules of lactate.
4. Myocytes: The muscle cells begin to expand and contract and use cellular energy (ATP) to do so.

Act 2: Exercise Continues - Heart Rate and Breathing Rate Increase

1. Brain & Autonomic Nerves: The brain detects that the body is in a potentially stressful situation: exercise. It sends a signal via the autonomic neurons to the adrenal glands, telling them to release epinephrine, also known as adrenaline. Send Nerve Signal token to the adrenal glands.
2. Adrenal glands: receive the signal from the brain, and Chromaffin cells produce epinephrine and release it into the bloodstream.
3. Epinephrine is delivered via the bloodstream and is delivered to the cells of the heart, lungs, skeletal muscles, and liver.
4. Heart: Receive epinephrine. Increased heart rate pumps more blood through the blood vessels.
5. Lungs: Receive epinephrine. Increased breathing rate. An increased amount of oxygen enters the lungs and passes from the lungs to the bloodstream via the alveolar epithelial cells. Receive an increased amount of carbon dioxide from the bloodstream.
6. Skeletal Muscles AND Liver: Myocytes and liver hepatocytes receive the epinephrine signal and begin breakdown of glycogen to produce more glucose.
7. Myocytes: continue to produce ATP, CO_2 , lactate and H+ ions from glucose. Transfer CO_2 to the bloodstream. Blood vessels transport an increased amount of carbon dioxide (a byproduct of anaerobic cellular respiration) back to the lungs. *(Anaerobic cellular respiration occurs once more, followed by the breakdown of muscle glycogen, and then the glucose from the glycogen is used for anaerobic respiration once again.)*

Act 3: Continued Exercise

1. Myocytes. Receive increased amounts of oxygen via the bloodstream. As more oxygen is available to the skeletal muscles, aerobic cellular respiration takes over as the primary energy source for the skeletal muscles.
    a. End anaerobic respiration.
    b. Begin aerobic respiration. Use one glucose and six oxygen to generate 38 ATP molecules and six carbon dioxide molecules.

Act 4: Muscle Burn & Fatigue

1. H+ ions and lactate (a byproduct of anaerobic cellular respiration) have built up in the skeletal muscles.
2. Pain receptors (nociceptors) in the skeletal muscles detect the lactate and H+ and alert the brain via a nerve signal. The brain interprets this signal as pain/burning.
3. Brain: the brain sends back a pain signal to those muscles to encourage them to slow down so that the lactate and H+ can be removed from the muscles.
4. Facilitator: Exercise ends.
5. Brain: No more electrical signals to initiate movements or to trigger adrenaline