REFLEXES

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REFLEXES

A reflex is an automatic response to a stimulus. It occurs without conscious thought.
REFLEX ARC

The neural pathway involved in accomplishing the reflex activity is known as a reflex arc. The reflex arc is the basic functional unit of the nervous system.

It typically includes five basic components:

A Sensory receptor
↓
A Sensory neuron (afferent pathway)
↓
An interneuron
↓
A Motor neuron (efferent pathway)
↓
An Effector organ
**NOTE:** At the receptor, at the CNS synapse & the NMJ, the response is a Graded Potential while in portions of the arc specialized for transmission, the responses are Action potentials.
(a) A **monosynaptic reflex** has a single synapse between the afferent and efferent neurons.

- **Stimulus** → **Receptor** → **Sensory neuron** → **Skeletal muscle** → **Spinal cord Integrating center** → **Somatic motor neuron** → **One synapse** → **Efferent neuron** → **Target cell effector** → **Response**

(b) **Polysynaptic reflexes** have two or more synapses.

- **Stimulus** → **Receptor** → **Sensory neuron** → **Spinal cord Integrating center** → **Interneuron** → **Synapse 1** → **Spinal cord Integrating center** → **Interneuron** → **Synapse 2** → **Spinal cord Integrating center** → **Efferent neuron** → **Target cell effector** → **Response**
Proper control of muscle function requires not only excitation of the muscle by spinal cord anterior motor neurons but also continuous feedback of sensory information from each muscle to the spinal cord.

The sensory information may be in the following questions:
- what is the length of the muscle?
  - What is it’s tension?
- How rapidly is the length or tension changing?

This information is provided by the Muscle Sensory receptors.
Muscle Sensory Receptors

- MUSCLE SPINDLE
  (muscle length & rate of change of length)
- GOLGI TENDON ORGAN
  (tendon tension & rate of change of tension)
Muscle spindles are stretch receptors present in the skeletal muscles. Muscle Spindle informs the brain about 3 things:

1. Muscle length
2. Changes in Muscle Length
3. Rate of change of Muscle Length
• Two Types of Muscle Fiber
  – Extrajusal fibers: Innervated by alpha motor neurons
  – Innervated by gamma motor neurons
**EXTRAFUSAL** fibers are the contractile skeletal muscle fibers (containing actin & myosin). They are supplied by **Alpha motor neurons (Remember the NMJ!).**

**Muscle spindle** is the Sensory receptor found inside the Extrafusal fibers. It consists of a connective tissue capsule that encloses a group of small muscle fibers called the **INTRAFUSAL** fibers. The ends of the Intrafusal fibers are contractile in nature while their center is non-contractile and forms the receptor itself. They are supplied by **Gamma motor neurons.**

- Each spindle is 3-10 mm long.
- 3-12 intrafusal fibers.
- Midway the intrafusal fibers have few or no actin and myosin filaments.
- Thus, the center does not contract when the ends do.
(b) **Muscle spindle** sends information about muscle stretch to the CNS.

- Gamma motor neurons from CNS innervate intrafusal fibers.
- To CNS
- Tonically active sensory neurons send information to CNS.
- Gamma motor neurons from CNS
- Intrafusal fibers are found in muscle spindles.
- Extrafusal fiber
**Sensory Innervation of the Muscle Spindle**

Muscle Spindle receptor can be excited in 2 ways:

1. Lengthening the whole muscle (Extrafusal fibers) stretches the midportion of the spindle, and, therefore, excites the receptor.

2. Even if the length of the entire muscle does not change, contraction of the spindle’s intrafusal fibers stretches the midportion of the spindle and therefore excites the receptor.
Types of Intrafusal Fibers

There are 2 types of Intrafusal Fibers:

1. **Nuclear Bag Fibers** with their nuclei located in a central dilated area of the bag
   - 7-8 mm long.
   - 25 µm in diameter.

2. **Nuclear Chain fibers** are thinner & shorter ribbon-like fibers.
   - Usually 4 or more of these fibers.
   - 3-4 mm long.
   - 10-12 µm in diameter.

**2 types of Sensory Nerve Endings supply these Intrafusal Fibers:**

1. Primary Nerve Endings
2. Secondary Nerve Endings
PRIMARY NERVE ENDINGS

- Annulo-spiral
  (17 µm, 70-120 m/sec)

  DYNAMIC RESPONSE
  Rapidly adapting

  Group 1-A Afferent nerve fibers
  Stimulated by sustained & brief stretch

  TONIC & PHASIC Stretch Reflex

SECONDARY NERVE ENDINGS

- Flower spray
  (8 µm)

  STATIC RESPONSE
  Slowly adapting

  Group II Afferent nerve fibers
  Stimulated by sustained stretch

  TONIC Stretch Reflex
Figure 54-3 Muscle spindle, showing its relation to the large extrafusal skeletal muscle fibers. Note also both motor and sensory innervation of the muscle spindle.
Stretching the Muscle Spindle increases the rate of firing (positive signals), whereas shortening the spindle decreases the rate of firing (negative signals).
The stimulation of the Muscle Spindle can lead to a STATIC RESPONSE

Central portion of the muscle spindle is stretched “slowly”

↓

Both Primary and secondary nerve endings are stimulated

↓

Group II fibers send information to the CNS

↓

Endings continue to transmit impulses for several minutes.
DYNAMIC RESPONSE

When the length of the muscle is changed *rapidly*,

↓

*Then only Primary nerve endings are stimulated*

↓

*This stimulation continues as long as the length of the muscle is actually changing*

↓

*As soon as the length stops increasing, this extra rate of impulse discharge returns to normal, which in the case of the muscle spindle is the STATIC RESPONSE.*
MUSCLE STRETCH REFLEX
(Function of the Muscle Spindle)

Whenever a skeletal muscle is stretched suddenly, reflex contraction of the same muscle takes place. This is called Stretch Reflex.

Neuronal Circuit of the stretch reflex:
Muscle Spindle → Type Ia Afferent fiber → Enters the dorsal root of the Spinal Cord → A branch synapses directly onto the Anterior Motor Neurons → Effector organ (Skeletal muscle from which the afferent fiber originated)

NOTE: Most Type II fibers from the muscle spindle terminate on multiple interneurons in the cord gray matter, and these transmit delayed signals to the anterior motor neurons or serve other functions.
Figure 54-5  Neuronal circuit of the stretch reflex.
When the afferent nerve fibers of the Sensory nervous system inform the spinal cord integrating center about the dynamic & stretch response, what happens?
Depending upon Dynamic or Static response, A corresponding stretch reflex will be initiated.

**DYNAMIC STRETCH REFLEX**

- When a muscle is suddenly stretched or relaxed, there is a strong reflex contraction (or decrease in contraction) of the same muscle.
- This reflex is elicited by the continuous firing of the dynamic receptors and APs are transmitted by the primary nerve endings (Type Ia).
- It lasts for as long as the muscle stretches, & stops as soon as the muscle stops stretching.
- Thus, *the reflex functions to oppose sudden changes in muscle length.*

**STATIC STRETCH REFLEX**

- Once a muscle stops stretching, then a weaker static stretch reflex continues.
- This reflex is elicited by the continuous firing of the static receptors and APs are transmitted by both primary and secondary endings.
- This reflex informs the brain about the length of the muscle at all times, when there is no stretch of the muscle.
- This reflex causes the degree of muscle contraction to remain reasonably constant.
The Dynamic & Static stretch reflexes are accomplished by the gamma-dynamic (gamma-d) and gamma-static (gamma-s) motor nerves. They supply the same muscle fibers from where the sensory input (via the primary and secondary nerve endings) originated.
Muscle stretch activates muscle spindles, but what happens to muscle spindle activity when a resting muscle contracts and shortens?

ALPHA-GAMMA MOTOR CO-ACTIVATION takes place.
Without gamma motor neurons, muscle contraction causes the spindle firing rate to decrease.

1. Alpha motor neuron fires.
2. Muscle contracts.
3. Less stretch on center of intrafusal fibers
4. Firing rate of spindle sensory neuron decreases.

Muscle length

Less stretch on intrafusal fibers
Action potential

Action potentials of spindle sensory neuron

Muscle shortens

Time
Gamma motor neurons innervate muscle fibers at the ends of muscle spindles. Alpha-gamma coactivation keeps the spindles stretched when the muscle contracts.

(a) **Alpha-gamma coactivation** maintains spindle function when muscle contracts.

1. Alpha motor neuron fires and gamma motor neuron fires.
2. Muscle and intrafusal fibers both contract.
3. Stretch on centers of intrafusal fibers unchanged. Firing rate of afferent neuron remains constant.

Muscle length:
- Muscle shortens

Action potentials of spindle sensory neuron:
- Intrafusal fibers do not slacken so firing rate remains constant.

Time:
- Muscle shortens
(a) How muscle stretch is detected

Unstretched muscle. Action potentials (APs) are generated at a constant rate in the associated sensory fiber.

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

(b) The purpose of α-γ coactivation

If only α motor neurons were 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.

But normally α-γ coactivation occurs. Both extrafusal and intrafusal muscle fibers contract. Tension is maintained in the muscle spindle and it can still signal changes in length.
DAMPING MECHANISM OF THE STRETCH REFLEXES.

Signals from the spinal cord are transmitted in an unsmooth form, increasing in intensity for a few milliseconds and then decreasing in intensity, than changing to another intensity level and so on.

When the muscle spindle is not functioning normally, then the muscle contraction is also jerky.

The muscle spindle ensures that the skeletal muscle movement is smooth. This is also called the signal averaging function of the muscle spindle reflex.
WHAT ARE THE FUNCTIONS OF THE MUSCLE STRETCH REFLEX?
(What are the functions of the Muscle Spindle?)
Functions of the Stretch Reflexes

1. Prevents overstretching of the muscles and, thus prevents damage to the muscle.
   • Also maintains continuous tone of the muscle when it is inactive.

2. Damping mechanism in smoothing muscle contraction (thru the gamma efferent mechanisms).
   • Prevents oscillations & jerkiness of body movements.

3. Stabilizes body position during tense motor action (thru simultaneous activation of opposing muscles on the same joint).
KNEE JERK REFLEX
KNEE JERK

Knee Jerk Reflex is a combination of Monosynaptic stretch reflex and Reciprocal Inhibition.

In the leg, this requires relaxation of the hamstring muscles running up the back of the thigh.
It tests segment L2-4.

Tap the patella
↓
Instantaneous stretching of the Quadriceps muscle
↓
Dynamic Stretch Reflex
↓
Lower leg jerks forward
JENDRASSIK Maneuver
What is the significance of the Knee Jerk?

- It keeps your knee from collapsing under the effect of gravity as you walk or run.
- The test itself assesses the nervous tissue between and including the L2 and L4 segments of the spinal cord.
- Neurologists assess the health of the CNS.

- **If it is exaggerated:** A large number of facilitatory impulses are transmitted from higher centers in the CNS to the spinal cord (Upper Motor Neuron Lesion, anxiety, Hyperthyroidism).
- **Pendular Reflex:** multiple oscillations of the leg (Cerebellar disease).
- **If it is Absent:** usually seen in Lower Motor Neuron Lesion
GOLGI TENDON ORGAN

Golgi Tendon Organs are the second type of muscle proprioceptors, found at the junction of tendon and muscle fiber, placing it in series with the muscle fibers. They respond primarily to muscle tension and are relatively insensitive to muscle stretch.

Golgi tendon reflexes cause relaxation, the opposite of the reflex contraction caused by muscle spindle reflexes.
STRUCTURE OF GOLGI TENDON ORGAN

Golgi tendon organs consist of endings of afferent fibers entwined within bundles of connective tissue (collagen) fibers that make up the tendon. It is encapsulated.

About 10-15 muscle fibers are attached to each Golgi tendon organ.

The Golgi tendon organ also shows a *Dynamic* and a *Static* response.

Thus, it informs the brain regarding the degree of tension in each muscle fiber. It reacts intensely when the muscle tension suddenly increases *(dynamic response)* but settles down within a fraction of a second to a lower level of steady state firing that is almost directly proportional to the muscle tension *(static response)*.
Extra fuscal muscle fibers contract.
\[\downarrow\]
Resulting pull on the tendon tightens the connective tissue bundles.
\[\downarrow\]
Increase in the tension in the tendon attached to the bone.
\[\downarrow\]
Golgi Tendon Organ (sensory receptor) is stretched.
\[\downarrow\]
Sensory Afferent fibers fire (Type I b) 
(Frequency of firing is directly related to the tension developed.)
\[\downarrow\]
Type 1b fibers synapse on inhibitory interneuron in the spinal cord.
\[\downarrow\]
The interneuron inhibits alpha motor neurons innervating the skeletal muscle.
\[\downarrow\]
Muscle contraction decreases or is inhibited completely.
(d) Muscle contraction stretches Golgi tendon organ.

(e) If excessive load is placed on muscle, Golgi tendon reflex causes relaxation, thus protecting muscle.
Afferent information from the Golgi tendon organ reaches the level of conscious awareness, unlike the information from the muscle spindle which does NOT!

YOU ARE AWARE OF THE TENSION WITHIN A MUSCLE BUT NOT OF ITS LENGTH.
When tension on the muscle (& thus on the tendon) becomes extreme, the inhibitory effect of the Golgi Tendon can be so great that it causes instantaneous relaxation of the entire muscle.

This is called the Lengthening reaction.
(a protective mechanism to prevent tearing of the muscle or avulsion of the tendon from its attachment to the bone)
Figure 54-2 Peripheral sensory fibers and anterior motor neurons innervating skeletal muscle.
The **SPINOCEBELLAR (Dorsal and Ventral) TRACTS** carry instantaneous information from both the muscle spindle and golgi tendon organs to terminate in the Cerebellum at conduction velocities of upto 120 m/sec.
1. Bulboreticular facilitatory region
2. Impulses going into the Bulboreticular area from
   - Cerebellum
   - Basal Ganglia
   - Cerebral cortex

BRAIN AREAS FOR CONTROL OF THE GAMMA MOTOR SYSTEM
(CONCERNS WITH ANTIGRAVITY MUSCLES)
FLEXOR REFLEX
OR WITHDRAWAL REFLEX
(Also called the Pain or Nociceptive reflex)

It is a typical Polysynaptic reflex that occurs in response to a noxious stimulus to the skin or subcutaneous tissues & muscle. The response is flexor muscle contraction & inhibition of extensor muscles so that the body part stimulated is withdrawn. It occurs on the same side of the body.
hot saucepan!!
What is “Local sign” in a Withdrawal Reflex?

- In a flexor or withdrawal reflex, the exact nature of the limb movement and the final position of the limb depends upon the site of stimulation. This phenomenon is often called *local sign*.

- Because of the local sign, the withdrawal of the limb from the damaging stimuli is usually appropriate in both magnitude and direction.
CROSSED EXTENSOR REFLEX

About 0.2 to 0.5 sec after a stimulus elicits a flexor reflex in one limb, the opposite limb begins to extend. This is called the Crossed Extensor Reflex.

It is a postural reflex that helps maintain balance when one foot is lifted from the ground.
When a person steps on a sharp object, the affected limb is withdrawn from the stimulus (withdrawal reflex) while the other limb is extended (crossed extensor reflex). Initiating a withdrawal reflex in both legs at the same time would cause a person to fall.
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.
RECIPROCAL INHIBITION & RECIPROCAL INNERVATION

When a stretch reflex occurs, the antagonist muscles relax. This is Reciprocal Inhibition.

The neuronal circuit that causes this reciprocal relation is called the Reciprocal Innervation.

It can be present on the same side of the body (knee jerk) or on the opposite side of the body (crossed extensor reflex).