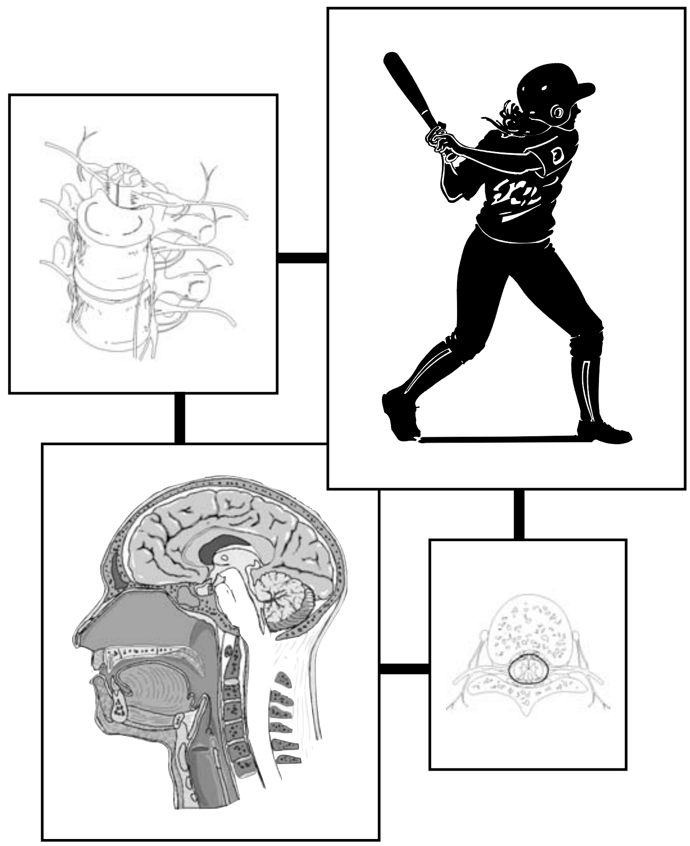
NEURAL NETWORKS

MIDDLE SCHOOL LEVEL
THE AMERICAN PHYSIOLOGICAL SOCIETY



DEVELOPED BY THE COLUMBUS, OH
LOCAL OUTREACH TEAM

This classroom unit was developed as part of
the American Physiological Society's
Frontiers in Physiology project
by a Local Outreach Team
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TEACHER'S GUIDE

Introduction

This unit covers aspects of neurophysiology and neural responses that are important to the functioning of many body systems. It is designed to provide students with a scientific basis for understanding "reflexes," especially why reflexes are special types of responses and how reflexes can/cannot be modified. The unit can be used as an integrative review of these topics, or selected activities can be used to introduce some of the topics. It was designed by a team of middle school teachers and research physiologists to be useful for "Biology" and "Life Sciences" classes. It can serve as an introduction for basic understanding of the nervous system.

The unit utilizes the Learning Cycle approach (Karpus & Thier, 1967; Lawson, 1988), where various modules can be used to *engage* students in thinking about the topic(s) (Module #1); offer them opportunities to *explore* via hands-on and inquiry approach activities (Module #2); *explain* their findings and how they relate to the concepts included in the unit (Module #3); *elaborate* on the concepts (Modules #4 and 5); and *evaluate* students' understanding of the unit concepts via authentic assessment (Module #6). The unit also makes use of concept mapping and inquiry approach activities. The relationship of each activity to both content and pedagogy standards, as described by the *National Science Education Standards*, is outlined in the table on page 2.

The modules are designed to teach the students general physiological principles that are based on physical and biochemical principles. An important educational objective of the unit is that students should be able to relate what they learn about the nervous system to its many important interactions with other systems in the body.

Suggestions for Teachers are provided for each module; these contain information necessary to teach the units. The Background Information section is designed to supplement the information available in any good physiology or biology textbook used in middle or high school. **Boldfaced** terms typically can be found in the index of your textbook or other references.

This unit was developed as part of an American Physiological Society program designed to form partnerships between scientists and teachers. Therefore, the units also can be used in consultation with research scientists, such as a university faculty member or pharmaceutical researcher. The Education Officer of the American Physiological Society can assist you in making connections with physiologists in your area (301-634-7132; education@the-aps.org).

References

Karplus, R. & Thier, H.D. (1967). *A new look at elementary school science*. Chicago: Rand McNally.
Lawson, A.E. (1988). A better way to teach biology. *American Biology Teacher, 50 (5)*, p. 266-289.

Background Information — Neural Networks

Why are neural networks important?

Neural networks are responsible for the basic functions of our **nervous system**. They determine how we behave as individuals. Our emotions experienced as fear, anger, and what we enjoy in life come from neural networks in the brain. Even our ability to think and store memories depends on neural networks. Neural networks in the brain and spinal cord program all our movements including how fast we can type on a computer keyboard to how well we play sports. Our ability to see or hear is disturbed if something happens to the neural networks for vision or hearing in the brain. Neural

RELATIONSHIP OF NEURAL NETWORKS UNIT TO NATIONAL SCIENCE EDUCATION STANDARDS FOR CONTENT AND TEACHING

Selected Content Standards	*Neural Networks*
Grades 5-8	
Structure and function in living systems	*
Regulation and behavior	*
Personal health	*
Risks and benefits	
History and nature of science	*
Grades 9-12	
Matter, energy, and organization of living systems	*
Behavior (responses to stimuli)	*
Personal and community health	*
History and nature of science	*

Unit Activities	Pedagogy		
	Hands-On	Inquiry	Authentic
#1: What Can You Observe About Reflexes and Reactions?		*	
#2: What Do You Know About Reflexes?	*		*
#3: Reflexes and Reactions — An Overview			*
#4: Is Heart Rate Constant?	*	*	*
#5: Effects of External Stimuli on Reaction Times	*	*	*
#6: What Do You Know Now About Reflexes and Reactions?	*		*

networks also control important functions of our bodies. Keeping a constant body temperature and blood pressure are examples where neural networks operate automatically to make our bodies work without us knowing what the networks are doing. These are called **autonomic functions** of neural networks because they are automatic and occur continuously without us being aware of them.

Who should know about neural networks?

Workers in areas dealing with people's health must understand neural networks. Doctors and nurses must understand them in order to take care of their patients. Paramedics (firefighters and ambulance teams) need the knowledge to make quick decisions for saving the lives of accident victims. Doctor's assistants in many different areas of special medical treatment use their understanding of the nervous system to do their jobs. Scientists must know what is already known in order to design studies that will produce new knowledge of how the nervous system works and new ways to treat diseases of the nervous system. Finally, it is important for each of us to understand how our own bodies work.

What is a neural network?

Simply, neural networks are groups of select neurons that are connected with one another. Neural networks are functional circuits in the brain that process information and create useful activities by sending outputs to the body. Some **neurons** (nerve cells) transmit this neural network information over a distance much the same as information is transmitted over a telephone line. Neurons have a cell body and a fiber that carries the information (Figure 1, page 4).

Electrical impulses, called **action potentials,** are used by neurons to transmit information over the distance from the cell body to the end of the fiber. Nerve fibers from one neuron in a network are connected to others in the network by **synapses**, the tiny gaps between the end of one neuron and the beginning of another. The fibers do not make direct contact with the other neuron at a synapse. Instead, each impulse triggers release of a chemical substance from the end of the fiber. The chemical, called a **neurotransmitter**, then carries the information across the synaptic space on to the next neuron. Neurons make and release over 50 different kinds of neurotransmitters. Some neurotransmitters, called **excitatory neurotransmitters**, start a new electrical impulse in the neuron at the other side of the synapse. Other neurotransmitters prevent impulses from occurring in the neuron at the other side of the synapse. These are called **inhibitory neurotransmitters**.

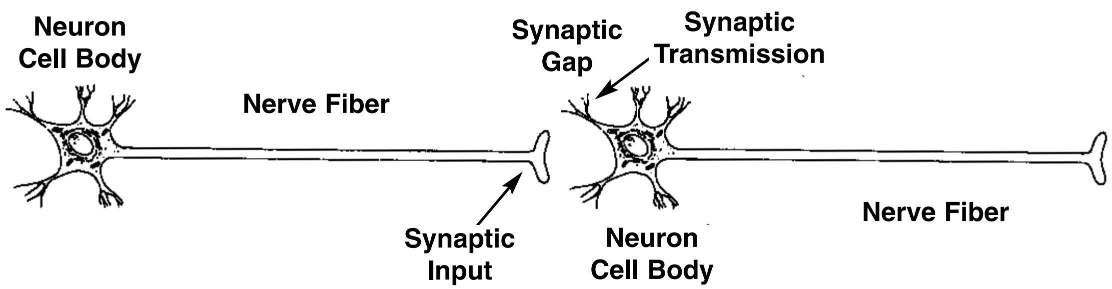
Large numbers of neurons are interconnected by synapses to form a network. Depending on the job to be done, a network can have a few hundred to more than a million neurons. Each neuron in the network may receive a synaptic input from one hundred or more other neurons in the network. Moreover, one network may have connections for sharing information with other networks. For example, neural networks in the brain share information with networks in the spinal cord. Neural networks are complex and much remains to be learned before we fully understand how they work. This is why neuroscientists in universities, industry, and government continue with research on the nervous system.

Sensory neurons

Sensory neurons, interneurons, and motor neurons are important parts of neural networks. Sensory neurons, interneurons, and motor neurons are connected to perform the control for most of the things we do (Figure 2, page 4). Most of the time, this is control of the movement of our muscles and of the function of body organs, such as the heart and stomach. The job of **sensory neurons** is to detect what is happening outside and inside the body and report the information to networks of interneurons. Sensory neurons have a specialized receptor region at some point on the body where sensation occurs, a cell body, and a fiber that transmits information in the form of nerve impulses to the brain for processing.

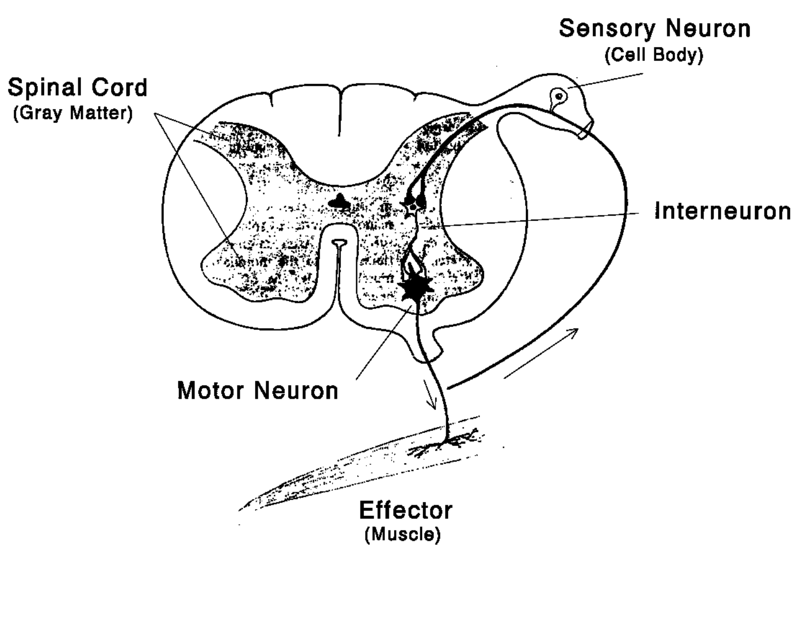
There are sensory neurons that detect changes in mechanical forces, light, sound, and temperature for the body. Sensory neurons in the skin detect touch. Others detect when something may be happening that could damage the skin and body. Without light detectors, we could not see. Without sound detectors we could not hear. Without temperature detectors we

FIGURE 1



Two major parts of a neuron are the cell body and a nerve fiber that may extend over long distances. Information in the form of nerve impulses is transmitted by nerve fibers. Nerve fibers meet other neurons in neural networks at synapses. Information is transmitted across the synaptic gap by a chemical signal (neurotransmitter substance) released at the terminals of nerve fibers. Arrival of each nerve impulse at the terminal of a nerve fiber releases a burst of neurotransmitter substance that then excites or inhibits the next neuron. This is rather like a runner in a relay race handing off the baton (neurotransmitter) to the next runner.

FIGURE 2



Cross-section of the spinal cord to illustrate the connections of a sensory neuron, interneuron, and motor neuron in a neural network. Each neuron in the illustration represents a pool of several hundred neurons in the actual network. The cell bodies of sensory neurons are found outside the gray matter of the spinal cord. Cell bodies of interneurons and motor neurons are within the gray matter. In this example, sensory fibers transmit information of muscle contraction to interneurons for processing. After processing, information for control of the muscle is transmitted by motor neurons. The muscle in this example is the effector.

could not know if it was warm or cold and our nervous system could not adjust our bodies to changes in outside temperatures. Without touch receptors, we could not feel the wind blowing on our skin or when someone touches us. Without damage receptors, we could burn our skin and not know it.

Interneurons

The “inter” of **interneurons** comes from the position of this kind of neuron between sensory and motor neurons in a neural network. Interneurons are connected one with another by synaptic connections to form networks that receive information from sensory neurons (Figure 2). The interneuronal networks have two main jobs. One job is to receive information about the outside environment or inside state of the body from sensory neurons. The other is to activate motor neurons. Interneuronal networks interpret and make sense of the streams of information coming from sensory neurons. This function is sometimes called **information processing**.

Motor neurons

Motor neurons are the pathways for transfer of information from interneuronal networks to effector systems. **Effector systems** are parts of our bodies like muscles, glands, and internal organs. Nerve fibers of motor neurons can be very long. Those extending from the neural networks in the spinal cord to muscles in the lower leg may be three or more feet in length. The interneuronal networks tell the motor neurons when to “fire” and transmit the signal to the effector cell. If the effector is a muscle cell, the signal makes the muscle contract and move the body. Patterns of movement like shooting a basketball require precise timing of the contraction of different groups of muscles. The timing of movements are organized by interneuronal networks and the signals are then sent over motor neurons to the different muscles. Some of the networks for complex movements, like shooting a basketball or playing the piano, include components in both the brain and spinal cord. Some less complex movements, called spinal reflexes, are determined by networks in the spinal cord without involvement of networks in the brain. Other kinds of reflexes, such as the response of the pupil in the eye to light, involve neural networks in the brain.

Reflexes

Local reflex circuits are organized at various locations in the nervous system. The constriction of the pupil of the eye in a bright light is an example of a local reflex response. **Reflexes** require sensory neurons, interneurons and motor neurons to the effector system in which the reflex behavior is seen. In this exercise, we will study tendon reflexes in muscles as the effector, and light reflexes in which the pupil of the eye is the effector.

Reflexes are part of our day-to-day experience of living. For example, if someone accidentally touches the hot burner of a cook stove, the hand is immediately and rapidly withdrawn from the source of danger. This is a reflex that includes the added behavior of extending the arm and leg on the opposite side of the body to provide balance as the other arm is bent to withdraw the hand from the hot surface. If you have had this experience, you will recall that the withdrawal of the hand from the hot surface and the extension of the arm and leg on the opposite side took place before you realized that the hand had been in danger of injury and the source of the danger. Two main networks were involved in the experience. One in the spinal cord processed the information from sensory neurons for the hand and organized withdrawal from the source of injury while the information from the same neurons was being transmitted to processing networks in the brain. Networks in the brain determined what had happened and brought about conscious awareness of the event.

Reflex behavior has three main properties. The first is **speed of response**. In the above example, reflex behavior organized by networks in the spinal cord removed the hand from danger during the longer time required for the information to reach the brain networks for processing to the level of consciousness.

The second property of reflex behavior is **purposefulness**. Reflex responses generally accomplish a useful purpose like withdrawing the hand from danger in the above example. An experiment performed on a frog is often used to show the purposeful nature of reflexes. The experiment begins by an operation that severs the frog's brain from the spinal cord. This is called a spinal animal and is the same situation as seen in a paraplegic or quadriplegic human. The frog is suspended so the lower legs hang free. When a small piece of paper soaked with vinegar is placed on the thigh, the frog raises its foot, locates the source of irritation with the foot and kicks it away. If the foot on the irritated leg is held so the frog cannot move that leg, the opposite leg will be used to kick away the paper irritant. Watching this, you may feel that the spinal cord knows what it is doing as if it has consciousness. If fact, the behavior is a purposeful reflex organized by a neural network in the spinal cord apart from the brain.

The third property of locally organized reflexes is their **stereotyped nature**. This means that a reflex response behaves in the same way each time it is evoked. Reflex responses are, therefore, predictable. In the above examples, the withdrawal reflex in humans is always the same. The hand is always withdrawn from the source of irritation — never extended toward the danger. Likewise, in the frog experiment the leg always moves in the same way to remove the source of irritation.

Reactions

Reactions are voluntary responses to stimulation from the environment. Unlike reflexes, which are involuntary, reactions require neural networks in the brain that are involved with conscious behavior. Reactions require more time for a response due to the more complex processing of information in the brain networks. Reaction times are defined as the length of time required for a voluntarily response to the stimulation of sensory neurons. The average reaction time for humans to a visual stimulus is about 0.25 second; for hearing, 0.17 second; for touch about 0.15 second.

Reaction times vary among individuals. Some persons react faster than others to a stimulus. Star athletes usually have faster reaction times than non-athletes. Reaction times may be decreased slightly by practice. They are increased when you are tired, emotionally upset, or under the influence of alcohol. The length of an individual's reaction time is of great importance in many situations such as driving a car and the tasks required by many industrial jobs.

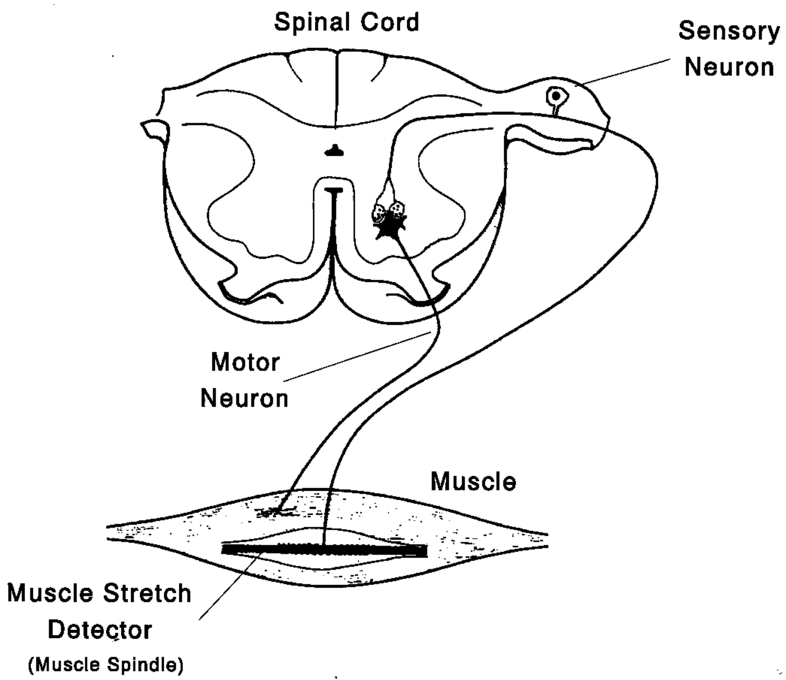
Experiments with reflexes

Tendon reflexes in humans are examples of reflexes readily demonstrated in the classroom. The knee jerk in response to tapping the patellar tendon is an example of a tendon reflex. Extension of the foot (ankle jerk) evoked by tapping the Achilles tendon is another example. These are also called stretch reflexes because they reflect the action of neural networks in the spinal cord to counteract the effects of stretch on the muscle.

Many s**tretch reflexes** automatically maintain tone in the muscle that offsets the pull of gravity. The fibers of sensory neurons for these reflexes are connected to structures in the muscle called "spindles" (Figure 3). When the muscle is stretched, the muscle spindles initiate nerve impulses in the sensory fibers. The impulses are then conducted from the muscle to the networks of interneurons where they are processed. The more the muscle spindles are stretched, the more impulses are fired per second. Frequency of impulses then becomes the sensory code for the degree of stretch of the whole muscle. A faster frequency is interpreted by the interneuronal networks as lengthening of the muscle. The interneuronal networks compensate by activating motor neurons to make the muscle contract and shorten to the desired length. This reflex operates continuously to keep the muscle at the needed length for it to do its job in supporting the body.

Figure 4 illustrates the **knee jerk reflex**. The patellar tendon connects the muscle of the front of the thigh to the lower leg. This is called an extensor muscle because it extends the lower leg when it contracts. A tap on the patellar tendon produces a quick stretch of this muscle. This also stretches the spindles in the same muscle which, in turn, fire impulses at a higher frequency. The increased frequency of impulses reaches the interneuronal networks by way of the sensory neurons. The interneuronal networks interpret the information as a rapid increase in length of the muscle and compensate by sending signals that contract the muscle. Contraction is seen as rapid extension (forward jerk) of the lower leg. The

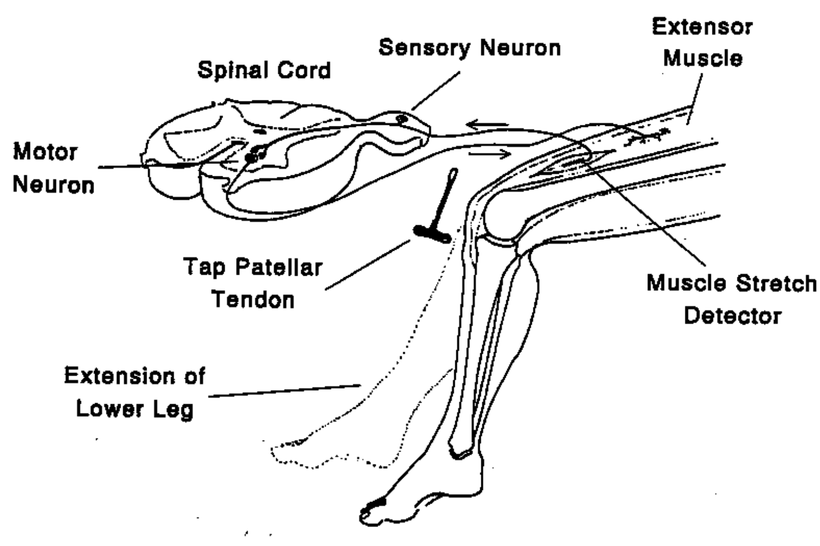
FIGURE 3



Skeletal muscles have sensory structures that detect the length of the muscle. These are called muscle spindles. They detect and signal the spinal cord when the muscle is stretched and the length increases. When the length of the muscle is increased, the muscle spindles send impulses along sensory fibers into the spinal cord. The frequency (number per second) of impulses increases as the length increases. Consequently, the frequency of firing represents the information code for the moment-to-moment length of the muscle. In this example, the sensory neuron connects directly to the muscle's motor neuron. This allows for rapid activation of contraction of the muscle in response to a stretch.

FIGURE 4

Diagram of the neural connections for the "knee jerk" reflex. A sharp tap on the patellar tendon stretches the extensor muscles for the lower leg. Stretch of the muscle also stretches the sensory detectors within the muscle. Stretch of the detectors (muscle spindles) fires impulses in the sensory fibers to the spinal cord. The sensory fibers make a direct synapse with the motor neurons to the same extensor muscle. Release of a neurotransmitter at the terminal of the sensory neuron excites the motor neuron and impulses are transmitted to the extensor muscle. This triggers contraction of the extensor muscle that is seen as extension of the lower leg.



reflex time is that required for impulses to travel into the spinal cord from the muscle spindles, be processed, and be returned in motor neurons to contract the muscle.

Because of the complexity of the nervous system and the large number of stimuli constantly impinging on the body, the activity of neural networks in one part of the nervous system often modifies another. This is the case for reflexes, such as the knee jerk. The magnitude of the knee jerk is greater when the contractile tone in the extensor muscle is higher. Conditions that increase muscle tone, such as mental excitement increase the extent of the knee jerk. A decrease in mental excitement (sleep, a restful state, etc.) is associated with a decrease in the reflex. The strength of the "tap" required to evoke the reflex is higher after physical or mental work. The knee jerk may be reinforced by a second stimulus, such as a loud noise when the noise is appropriately timed with respect to the tapping of the tendon.

Pupillary reflexes

Pupillary reflexes affect the size of the pupil of the eye. By changing the size of the pupil, reflex responses control how much light enters the eye. A special kind of muscle, called the pupillary muscle, surrounds the pupil. The pupillary muscle is the effector in pupillary reflexes. When the pupillary muscle contracts, it reduces the size of the pupil and the amount of light entering the eye. Impulses in motor neurons to the muscle produce the contraction.

The pupillary light reflex is seen readily by observing the pupil of an individual when the light from a pen light is directed to the eye. Another term for the constriction of the pupil is photopupil reflex. The "purpose" of the reflex is to shield the eye from too great and sudden light exposure. This protects the sensitive light detecting parts of the eye called the retina.

The neural network for a pupillary reflex consists of a light detector (sensory neuron), interneurons and motor neurons back to the pupillary muscle. Some parts of the neural network are located in or near the eye itself and others are found in the mid-regions of the brain (Figures 5 and 6).

There are three kinds of pupillary reflexes. One called the **direct light reflex** consists of constriction of the pupil of the same eye when light is directed into the eye. The second is called the **consensual light reflex**. It consists of constriction of the pupil of the opposite eye from one in which light is directed. The consensual reflex is demonstrated by shining light into one eye and observing constriction of the pupil in the opposite eye that receives no light stimulus. The third kind of pupillary reflex is called the **accommodation reflex**. This is observed as constriction of the pupil as an object is brought progressively closer to the eye.

Pupillary reflexes are important indicators of the state of the brain. Because they require neural networks in the brain, damage to parts of the brain containing the networks may be seen as a malfunction of the reflex. Shining a penlight into the eyes of an accident victim provides emergency personnel with a quick assessment of potential head trauma.

For the practicing anesthesiologist, pupillary size can be an indicator of depth of general anesthesia during surgical procedures. In Stages I and II of anesthesia, the anesthesiologist knows that the pupils are dilated due to emotional stress. In Stage III anesthesia, which is surgical anesthesia, the pupil constricts. In Stage IV, which is paralysis of the neural networks in the brain, the pupils become dilated.

Background Information — Autonomic Nervous System

What is the autonomic nervous system?

There is a part of your nervous system that is called the autonomic nervous system. "Autonomic" means that most of the time it acts all by itself without you consciously trying to control it.

FIGURE 5

Constriction and dilation of the pupil is determined by two groups of muscles. The dilator muscle enlarges the radius of the pupil (*mydriasis*) when it contracts. The constrictor muscle reduces the size of the pupil when it contracts (*miosis*). Nerves that release the neurotransmitter substance, acetylcholine, evoke contraction of the constrictor muscle. Nerves that release the neurotransmitter, norepinephrine, evoke contraction of the dilator muscle. There are three kinds of pupillary muscle reflexes: (a) direct; (b) consensual; and (c) accommodation. The direct light reflex is the case where bright light evokes pupillary constriction in the same eye (a). The consensual light reflex is the case where bright light in one eye evokes pupillary constriction in both eyes (b). The accommodation reflex is pupillary constriction that occurs as a distant object 1 meter or less from the eye is moved progressively closer to the eye (c).

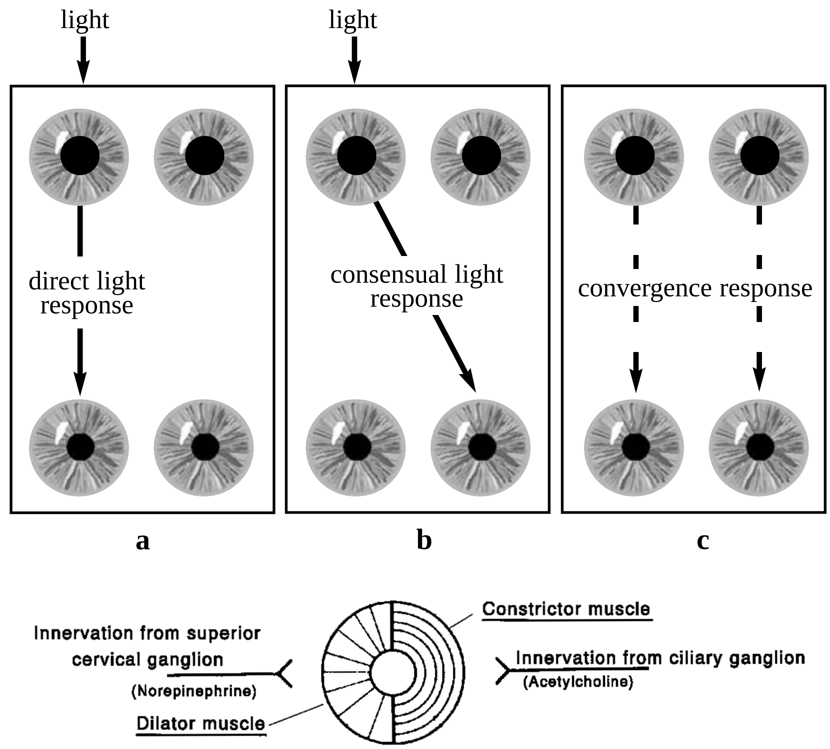
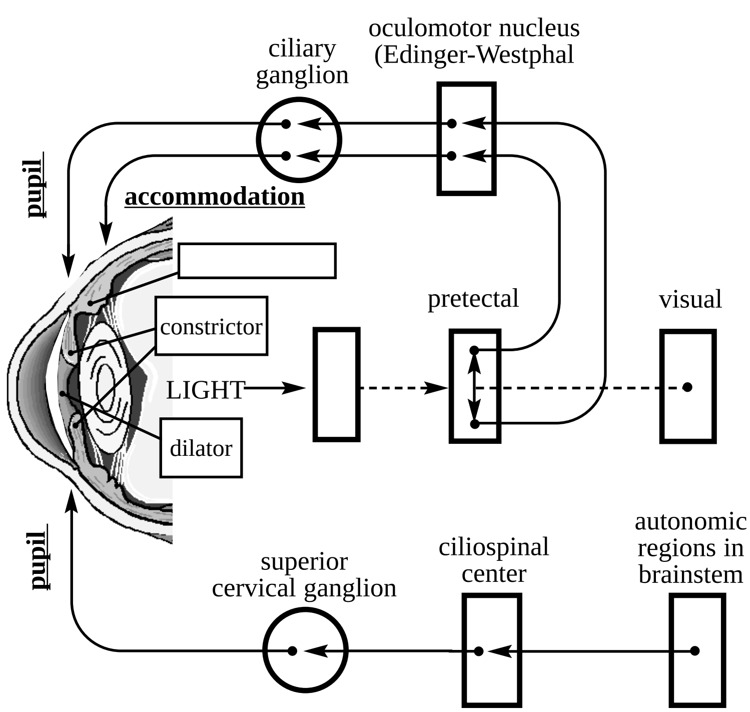


FIGURE 6



Neural networks for pupillary reflexes are interconnected inside and outside the brain. The retina of the eye detects changes in light intensity and focus. The retina codes the changes as neural signals that are transmitted to the pretectal region of the brain for processing. If the processing networks in the tectal region determine to activate constriction of the pupil, information is transmitted to the region of the brain stem called the oculomotor nucleus. From the oculomotor nucleus, signals are transmitted to a network of neurons in the ciliary ganglion located at the back of the eye socket. Nerve projections from the ciliary ganglion to the constrictor muscle evoke pupillary constriction. If the processing networks in the tectal region determine to activate dilation of the pupil, information is transmitted to the spinal cord, down the cord to the neck region and then out of the cord to a group of neurons in the superior cervical ganglion. Nerve projections from the superior cervical ganglion to the dilator muscle evoke contraction and increased pupil size.

As an example, the autonomic nervous system determines how fast your heart beats (this is called your heart rate). If you would measure your heart rate at different times during the day, you would get many different values. At times your heart rate is higher and at other times it is lower. You may have noticed, for example, that your heart beats faster after you have just walked from one classroom to another, especially if you had to walk up some steps. You don't have to think about raising your heart rate when you climb steps; the autonomic nervous system takes care of that.

There are control centers in the central nervous system (brain and spinal cord) that determine how fast the heart should beat and there are neural connections between these areas and the heart. It is along these connections that messages are sent to speed up or slow down the heart. These neural connections are part of the autonomic nervous system.

Not only the heart but all of the organs and blood vessels in the body receive messages from the brain and the spinal cord along neural connections that are part of the autonomic nervous system. After you eat a meal, for example, your stomach receives messages to work harder so that the food will be digested.

Autonomic reflexes

How high your heart rate is at any particular time depends on a lot of factors, for example how much oxygen your body needs or how nervous or how calm you are. Your heart rate also plays a role in regulating your blood pressure. Your blood pressure is very important. When you visit a doctor, she or her nurse will almost always measure your blood pressure to make sure it is not too low or too high. It is very important that your blood pressure is close to normal. The autonomic nervous system helps control your blood pressure. If your blood pressure would suddenly fall a bit, your heart rate will increase and the contraction of your heart will become stronger so that your heart pumps out more blood and increases your blood pressure until it is normal again. What we just described is an example of an autonomic reflex. It is called the baroreceptor reflex.

How does the baroreceptor reflex work? Since it controls blood pressure you may expect that there will be something that keeps an eye on your blood pressure so that it can be compared to a normal value. Indeed some large blood vessels contain blood pressure sensors that measure blood pressure. Physiologists call them baroreceptors. The blood pressure that they measure is sent via nerves to an area of the brain where it is compared to a normal value. If blood pressure is too low, for example, this area of the brain will send a message to the heart to increase the heart rate via neural networks. In this way the blood pressure will be brought back to normal.

An experiment

Two people work together. First the subject lies down on the floor or a table for three minutes. After the three minutes the other person measures the subject's heart rate and writes it down. then the subject stands upright for three minutes. Again at the end of these three minutes the other person measures the subject's heart rate and writes it down. Compare the two heart rates.

Explanation

After standing up for three minutes the heart rate will normally be increased when compared to lying down. The reason is that as a result of standing up, blood pools in the legs and less blood is in the heart. If you looked on an X-ray you would see that the heart appears smaller because it contains less blood when a person stands up. As a result, the heart pumps out less blood volume with every beat and that causes the blood pressure to fall a bit. The baroreceptor reflex we talked about increases the heart rate to bring the blood pressure back to normal. That is why we measure a higher heart rate initially in a person who stands upright.

SUGGESTIONS FOR TEACHERS

Module #1 *(Engage)*
What Can You Observe About Reflexes and Reactions?

Purpose
Engage students in exploring reflexes and reactions.

Objectives
1. Engage students in making active observations about various reflexes and reactions and what the difference is between the two.
2. Allow students to connect their own experiences with reflexes and reactions to the observations they make.
3. Assess students' current understanding and possible misconceptions about reflexes and reactions.

Materials
- videotape of the movie, *Jurassic Park*
- overhead transparencies
- transparency pens

Procedure
1. Find the sequence in *Jurassic Park* (or a similar type of movie sequence) where the cars are stranded in the rain by the Tyrannosaurus rex enclosure. In the encounter with the T. rex, there are a number of good reactions and reflexes displayed, including a pupillary reflex of the dinosaur when a flashlight is shined into its eyes. Stop the sequence when the archaeologist begins waving flares at the dinosaur. Show the sequence first with the sound muted; this allows students to focus on the responses that they can pick up visually. Ask students to write down every reflex or reaction that they see, either by people or animals. Then repeat the video sequence with the sound on; students will pick up many more responses from the audio track (gasps, exclamations, etc.).
2. Using the overhead projector, divide your transparency into two columns: Reflexes and Reactions. Ask students to tell you the responses that they saw in the movie and to say whether they thought that response was a reflex (such as removing your hand from a hot stove) or a reaction (such as grabbing for a basketball when it's tossed your way).
3. As you complete this activity with students, note any misconceptions that you hear voiced. You can reconfirm these using the concept map activity that follows and work to correct the misconceptions in the third activity (the "explain" activity).

Safety Issues
None.

Suggestions for Assessment
Monitor student participation. Try to assure that every student contributes one or more responses to your listing. The video segment is rich in possible answers.

References and Resources
Spielberg, S. (1994). *Jurassic Park*. Universal City, FL: MCA Universal Home Video.

Note: There is no student handout for Module #1.

SUGGESTIONS FOR TEACHERS

Module #2 *(Explore)*
What Do You Know About Reflexes?

Purpose
Assess students' understanding of reflexes and give them a real life example of a reflex.

Objectives
1. Engage students in making active observations about various reflexes and reactions and the difference between them.
2. Allow students to connect their own experiences with reflexes and reactions to the observations they make.
3. Assess students' current understanding and possible misconceptions about reflexes and reactions.

Materials
- poster board
- Post-Itfi notes
- colored markers or pencils
- percussion mallets (or something to generate a knee jerk reaction)
- pen lights or flashlights
- various materials to generate a distraction (water, radio, reading material, etc.)

Procedure
1. Starting with the list they generated during Module #1, assign groups of students to generate a concept map of what they know about reflexes. They should put concepts on the Post-It® notes and connect concepts using pencil-drawn lines and text on the poster board so they can be changed later, as needed. (Information on concept mapping follows.)
2. Students can present their concept maps and/or they can be used as a pre-assessment by the teacher.
3. Next, ask students to define a simple question and design a corresponding experiment to learn more about the pupillary reflex or the knee jerk reflex. Their experiments must use only those materials made available to them. Each group must design their experiment and clear their plan of action with the teacher before proceeding.
4. Allow students to conduct their experiments, gather and analyze their data, and present their findings briefly to the class. Part of their presentation should be a list of two to three additional questions they have about reflexes.

Safety Issues
The percussion mallet should be used gently to elicit the knee jerk response. Students should design experiments that will not harm the subject. Extremely loud noises may damage hearing and any stimulus that results in pain must be avoided. This is a good opportunity to discuss the need for human and animal protocol approval for experimentation. All experiments must be approved by the teacher before they are begun.

Suggestions for Assessment
Student concept maps (both pre- and post-lesson) and experimental reports or posters can serve as assessment tools. Develop a rubric for evaluation of group activities. Require students to keep detailed records of the experiments they conduct and collect these for evaluation. Finally, students could write a research paper on their experiments in the form of a scientific poster that they can present to the class.

References and Resources
Spielberg, S. (1994). *Jurassic Park*. Universal City, FL: MCA Universal Home Video.

BUILDING CONCEPT MAPS

Step 1: Identify the major concepts, principles, components, and contributing factors.

How To Do It: While "brainstorming" the subject, write down each possible item on paper. After editing and amending the list, write each final selection on a card, small piece of paper, or Post-It® note.

Step 2: Organize the items. Rank each in a hierarchy of importance(s), or sequence(s), or interactive relationship(s), or from general to specific, or start to finish.

How To Do It: Arrange concept label cards (generated in Step 1) on a table or board or place Post-It® notes on a large sheet of paper to best fit the selected hierarchy and lead into Step 3.

Step 3: Determine the relationships and interconnections between the concepts, principles, components, etc.

How To Do It: Draw connecting lines in pencil (so they can be changed as needed) and write appropriate verbs and/or phrases on the lines to describe the connections.

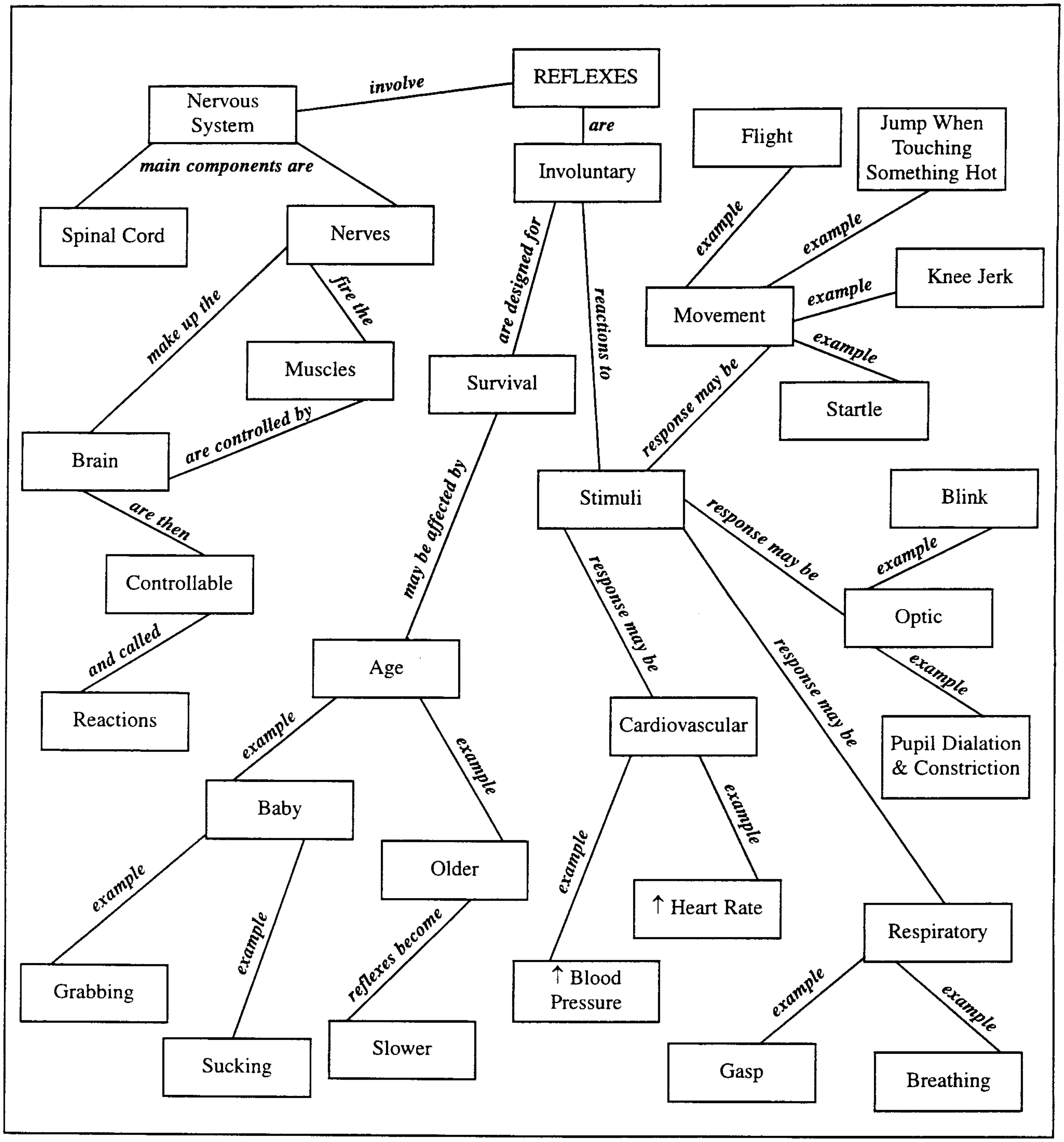
Step 4: Neatly lay out the final concept map, either by hand on poster board or by using a computer graphics program.

References and Resources on Concept Mapping

Wesley, W.G., & Wesley, B.A. (October 1990). *Concept mapping: A brief introduction*. The Teaching Professor, p. 3-4.
Novak, J. (October 1991). *Clarify with concept maps: A tool for students and teachers alike*. The Science Teacher, p. 45-49.

NOTE: The concept map on the following page was developed by a group of middle and high school science teachers during an APS workshop on neural reflexes.

SAMPLE CONCEPT MAP



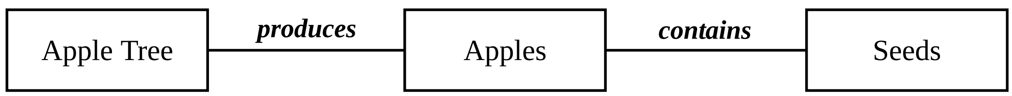
STUDENT ACTIVITY SHEET

Module #2
What Do You Know About Reflexes?

PART I:

Materials
- poster board
- Post-It® notes
- colored markers or pencils

Procedure
Construct a concept map detailing what you know about reflex actions (such as a knee jerk response). Place each concept on a Post-It® note. Each concept must be connected by a line labeled with the relationship of the concepts. For example:



PART II:

Materials
- percussion mallets (or something to generate a knee jerk reaction)
- pen lights or flashlights
- various materials to generate a distraction (water, radio, reading material, etc.)

Procedure
The knee jerk and pupil reflexes are simple responses that can be studied easily. With your group, define a question concerning one of these responses and design a simple experiment to answer your question. Check with your teacher before proceeding with your experiment.

Be sure to include the following in your experiment:
- your question (purpose)
- your hypothesis (what you think will happen)
- materials
- methods (how you will do the experiment)
- chart to record your data
- results
- conclusions
- additional questions you'd like to explore (where would you go from here?)

SUGGESTIONS FOR TEACHERS

Module #3 *(Explain)*
Reflexes and Reactions — An Overview

Purpose
Provide students with additional information on reflexes and reactions to explain the results and questions they generated in the previous two activities.

Objectives
1. Engage students in developing and sharing their questions about reflexes and reactions.
2. Allow students to connect their own experiences with reflexes and reactions to the observations they make.
3. Increase students' understanding and correct misconceptions about reflexes and reactions.

Materials
- overhead projector
- overhead transparencies
- transparency markers

Procedure
1. Ask students to share some of the questions they have about reflexes and responses. They should have generated questions as they developed their concept maps and as they did the experiment in Module #2.
2. Review the concepts presented in the background material in this unit on reflexes, reaction times, and neural networks. You may want to duplicate the illustrations on pages 2, 5, and 7 for students.

Questions to Ask
- What is the difference between a hand jerk reflex following contact with a hot object and a reflex reaction to catch or block an object thrown towards your face? Is the brain involved in either response? Explain. Draw a simple diagram of the neural paths for the two reactions.
- What impact do drugs, including alcohol, diet, and tobacco use have on reaction times?
- Is the saying "Practice makes perfect" true? Can you design an experiment to test the hypothesis that practice can improve reaction time?
- What exactly is a reflex? What tissues are involved and what controls them?

Safety Issues
None.

Suggestions for Assessment
Students can revise their concept maps on reflexes or generate a new one on reflexes and reactions.

References and Resources
Textbooks on anatomy and physiology.

Note: There is NO student handout for Module #3.

SUGGESTIONS FOR TEACHERS

Module #4 *(Elaborate)*
Is Heart Rate Constant?

Purpose
Explore further the concept of reflexes in terms of the heart's response to various stimuli via a hands-on, inquiry approach laboratory.

Objectives
1. Engage students in making active observations about the baroreflex and how it can be stimulated.
2. Improve student skills in developing experimental questions, designing experiments, collecting and analyzing data, and drawing conclusions.

Materials
- stopwatches
- pulse or heart rate monitors (desirable but optional)
- stethoscopes (desirable but optional)

Procedure
1. Ask the class if heart rate is constant. Obviously, it is not, but what sort of stimulus might raise or lower heart rate?
2. Ask them to design an experiment to test the effect of a stimulus, e.g. standing from a prone position or mild exercise, on heart rate. They will need a way to measure heart rate. The pulse is an obvious method, but it is not necessarily the most accurate. If possible, have stethoscopes and/or heart or pulse monitors available.
3. Have them share their experimental design, results, and analysis.
4. Ask them if heart rate can be controlled just by thinking about it — by and large no, but some degree of biofeedback is possible.

Safety Issues
Students should design experiments that will not harm the subject. Extremely loud noises may damage hearing and any stimulus that results in pain must be avoided. This is a good opportunity to discuss the need for human and animal protocol approval for experimentation. All experiments must be approved by the teacher before they are begun.

Suggestions for Assessment
Class presentations of experiments, results, and conclusions. Develop a rubric for evaluation of group activities.

References and Resources
Textbooks on anatomy and physiology.

STUDENT ACTIVITY SHEET

Module #4
Is Heart Rate Constant?

Materials
- stopwatches
- pulse or heart rate monitors (desirable but optional)
- stethoscopes (desirable but optional)

Procedure
Does heart rate change in response to a stimulus? Measure the heart rate or pulse of the members of your group. Are they all the same? Compare your heart rates to those of others in the class. Do you see any patterns? Did everyone measure their heart rates the same way? Decide on a method of measurement and design an experiment to test the effect of a stimulus, e.g. going from a prone to a standing position, on heart rate. DO NOT include strenuous exercise in your protocol. After obtaining approval from the instructor, run the experiment. Carefully record the experimental design, results and interpretation. Summarize your experimental design, results and conclusions for presentation to the class.

Be sure to include the following in your experiment:
- your question (purpose)
- your hypothesis (what you think will happen)
- materials
- methods (how you will do the experiment)
- chart to record your data
- results
- conclusions
- additional questions you'd like to explore (where would you go from here?)

SUGGESTIONS FOR TEACHERS

Module #5 *(Elaborate)*
Effects of External Stimuli on Reaction Times

Purpose

Explore further the concept of reactions and how they can be altered via a hands-on, inquiry approach laboratory.

Objectives

1. Engage students in making active observations about reactions and how they can be altered.
2. Improve student skills in developing experimental questions, designing experiments, collecting and analyzing data, and drawing conclusions.

Materials

- meter sticks
- reaction time strips
- stopwatches
- poster board
- colored markers or pencils

Procedure

1. Have the students design and complete an experiment to determine the effect of an external stimulus on reaction time. This will require that they first develop a way to measure reaction time. One very simple way is to have one student hold a meter stick suspended near the 0 cm end between the fingers of another student. This student must catch the meter stick when it is released without warning. (Precalibrated reaction time sticks are available from scientific supply catalogs). The distance the stick falls is recorded and reaction time recorded as:

$$\textbf{Reaction time (in seconds)} = \sqrt{\frac{\textbf{2 x distance (in cm)}}{\textbf{980 cm/sec}^2}}$$

2. Another is to record the time it takes a student to sequentially touch 16 numbers randomly distributed in a 4x4 pattern on a sheet of paper. Similar patterns can be setup with letters that spell out a name or word. This may useful for introducing a new word such as neurophysiology. Electronic reaction time devices are also available from scientific supply catalogs.
3. Review each group's design prior to the experiment. Stimuli that might be tested include distractions such as external noise or engagement in another activity (reciting the Gettysburg Address), right vs. left hand, repetition (practice), auditory vs. visual signal, age, gender etc.
4. Have the students record their experimental design and summarize their data for presentation to the class. They should present their experiment, the rationale for their design and the results in a manner that can be easily understood. They should also provide their own interpretation of the results.

Safety Issues

Students should design experiments that will not harm the subject. Extremely loud noises may damage hearing and any stimulus that results in pain must be avoided. This is a good opportunity to discuss the need for human and animal protocol approval for experimentation. All experiments must be approved by the teacher before they are begun.

Suggestions for Assessment

Class presentations of experiments, results, and conclusions. Develop a rubric for evaluation of group activities.

References and Resources

Textbooks on anatomy and physiology.

STUDENT ACTIVITY SHEET

Module #5
Effects of External Stimuli on Reaction Times

Materials
- meter sticks
- reaction time strips
- stopwatches
- poster board
- colored markers or pencils

Procedure
Design and conduct an experiment to test the effect of an external stimulus on reaction time. Before you do this you must develop a method to measure reaction time. Get approval of your method to measure reaction time and of your experimental design before proceeding. Summarize your experimental design and results for presentation to the class.

Be sure to include the following in your experiment:
- your question (purpose)
- your hypothesis (what you think will happen)
- materials
- methods (how you will do the experiment)
- chart to record your data
- results
- conclusions
- additional questions you'd like to explore (where would you go from here?)

SUGGESTIONS FOR TEACHERS

Module #6 *(Evaluate)*
What Do You Know Now About Reflexes and Reactions?

Purpose
Assess students' understanding of reflexes and reactions.

Objectives
1. Allow students to revise their concept maps to correct misconceptions and add new concepts gained.
2. Provide students with opportunities to see their progress in understanding of the nervous system and its function.

Materials
- poster board
- Post-It notes
- colored markers or pencils

Procedure
1. According to your preference, students can either revise their existing concept map on reflexes to add what they've learned about both reflexes and reactions or they can generate a new concept map.
2. In either case, students should have an opportunity to see their progress in understanding the nervous system and its functions.

Safety Issues
None.

Suggestions for Assessment
Compare pre- and post-concept maps. Develop a rubric for evaluation of concept maps.

Where to Go From Here
- Explore in more detail the mechanism of reflex actions including muscle contraction and transmission of impulses.
- Explore through literature research the mechanism of action of neurotoxins such as botulism toxin, tetanus toxin, curare, etc. Do any of these have medical application?
- Discuss the importance of controlling emotional responses in reflex reactions, such as the anger response.
- Interview a scientist who does research on reflex reactions.

Extension
The above activities work from a simple reflex action involving a simple neural network (pain receptor — spinal cord — neuromuscular signal) to more complex reactions requiring the brain. But these networks are still somewhat simple compared to the mechanisms of visual and auditory perception. These can be explored by introducing the students to optical illusions. Numerous examples can be found but a few are included on the following pages. More than likely the students have seen the 3D images that have become popular recently. Simple observation of the images can lead to further study of perception and why different people may come away with different interpretations of the same observations.

References and Resources

None.

Note: There is NO student handout for Module #6.

NEURAL NETWORKS

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