Reflexes

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Objectives

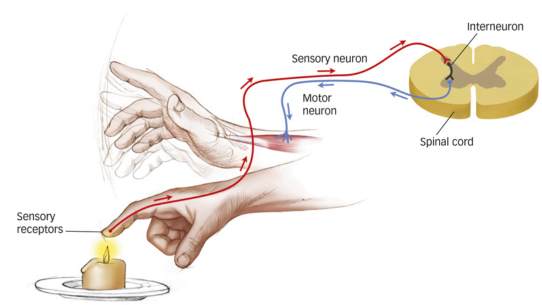
1. Define reflexes and understand their purpose
2. Provide examples of human reflexes

Background Information

Reflexes are automatic, rapid responses to stimuli that are crucial for protecting the body. They are an essential component of the motor system, allowing for quick, involuntary actions without the need for conscious thought or brain involvement. Reflexes are typically mediated by neural circuits known as reflex arcs, which involve sensory neurons that detect a stimulus, interneurons in the spinal cord, and motor neurons that execute the response. This lesson will explain a variety of reflex arcs with ways you can incorporate some of them into the classroom.

Withdrawal reflex

Have you ever accidentally touched a hot pan only to quickly move your hand away without thinking about it? This is an example of a spinal reflex called the withdrawal reflex. The withdrawal reflex protects the body from damaging stimuli, such as hot or sharp objects.

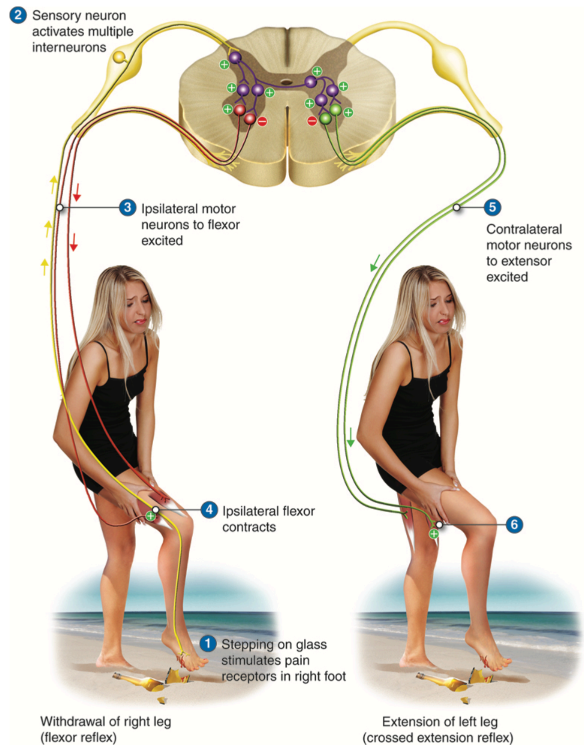


Your skin contains special receptors called nociceptors that detect pain (i.e. something hot or sharp). These nociceptors send signals through sensory neurons to the spinal cord. Here, they make connections with intermediate neurons called interneurons. These interneurons process the incoming sensory information and send it to a motor neuron. The motor neuron then activates the flexor muscles of the affected limb, causing the muscle to contract and rapidly pull away from the painful stimulus. At the same time, there is a process called reciprocal inhibition, where the extensor muscle in the affected limb is relaxed to allow the flexors to contract more effectively. This reflex is mediated at the level of the spinal cord. This means that the signal doesn't have to take time to travel to the brain and be processed in the brain, allowing you to quickly move away from the painful stimulus.

Crossed extensor reflex

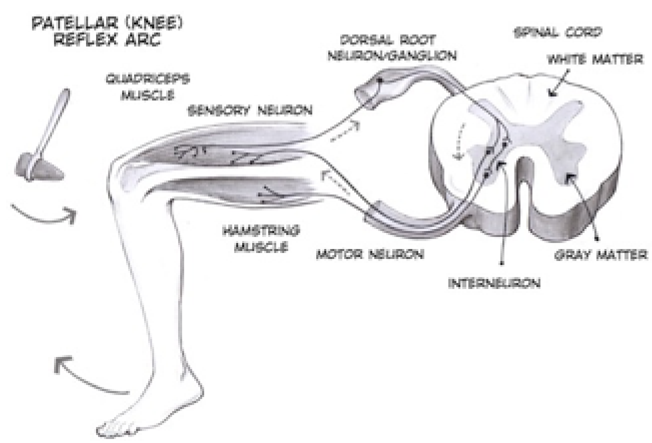
Have you ever accidentally stepped on a Lego and needed to step back? Moving your foot away uses the withdrawal reflex explained above, but it also incorporates the crossed extensor reflex to help you maintain your balance.

Say you step on a Lego with your right foot which activates your withdrawal reflex. The nociceptors send signals about the pain to the spinal cord, where they connect with interneurons. Interneurons that signal to the right side of the body will cause the flexors to contract and the extensors to relax. At the same time, this interneuron will signal to other interneurons that control muscles on the left side of your body. These interneurons will activate motor neurons in your left leg. Specifically, they will activate the extensor muscles and inhibit the flexor muscles, causing your left leg to extend. Together, these two reflexes help to stabilize the body and prevent falling as you withdraw your right leg.



Knee-jerk reflex

Do you remember visiting the doctor's office where they'd tap your knee with a hammer, causing your leg to kick out? This is called the knee-jerk reflex. This reflex helps to maintain our balance and posture. When we stand up, gravity might cause our knee to bend slightly, and this could make us fall if we did not have this protective reflex to straighten out the knee and keep us upright.



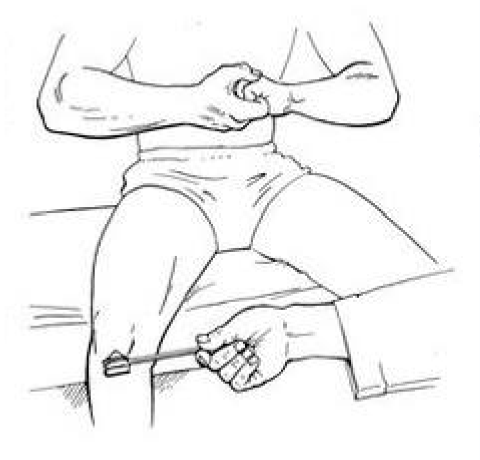
The knee-jerk reflex is one of the simplest reflex arcs in the body. When the knee gets tapped with the hammer, it stretches the quadriceps muscle and activates the sensory neurons in that muscle. That sensory neuron sends its information to the spinal cord where it connects directly with a motor neuron in the spinal cord. The motor neuron is activated and sends a signal to the hamstring to make it contract. Because there is only one connection (aka only one synapse) between the sensory neuron and the motor neuron, this reflex arc is also called the monosynaptic reflex. Try out this monosynaptic reflex with students in the classroom!

Materials

Item	**Quantity**	**Notes**
Reflex hammer	1	Can be bought on Amazon or at Walmart for ~$6
Desk or tabletop	1	Students need to sit on top of an elevated surface in order for their legs to dangle

In the Class

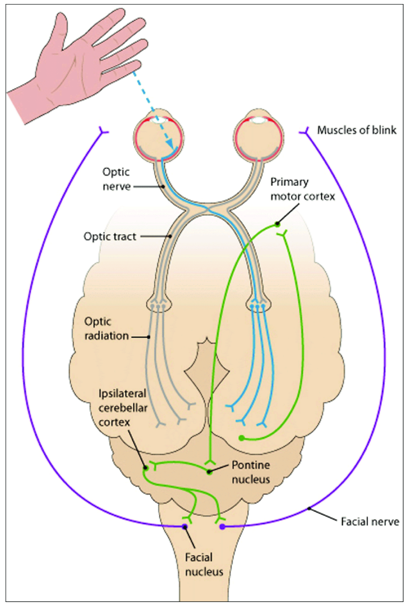
1. Have students sit on top of an elevated surface, such as a desk or science bench table. Their legs need to be dangling down in order for this reflex to work.
2. Locate the student's patellar tendon. This is a soft gap right below the kneecap.
3. With a reflex hammer, tap the tendon.
4. Watch the leg kick out!
5. If the student's leg isn't kicking out, try having the student use the Jendrassik Maneuver. The student should clench their teeth, flex both fingers together in hook-like form and interlock, and close their eyes.
    a. This should help to increase the reflex response. It both redirects the student's attention away and increases the excitatory information sent to the reflex arc.



Menace reflex

The menace reflex occurs when we see a sudden threat approach our eyes. In order to protect the eyes from potential damage, we blink. We may also turn our head, neck, or torso away from the optical stimulus that triggers this response.

This reflex requires both our visual and motor systems to work. First, our eyes must process that there is an incoming stimulus and must detect details like the object's speed or trajectory. Information from our retinas gets sent to the primary visual cortex via the optic nerve and optic tract. From the primary visual cortex, information is sent through the pons, a brainstem structure, to the facial nucleus. The facial nucleus is a group of neurons located in the nucleus that control the muscles of the face. The facial nerves innervate the facial muscles, causing you to blink!



Materials

Item	Quantity	Notes
Cotton balls	1 pack	Can be bought from Target or Walmart for $2

In the Class

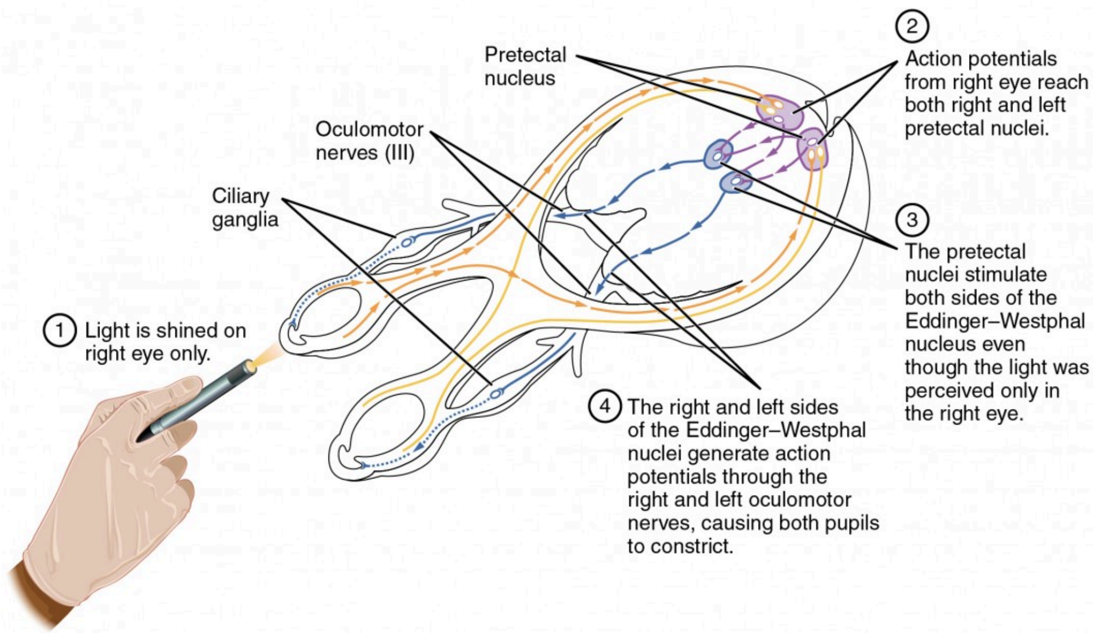
1. Have a pair of students stand facing each other at a distance away.
2. Have Student 1 throw a cotton ball (with a soft throw) directed at Student 2's face
3. Observe Student 2's blink!

Pupillary reflexes

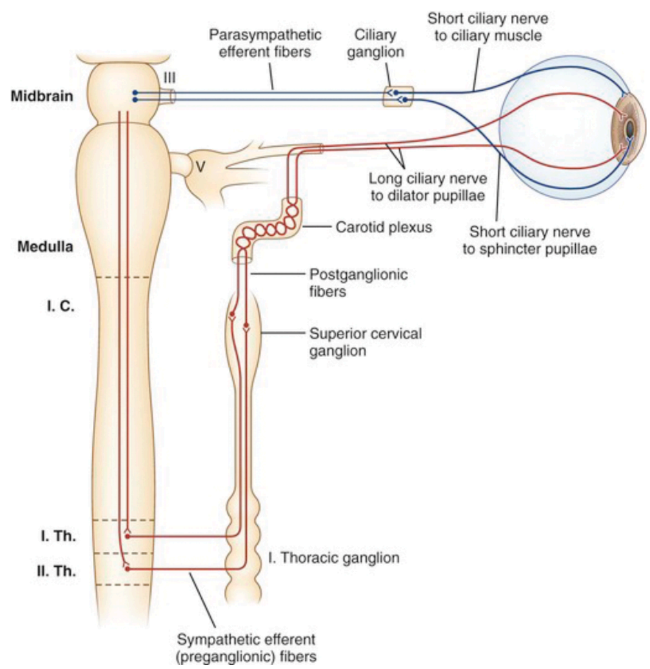
We rely on our eyes to see the world around us. Our eyes have a built-in reflex to protect them from receiving too much light. This pupillary light reflex changes the size of the pupils depending on the light levels.

The pupillary light reflex constricts the size of the pupils to decrease the amount of light entering the eye. Light travels through the cornea and reaches the retina at the back of the eye. Photoreceptors in the retina convert the light into an electrical signal, and this signal is sent via the optic tract to the pretectal nucleus. The pretectal nucleus is a group of neurons located in the midbrain, a brainstem structure. The pretectal nucleus sends information to the Edinger-Westphal nucleus, another group of neurons located in the midbrain. The signals from the Edinger-Westphal nucleus travels via the oculomotor nerve to connect with the ciliary ganglion. The ciliary ganglion is a cluster of nerve cell bodies that directly connect with the muscles in the iris. When there is too much light, this pathway activates, causing the muscles of the iris to contract and the pupils to constrict.

So, when you shine a light into the right eye, the right pupil constricts. But something else happens - your left pupil constricts too! This is due to the consensual reflex, where both pupils constrict even after shining a light into only one eye. This is because the optic tract carries visual information from both eyes, and the pretectal nucleus sends information to Edinger-Westphal nuclei in both halves of the brain. This way, both pupils constrict.



On the contrary, the pupillary dark reflex allows the pupils to dilate when it is dark, allowing more light to enter into the eyes. Photoreceptors in the retina detect the darkness, and this signal is transmitted via the optic nerve. These signals are sent to a brain region called the hypothalamus, where the signal is then transmitted to the spinal cord. Neurons in the spinal cord send information via the long ciliary nerve to the iris dilator muscle.



Materials

Item	Quantity	Notes
Small flashlight	1	Can be bought from Amazon for $10. Can also use phone flashlight

In the Class

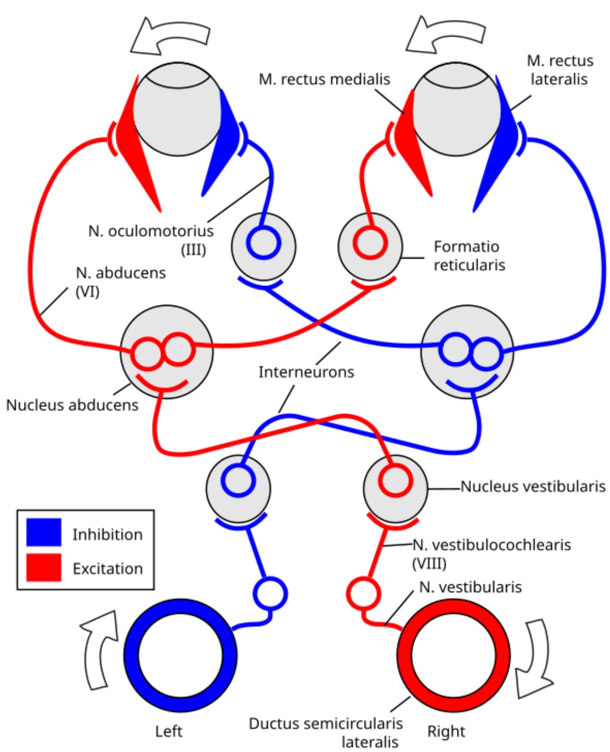
1. Have students pair up and look at each other's eyes. Note the size of the pupil.
2. Turn off the lights, and wait for a little bit for the eyes to adapt to the darkness
    a. Have students note the new size of the pupil. It should be dilated - this is the pupillary dark reflex.
3. Have Student 1 use a flashlight to shine a light into one of Student 2's eyes.
    a. Student 1 should observe both of Student 2's pupils constricting - this is the pupillary light reflex and the consensual reflex
    b. Repeat with Student 2 holding the flashlight

Vestibulo-Ocular Reflex

The vestibulo-ocular reflex (VOR) keeps our eyes stabilized when our heads move. For example, if we are told to focus on an object in front of us, movement of our head towards the right will cause the eyes to move to the left, staying focused on the object. Our heads move all the time, even if we're not aware of it. The VOR allows us to keep our eyes steady in spite of this head movement.

This reflex is driven by our vestibular system. The vestibular system is a sensory system in the inner ear that helps us understand where our heads are in space and how our head is moving. This system helps us maintain our sense of balance and orient ourselves in space.

This reflex begins when vestibular organs in the inner ear detect head rotations and head movements. These vestibular organs send information to the vestibular nucleus, a cluster of cells located in the pons. The vestibular nucleus sends information to the abducens nucleus, another cluster of cells located in the pons, on the opposite side of the brain. The signal from the abducens nucleus splits. One branch goes to the lateral rectus muscle of both eyes. The other branch goes to the oculomotor nucleus on the other



side of the brain. This oculomotor nucleus sends signals via the oculomotor nerve to the medial rectus muscles of the eyes. Ultimately these eye muscles receive commands to move the eyes in a way that counterbalances the head movement.

Materials

Item	Quantity	Notes
Nothing! Just your students		

In the Class

1. Have students pair up and look at each other's eyes.
2. Student 1 should hold their hand/finger straight out in front of them. Tell Student 1 to keep their eyes focused on their hand/finger, and have them move their head around.
    a. Student 2 should watch how Student 1's eyes stay focused on the hand/finger despite the head movements.
3. Repeat with Student 2.

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1. http://digfir-published.macmillanusa.com/schacterbrief3e/asset/img_ch3/Sch3e_ch3_fig_9.html
2. https://en.wikipedia.org/wiki/Crossed_extensor_reflex
3. https://lions-talk-science.org/2021/10/27/the-knee-jerk-reflex-more-than-a-simple-medical-test/
4. https://jcphysiotherapy.com/blog/the-jendrassik-maneuver/
5. https://pmc.ncbi.nlm.nih.gov/articles/PMC2671880/
6. https://courses.lumenlearning.com/suny-ap1/chapter/central-control/
7. https://www.eyenews.uk.com/education/trainees/post/the-assessment-of-pupils-and-pupillary-reactions
8. https://en.wikipedia.org/wiki/Vestibulo-ocular_reflex