**REFLEXES**

A reflex is a rapid, involuntary sequence of actions occurring in response to a stimulus. Reflexes control actions with a wide range of functions, such as protection (limb withdrawal reflex) or influencing locomotor activity. Many reflexes are relayed via the brainstem or spine, and testing the reflexes can be clinically useful in establishing the location of damage to the nervous system.

Reflexes may be categorized as:

<table>
<thead>
<tr>
<th>Type</th>
<th>Description</th>
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<tbody>
<tr>
<td>Spinal reflex</td>
<td>Information is relayed via the spinal cord, for example, the knee jerk reflex.</td>
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<tr>
<td>Cranial reflex</td>
<td>Information is relayed via the brainstem, for example, tracking motion of the eyes.</td>
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<tr>
<td>Somatic reflex</td>
<td>Involves skeletal muscle contraction, for example, the knee jerk reflex.</td>
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<tr>
<td>Autonomic (visceral) reflex</td>
<td>Involves smooth muscle contraction, cardiac muscle contraction, or glandular secretion. These are conveyed through the autonomic nervous system; producing a response in an organ that is not under conscious control. Examples include the contraction of cardiac muscle producing a heartbeat, and peristaltic contraction of the smooth muscle of the intestinal walls.</td>
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**REFLEX ARCS**

A reflex is a rapid, involuntary sequence of actions that occur in response to a specific stimulus. A reflex arc is the neural pathway by which a reflex is mediated. It is composed of a sensory neuron, interneuron, and motor neuron.

1. **Sensory receptor**
   
   A reflex begins when sensory receptors are activated in response to a particular stimulus.

2. **Sensory neuron**
   
   This fires an action potential along a sensory neuron, which travels via the dorsal root of a spinal nerve into the spinal cord.

3. **Synapses and interneurons**
   
   Here, the sensory neuron may synapse directly with a motor neuron or via one or more interneurons.

4. **Motor neuron**
   
   This initiates an action potential which is then propagated along a motor neuron, via the ventral root of a spinal nerve to an effector, such as a skeletal muscle.

5. **Effector**
   
   The effector responds with a reflex action, such as contraction.

There are several ways to describe the types of reflex arcs:

- **Monosynaptic reflex**
  
  A monosynaptic reflex has only one synapse in its reflex arc; there are no interneurons.

- **Polysynaptic reflex**
  
  A polysynaptic reflex has more than one synapse and one or more interneurons in its reflex arc.

- **Intersegmental reflex arc**
  
  An intersegmental reflex arc has synapses in more than one segment of the spinal cord, for example, the biceps flexor reflex.
Ipsilateral reflex

Motor impulses leave the spinal cord via the motor neuron on the same side as the sensory impulses that enter via the sensory neuron. Therefore, an ipsilateral reflex produces a reflex action on the same side of the body to where the stimulus was perceived. All monosynaptic reflexes are ipsilateral.

Contralateral reflex

Motor impulses leave the spinal cord via the motor neuron on the opposite side as the sensory impulses that enter via the sensory neuron. Impulses cross through the center of the gray matter in the spinal cord as they follow their reflex arc. Therefore, a contralateral reflex produces a reflex action on the opposite side of the body to where the stimulus was perceived.

STRETCH REFLEX

A stretch reflex is initiated by the stretching of a skeletal muscle and results in its reflex contraction. A knee jerk reflex is an example of a stretch reflex that can be artificially initiated by tapping the patellar tendon.

1. Muscle spindles

The reflex begins when sensory receptors known as muscle spindles are activated. Muscles spindles are located in skeletal muscle (in this case the extensor muscles of the knee) and are activated in response to slight stretching of the muscle, such as when a tendon is tapped with a tendon hammer for example.

2. Sensory neuron

This fires an action potential along a somatic sensory neuron, which travels via the dorsal root of a spinal nerve into the spinal cord.

3. Excitatory synapse

Here, the sensory neuron synapses ipsilaterally with a motor neuron in the anterior gray horn of the spinal cord.

4. Motor neurons

This triggers an action potential to be propagated, via the ventral root of a spinal nerve, to presynaptic axon terminals of neuromuscular junctions in the stretched skeletal muscle fibers.

5. Skeletal muscle

This leads to muscular contraction, relieving the stretching of the muscle.

The sensory neuron also synapses with an inhibitory interneuron, which in turn synapses ipsilaterally with a motor neuron that controls antagonistic muscles (in this case the flexors of the knee). This leads to relaxation of these muscles, which causes the simultaneous contraction of the stretched muscles. The relaxation of one muscle that results in the contraction of its antagonist is known as reciprocal innervation.

TENDON REFLEX

A tendon reflex is initiated by a substantial amount of tension in a muscle tendon, and results in the reflex relaxation of the skeletal muscle attached to that tendon. It is less sensitive than the stretch reflex, but produces an opposite effect.

1. Golgi tendon organ

The reflex begins when sensory receptors known as Golgi tendon organs are activated. Golgi tendon organs are located within a tendon, at its junction with a muscle, and are activated in response to increased tension, such as when a tendon is tapped with a tendon hammer for example.
2. **Sensory neuron**
This fires an action potential along a somatic sensory neuron, which travels via the dorsal root of a spinal nerve into the spinal cord.

3. **Inhibitory interneuron**
Here, the sensory neuron synapses with an inhibitory interneuron, which in turn synapses ipsilaterally with a motor neuron in the anterior gray horn of the spinal cord.

4. **Motor neurons**
The interneuron releases an inhibitory neurotransmitter that inhibits the motor neuron, making it less excitable and reducing the likelihood of an action potential being generated.

5. **Skeletal muscle**
This leads to relaxation of the skeletal muscles attached to the stretched muscle tendon (in this case the extensor muscles of the knee), thereby reducing tension in the tendon and protecting it from damage.

In addition, the sensory neuron also synapses with an excitatory interneuron, which in turn synapses ipsilaterally with a motor neuron that controls the antagonistic muscles (in this case the flexors of the knee). This leads to contraction of these muscles, which causes the simultaneous relaxation of the muscle connected to the tendon under tension. The contraction of one muscle that results in the relaxation of its antagonist is known as **reciprocal innervation**.

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### FLEXOR REFLEX

A flexor reflex is initiated by a painful stimulus and results in the reflex contraction of flexor muscles, withdrawing the limb from the stimulus.

1. **Pain receptor**
The reflex begins when free nerve endings of a pain-sensitive neuron are activated in response to a painful stimulus, such as stepping on a nail.

2. **Sensory neuron**
This fires an action potential along a sensory neuron, which travels via the dorsal root of a spinal nerve into the spinal cord.

3. **Intemeurons**
Here, the sensory neuron synapses with ascending and descending interneurons.

4. **Motor neurons**
The intemeurons synapse ipsilaterally with motor neurons in the anterior gray horn in multiple segments of the spinal cord, triggering action potentials to be propagated via the ventral roots of spinal nerves, to presynaptic axon terminals of neuromuscular junctions in the flexor muscle fibers of the thigh. Several nerves are required to stimulate all the muscle groups required to move the whole limb away.

5. **Flexor muscles**
This leads to muscular contraction and triggers the withdrawal of the limb away from the nail.

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### EXTENSOR REFLEX

An extensor reflex is initiated by a painful stimulus and occurs at the same time as the flexor reflex. It results in the reflex contraction of the extensor muscles of the unharmed limb, allowing the body to retain its balance whilst the flexor reflex withdraws the harmed limb away from the stimulus.
### 1. Pain receptor
The reflex begins when free nerve endings of a pain-sensitive neuron are activated in response to a painful stimulus, such as stepping on a nail.

### 2. Sensory neuron
This fires an action potential along a somatic sensory neuron, which travels via the dorsal root of a spinal nerve into the spinal cord.

### 3. Interneurons
Here, the sensory neuron synapses with interneurons. The interneurons synapse contralaterally with motor neurons in the anterior gray horn, in multiple segments of the spinal cord.

### 4. Motor neurons
Action potentials are propagated along these motor neurons, via the ventral roots of spinal nerves, to presynaptic axon terminals of neuromuscular junctions in the extensor muscle fibers of the thigh of the unharmed limb.

### 5. Extensor muscles
This leads to muscular contraction, causing the limb to stabilize the body during the withdrawal action.

The sensory neuron also synapses contralaterally with inhibitory interneurons which in turn synapse with motor neurons that control the antagonistic muscles.