Reflex Physiology

Dr. Ali Ebneshahidi
Reflex Physiology

- Reflexes are automatic, subconscious response to changes within or outside the body.

  - a. Reflexes maintain homeostasis (autonomic reflexes) – heart rate, breathing rate, blood pressure, and digestion.

  - b. Reflexes also carry out the automatic action of swallowing, sneezing, coughing, and vomiting.

  - c. Reflexes maintain balance & posture.

    ex. Spinal reflexes – control trunk and limb muscles.


    ex. Reflexes for eye movement.
Reflex Arc

The reflex arc governs the operation of reflexes. Nerve impulses follow nerve pathways as they travel through the nervous system. The simplest of these pathways, including a few neurons, constitutes a reflex arc. Reflexes whose arc pass through the spinal cord are called spinal reflexes.
1. **Receptor** – detects the stimulus.
   a) Description: the receptor end of a particular dendrite or a specialized receptor cell in a sensory organ.
   b) function: sensitive to a specific type of internal or external change.

2. **sensory neuron** – conveys the sensory info. to brain or spinal cord.
   a. Description: Dendrite, cell body, and axon of a sensory neuron.
   b. Function: transmit nerve impulses from the receptor into the brain or spinal cord.
Reflex Arc

3. **Interneuron**: relay neurons.
   a. Description: dendrite, cell body, and axon of a neuron within the brain or spinal cord.
   b. function: serves as processing center, conducts nerve impulses from the sensory neuron to a motor neuron.

4. **Motor neuron**: conduct motor output to the periphery.
   a. Description: Dendrite, cell body, and axon of a motor neuron.
   b. function: transmits nerve impulse from the brain or spinal cord out to an effector.
5. **Effecter**:

a. **Description**: a muscle or gland.

b. **function**: Response to stimulation by the motor neuron and produces the reflex or behavioral action.
Stretch and Deep Tendon Reflexes

- For skeletal muscles to perform normally:
  - **Stretch reflexes** initiated by muscle spindles must maintain healthy muscle tone.
  - The **Golgi tendon organs** (proprioceptors) must constantly inform the brain as to the state of the muscle.
  - Stretch reflexes cause muscle contraction in response to increased muscle length (stretch). Golgi tendon reflexes produce exactly the opposite effect: muscle relaxation and lengthening in response to tension. Golgi tendon organs help to prevent muscles and tendons from tearing when they are subjected to possibly damaging stretching force.
Muscle Spindles

- Are composed of a few intrafusal muscle fibers that lack actin and myosin in their central regions, are noncontractile, and serve as receptive surfaces.

- Muscle spindles are wrapped with two types of afferent endings: primary sensory endings of type Ia fibers and secondary sensory endings of type II fibers.

- These regions are innervated by gamma (γ) efferent fibers.

- Note: contractile muscle fibers are extrafusal fibers and are innervated by alpha (α) efferent fibers.
Muscle Spindles

- Flower spray endings (secondary sensory endings)
- Anulospiral endings (primary sensory endings)
- Muscle spindle
- Capsule (connective tissue)
- Tendon organ
- Tendon
- γ Efferent (motor) fiber to muscle spindle
- α Efferent (motor) fiber to extrafusal muscle fibers
- Extrafusal muscle fiber
- Intrafusal muscle fibers
- Sensory fiber

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Operation of the Muscle Spindles

- Stretching the muscles activates the muscle spindle
  - There is an increased rate of action potential in Ia fibers
- Contracting the muscle reduces tension on the muscle spindle
  - There is a decreased rate of action potential on Ia fibers
Operation of the Muscle Spindles

(a) Action potential frequency increases during stretch

(b) Action potential frequency declines during contraction
Stretch Reflex

- Stretching the muscle activates the muscle spindle
- Excited $\gamma$ motor neurons of the spindle cause the stretched muscle to contract
- Afferent impulses from the spindle result in inhibition of the antagonist
- Example: patellar reflex
  - Tapping the patellar tendon stretches the quadriceps and starts the reflex action
  - The quadriceps contract and the antagonistic hamstrings relax
The events by which muscle stretch is damped

1. When stretch activates muscle spindles, the associated sensory neurons (blue) transmit afferent impulses at higher frequency to the spinal cord.

2. The sensory neurons synapse directly with alpha motor neurons (red), which excite extrafusal fibers of the stretched muscle. Sensory fibers also synapse with interneurons (green) that inhibit motor neurons (purple) controlling antagonistic muscles.

3a. Efferent impulses of alpha motor neurons cause the stretched muscle to contract, which resists or reverses the stretch.

3b. Efferent impulses of alpha motor neurons to antagonist muscles are reduced (reciprocal inhibition).
Golgi Tendon Reflex

- The opposite of the stretch reflex.
- Contracting the muscle activates the Golgi tendon organs.
- Afferent Golgi tendon neurons are stimulated, neurons inhibit the contracting muscle, and the antagonistic muscle is activated.
- As a result, the contracting muscle relaxes and the antagonist muscle contracts.
Golgi Tendon Reflex

1. Quadriceps strongly contracts. Tendon organs are activated.

2. Afferent fibers synapse with interneurons in the spinal cord.

3a. Efferent impulses to muscle with stretched tendon are damped. Muscle relaxes, reducing tension.

3b. Efferent impulses to antagonist muscle cause it to contract.

+ Excitatory synapse
- Inhibitory synapse

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- Simplest reflex because it has only one synapse in the path of its arc.

- Muscle spindles contain the sensory receptors for the stretch reflex.

- Each spindle contains modified muscle fibers called spindle or intrafusal fibers (inside spindle), innervated by gamma efferent fibers.
- The middle segment of each spindle fiber acts as a mechanical stretch receptor that is connected to a sensory afferent nerve to the spinal cord.

- Stretching of the muscle stretches the spindle fibers activating the muscle spindle stretch receptors and the associated sensory fibers.
The terminals of the spindle sensory fibers make direct excitatory synaptic contact with alpha motor neurons serving the ordinary muscle fiber (extrafusal fibers).

Contraction of these fibers shorten the muscle and relaxes the spindle fibers terminating the stretch reflex and muscle contraction.

(b) Stretched muscle. Stretching activates the muscle spindle, increasing the rate of APs.

(c) Only α motor neurons activated. Only the extrafusal muscle fibers contract. The muscle spindle becomes slack and no APs are fired. It is unable to signal further length changes.
1. Passive stretch of a muscle (produced by tapping its tendon) stretches the spindle (intrafusal) fibers.

2. Stretching of a spindle distorts its central (chain) region, which stimulates dendritic endings of sensory nerves.

3. Action potentials are conducted by afferent (sensory) fibers into the spinal cord on the dorsal roots of spinal nerves.

4. Axons of sensory neurons synapse with dendrites and cell bodies of somatic motor neurons located in the ventral horn gray matter of the spinal cord.

5. Efferent impulses in the axons of somatic motor neurons (which form the ventral roots of the spinal nerves) are conducted to the ordinary (extrafusal) muscle fibers. These neurons are (alpha) motor neurons.
6. Release of Ach from the endings of alpha motor neuron stimulates the contraction of extrafusal fibers, and thus the whole muscle.

7. Contraction of the muscle relieves the stretch of its spindles, thus decreasing electrical activity in the afferent nerve fibers, and relaxes the spindle fiber and terminates the stretch reflex and muscle contraction.

Note: By sending command to the motor neurons, the brain set a muscle’s length. The stretch reflex makes sure the muscle stay at that length. The stretch reflex is therefore important for maintaining muscle tone and upright posture.
The deep tendon Reflex

- If you tap on the tendon of a muscle, it contracts. Its synergists contract and its antagonists are inhibited.
- Polysynaptic reflex.
- A tap on the patellar tendon stretches the extensor muscle and its spindles.
- The spindle discharges and excites the associated sensory fibers that excite the motor neurons to the extensor muscle.

- Contraction of the extensor muscle extends the lower leg (knee-jerk).

- Ipsilateral flexor muscle relax for extensors to function.

- Branches of the sensory fibers from muscle spindle activate inhibitory interneuron, which in turn inhibit the motor neuron to the flexor muscle.

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The withdrawal reflex (flexor reflex)

- The automatic withdrawal of an extremity from a painful stimulus.
- A polysynaptic reflex.
- Sensory pain signals excite motor neurons to the flexor muscles, eliciting flexion and withdrawal of the leg.
- Motor neurons to the extensor muscles are inhibited via inhibitory interneurons.
- This would relax the extensors of the same leg.
The withdrawal reflex

1. Painful stimulus activates nociceptor.
2. Primary sensory neuron enters spinal cord and diverges.
3a. One collateral activates ascending pathways for sensation (pain) and postural adjustment (shift in center of gravity).
3b. Withdrawal reflex pulls foot away from painful stimulus.
3c. Crossed extensor reflex supports body as weight shifts away from painful stimulus.

Spinal cord

- Ascending pathways to brain
- Gray matter
- White matter
- Spinal cord

Nociceptor

- Sensory neuron

Extensors inhibited

Flexors contract, moving foot away from painful stimulus.

Extensors contract as weight shifts to left leg.

Flexors inhibited

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The crossed-extensor reflex:

- A polysynaptic reflex.

- Ex. Painful stimulation of one foot causes flexion (withdrawal) of the ipsilateral leg as well as the extension of the contralateral leg, to stabilize the posture; thus the ipsilateral leg flexors are activated and the extensors are inhibited and vice versa in the contralateral leg.
The crossed-extensor reflex (upper limb)

- Excitatory synapse
- Inhibitory synapse

Afferent fiber

Extensor fibers

Flexor inhibited

Flexor stimulated

Flexes

Arm movements

Extends

Site of stimulus: A noxious stimulus causes a flexor reflex on the same side, withdrawing that limb.

Site of reciprocal activation: At the same time, the extensor muscles on the opposite side are activated.
Superficial reflexes

- **Biceps jerk reflex**: the examiner places finger on the inside of the extended elbow over the tendon of the biceps muscle and the finger is tapped. The biceps contracts in response, and the forearm flexes at the elbow.

- **Triceps jerk reflex**: tapping the short tendon of the triceps muscle close to its insertion near the tip of the elbow elicit this reflex. The muscle contracts in response, and the forearm extends, slightly.

- **Abdominal reflex**: the examiner strokes the skin of the abdomen with a dull pin from the side of abdomen upward towards the midline and above the umbilicus. The umbilicus moves towards the stimulated region.
- **Ankle – jerk reflex (plantar reflex):** tapping the Achilles tendon just above its insertion on the Calcaneous elicits this reflex. The response is plantar flexion, produced by contraction of the gastrocnemius and the solues muscles.

- **Cremastric reflex:** this reflex is elicited in males by stroking the upper inside of the thigh. In response, the testis on the same side is elevated by contracting muscles.
Clinical Terms:

- **Analgesia**: loss or reduction in the ability to sense pain, without loss of consciousness.
- **Analgesic**: pain – relieving drug.
- **Anesthesia**: loss of feeling.
- **Ataxia**: partial or complete inability to coordinate voluntary movements.
- **Epilepsy**: Disorders of the CNS that is characterized by temporary disturbances in normal brain impulses; it may be accompanied by convulsive seizures and loss of consciousness.
- **Huntington disease**: Hereditary disorders of the brain producing progressively worsening, uncontrollable dance-like movements and personality changes.

- **Neuralgia**: sharp, recurring pain associated with a nerve, usually caused by inflammation or injury.