www.pbs.org/saf/1209

Body Building

Activity 1: Grades 5-8

Modeling Breathing Action

As you saw in "Nerves of Steel," Functional Electrical Stimulation, or FES, uses surgically implanted wire electrodes to trigger muscle contractions. Like a signal from a motor neuron, the FES electrodes send an electrical signal to jolt the muscle into contraction. After the muscle contracts, it passively expands to its relaxed state. By electrically controlling these contractions, muscle actions can be triggered in victims of paralysis. As you saw in this episode, FES is currently being used to help such patients stand up and even walk.

Another type of injury that may one day be assisted by FES concerns lung function. Some severe spinal cord injuries render an individual incapable of independent breathing. For example, actor Christopher Reeve (*http://www.pbs.org/saf/1107/features/reeve.htm*) sustained a paralyzing horseback riding accident and must now depend on a ventilator to force air in and out of his lungs. Researchers hope that the implantation of FES electrodes could benefit patients like Reeve by stimulating the expansion and contraction of the chest cavity, and eliminate the need for ventilators. To better understand how this might work, you can construct this working lung model.

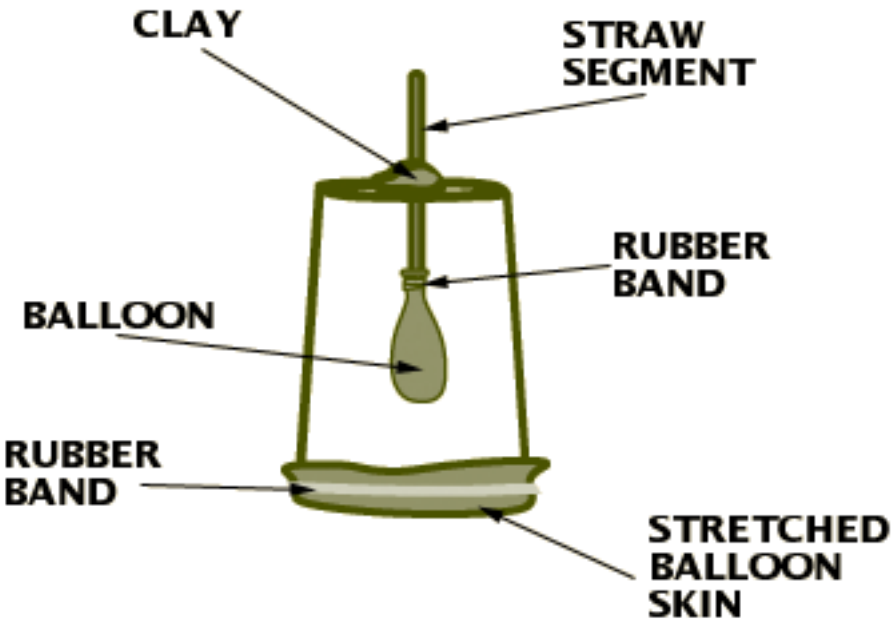
This activity page will offer:

- An introduction to Functional Electrical Stimulation (FES).
- A model-making activity that address the mechanics of breathing.
- Insight into the use of FES as a breathing support strategy.

PART 1 - Modeling the Mechanics of Breathing

MATERIALS

- Clear plastic cup (with hole drilled in bottom)
- Straw
- Balloon
- Scissors
- Clay
- Rubber band



Educator Note:
You should drill holes (about the same diameter as a drinking straw) into the center of each cup. Drilling reduces the fumes associated with burning a hole through the plastic material.

PROCEDURE

1. Use scissors to cut a segment of straw that is about 5 cm long.
2. Place the mouth of a balloon around one end of this straw segment. Use a rubber band to secure the balloon to this straw. Make sure that the seal is airtight.
3. Pass the other end of the straw through the hole that your instructor has drilled in the plastic cup.
4. Position the straw so that it sticks about halfway through the cup. Use a small rope of clay to secure the straw's position around the opening of

the cup. Make sure that the clay seals off the opening but doesn't pinch the straw closed.
5. Cut a balloon in half widthwise. Discard the nozzle half.

6. Carefully stretch the rubber balloon skin over the mouth of the cup. When you release the skin, the tension should secure the stretched balloon in place.
7. Push up on the stretched balloon fabric. Now, pull it down. Notice how these actions affect the appearance of the balloon inside the cup. Record your observations.

Questions

1. Identify the parts of the human respiratory system represented by this model.
2. How is this model fundamentally different from the human system?
3. What happens to the balloon inside the cup when the rubber skin wrapped around the base of the cup is pulled down? Why ?
4. What happens when the rubber skin is pushed upwards? Why?
5. Based upon this model, where would you insert the FES electrodes on a person who was unable to breathe on his own? Why?

EXTENSIONS

Critical Thinking Extension

Suppose you were in charge of programming the electronics that would trigger an FES signal to the diaphragm. How often would you send this signal to a person who normally experiences 7 inhalations and 7 exhalations in a one-minute period? Explain.

Workout Connection

Have you ever seen advertisements for electrical pad muscle toners, used most often to tone the appearance of abdominal muscles? These pads cause muscles to contract as a response to surface electric stimulation. Think about it. How are the mechanics of this device similar to FES? How are they different?

Uncovering a Misconception

Although most people identify the diaphragm as the "breathing muscle", its effect is not as great as the action of rib muscles. The contraction and relaxation of the rib muscles causes the chest to raise and lower. This action produces most of the pressure change responsible for breathing. Only when we breathe deeply do we really exploit the full potential of the diaphragm.

As you may have discovered, misconceptions in science can sometimes be passed along from source to source. Suppose you were to ask your parents or friends about the mechanics of breathing. What would they say? Are they aware of the role of the ribs? Do they know that the lungs are not muscles, but

passive structures that inflate and deflate due to the changes in the surrounding air pressure? Develop a survey using these and other questions. Compare your results with those of other students to try to uncover the misconceptions we often associate with breathing mechanics.

Reflex Actions

A reflex action is an automatic and involuntary response during which a motor signal is sent, not from the brain, but from a lower level of the spinal column. Think about it. What type of disorders or injuries would interfere with the knee-jerk reflex? Would a person who has a spinal injury maintain this reflex response? Why or why not?

WEB CONNECTION

Cleveland FES Center
http://feswww.cwru.edu/about/index.htm
The Cleveland FES Center is looking into the electrical activation of the diaphragm, among other projects.

New Spinal Realities
http://abcnews.go.com/onair/CloserLook/wnt_000214_CL_paralysis_feature.html
A story on FES with a downloadable movie file.

Functional Electrical Stimulation (FES) Research, Development and Clinical Service
http://www.salisburyfes.com/fes.htm
A UK site that addresses the functional application of FES technology.

The activities in this guide were contributed by Michael DiSpezio, a Massachusetts-based science writer and author of "Critical Thinking Puzzles" and "Awesome Experiments in Light & Sound" (Sterling Publishing Co., NY).

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Modeling Breathing Action

Answers

Questions

1. Identify the parts of the human respiratory system represented by this model.
   (Straw = windpipe; balloon = lung; balloon skin = diaphragm, cup = rib cage of lung cavity)
2. How is this model fundamentally different from the human system?
   (Humans have two lungs that are operated by the action of the diaphragm, rather than the one lung modeled here.)
3. What happens to the balloon inside the cup when the rubber skin wrapped around the base of the cup is pulled down? Why
   (The balloon inflates. The volume of the artificial lung is increased, so the pressure of the air inside is decreased. Outside air pressure pushes air into the cup to equalize the pressure, inflating the balloon.)
4. What happens when the rubber skin is pushed upwards? Why?
   (The balloon deflates. The volume of the artificial lung is decreased, so the pressure on the air inside is increased. Air is released from the cup to equalize the pressure, deflating the balloon.)
5. Based upon this model, where would you insert the FES electrodes on a person who was unable to breathe on his own? Why?
   (The electrodes should be inserted into the diaphragm since this is the muscular wall that creates changes in the size of the chest cavity, just as the rubber skin changed the size of the "cup cavity.")

EXTENSIONS

Critical Thinking Extension

Suppose you were in charge of programming the electronics that would trigger an FES signal to the diaphragm. How often would you send this signal to a person who normally experiences 7 inhalations and 7 exhalations in a one-minute period? Explain.

(You'd send about 7 signals per minute. Since only the inhalation needs to be "triggered", you need to send an FES signal to initiate these actions. The exhalations are passive and will automatically occur when the inhalation contraction ends.)

Workout Connection

Have you ever seen advertisements for electrical pad muscle toners, used most often to tone the appearance of abdominal muscles? These pads cause muscles to contract as a response to surface electric stimulation. Think about it. How are the mechanics of this device similar to FES?

(Both devices rely upon electrical signals to stimulate muscle contractions)

How are the different?

(One is for cosmetic use, the other for more necessary life functions).

Reflex Actions

A reflex action is an automatic and involuntary response during which a motor signal is sent, not from the brain, but from a lower level of the spinal column. Think about it. What type of disorders or injuries would interfere with the knee-jerk reflex? Would a person who has a spinal injury maintain this reflex response? Why or why not?

(A reflex action takes place at a certain slice of the spinal column. No message needs to travel up the spinal cord to the brain. Therefore, if the spinal cord is damaged above this reflex arc, the intact nerves will still produce a reflex response even though the individual may not have awareness of the movement. If, however, the spinal damage also compromises the activity of nerves below the injury point, then the reflex may be lost.)

CURRICULUM LINKS

Life Science:

Respiratory System, Muscle Structure and Function, Electrical Impulse in Muscle Function, Medical Technology

Physical Science:

Electricity, Air Pressure

NATIONAL SCIENCE STANDARDS (Grades 5-8)

Science as Inquiry- Content Standard A

Students will use models to explain cause and effect relationships. They will base their explanations on observation, logic, and personal experience.

Physical Science - Content Standard B

Students will explore electrical energy and its circuitry through the human body.

Students will investigate how energy can be transferred from one form to another.

Students will observe unbalanced forces and identify the forces causing change in motion.

Life Science - Content Standard C

Students will study the structure and function of the respiratory system. They will see the importance of function at a cellular and system level.

Students will learn about how organisms respond to external and internal stimulus in a complex way that involves multiple systems.

Science and Technology- Content Standard E

Students will model a technological design and understand how technology plays a role in scientific solutions to human problems.