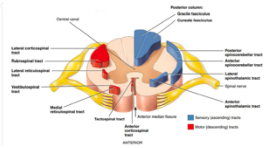
Sereen Draghmeh

Spinal cord

Functions of the spinal cord

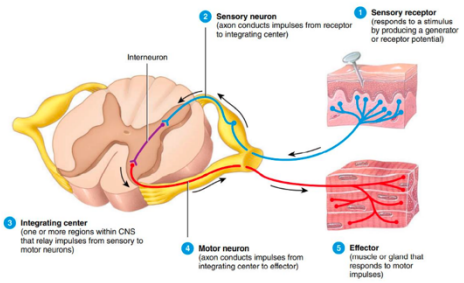
- Nerve impulse propagation:
  - The **white matter tracts** in the **spinal cord** are **highways for nerve impulse propagation**.
    - These tracts cane be sensory (ascending tracts) or motor tracts (descending tracts)
  - **Sensory input travels along these tracts toward** the **brain**, and **motor output travels from** the **brain along these tracts toward skeletal muscles** and **other effector tissues**.
  - **Tracts** in the **spinal cord**

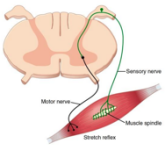


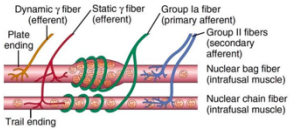
- Integration of information:
  - The **gray matter(contains cell bodies of the neurons)** of the **spinal cord receives** and **integrates incoming** and **outgoing information mainly** for **some reflexes**.
  - A **reflex** is a **fast**, **involuntary**, **unplanned sequence** of **actions** that **occurs** in **response** to a **particular stimulus**.

Reflex arc

- The **pathway followed** by **nerve impulses** that **produce** a **reflex** is a **reflex arc** (reflex circuit).
- A **reflex** arc **includes five functional components**.
- **Components** of the **reflex arc**
  - **Sensory receptor**
  - **Sensory/afferent neuron**
  - **Integrative center (grey matter of the spinal cord)**
  - **Motor/efferent neuron**
  - **Effector (e.g skeletal muscle)**







Sensory receptors in muscles

- the **muscles** and **their tendons** are **supplied abundantly** with **two special types of sensory receptors**:
  - (1) **muscle spindles**, which are **distributed throughout** the **belly** of the **muscle** and **send information** to the **nervous system about muscle length** or **rate** of **change of length**.
    - The **skeletal muscle fibers can be extrafusal muscle or intrafusal** and
      - the **intrafusal muscle fibers** are **very tiny** with **special structure that** in the **center** of **these fiber** there are **no or very little actin and myosin** so **no contraction** in **this** part
      - while the **peripheral part** of these **intrafusal muscle fibers** have **actin** and **myosin so** it **can contract**
    - **These intrafusal fibers can** be **categorized into either nuclear bag or nuclear chain fibers**
    - So the **muscle spindle respond to any stimulus** of **changing muscle length** (**stretching** or **unstretching**) this **information** goes **through** the **sensory neurons either** the **primary afferent/group 1A fibers and the secondary afferent fiber/group 2 fibers**
    - **Change** in **muscle length/stretch** of the **muscle can occur suddenly** and so this **dynamic change** will **activate** this **group 1a fibers which are more responsive** to the **change** in the **rate of the contraction**
    - So the **motor fiber** in the **peripheral part has actin and myosin so** there is **motor inervation** to **them** is **either static gamma fibers** or **dynamic gamma fibers**
    - **Skeletal muscle maintain some sort** of **tone** so there **is alwasy some sort** of **activation** to **these skeletal muscle fiber** and this is the **role of** the **static gamma fibers** while the **dynamic gamma fibers mostly respond** to a **sudden changes in muscle length**
  - (2) **Golgi tendon organs**, which are **located** in the **muscle tendons** and **transmit information** about **tendon tension** or **rate of change of tension**.

Motor innervation of muscle fibers

- **Aα motor nerve fibers innervate** the **large skeletal muscle fibers** (motor unit).
- **type A gamma (Aγ)** motor nerve fibers, go to **small**, **special skeletal muscle** fibers called **intrafusal fibers.**
- They **constitute** the **middle of the muscle spindle**, which **helps control basic muscle "tone**".
- **Interneurons** are **present in all areas of the cord gray matter.**

Muscle spindle

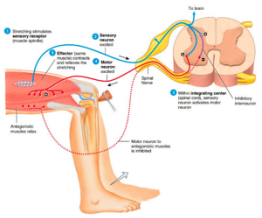
- **Normally**, when there is **some degree of gamma nerve excitation**, the **muscle spindles emit sensory nerve impulses continuously.**
- **Stretching** the **muscle spindles increases** the **rate of firing**, **whereas shortening the spindle decreases the rate of firing.**
- Thus, the **spindles can send to the spinal cord either positive signals** (increased numbers of impulses to indicate stretch of a muscle) or **negative signals** (reduced numbers of impulses) to **indicate that the muscle is unstretched**.

Stretch reflex arc

- **Simplest manifestation** of the **muscle spindle function** is the **muscle stretch reflex** or **deep tendon reflex**
- Simply **to elicit** this **reflex**, when the **patient comes** to **your clinic you** will **ask** the **patient** to **sit** and **relax** the **leg then hit** the **patellar tendon** with the **hammer this will cause stretching** in this **skeletal muscle** the **extensor** of the **knee** which **will activate** the **muscle spindle** and so the **signal will go** to the **sensory neuron** (**1a mainly**) **going** to the **anterior horn** of the **grey matter** of the **cord** and then **synapse with** the **anterior motor neuron** (**alpha motor neuron**) **activating** and **causing contraction** of the **extrafusal muscle** of the **muscle** that is **stretched**
- This is an **important reflex** to **prevent overstretching** to **oppose** this **stretching** by **contraction** by **preventing overstretching protecting** the **muscle fibers**
- This **reflex** will **happen quickly** that's why it **called** the **dynamic stretch reflex**
- **Another type** of **reflex** will be **carried by type 2 fibers** to the **CNS causing prolonged activation** and **contraction** of the **muscle**
- **Important** to **maintain smooth contraction** and **smoothentign** of this **contraction unless the CNS decided otherwise**
- Its **chractertized** by it **beign monosynaptic**, **ipsilateral**
- The **skeletal** muscle **around** the **limbs act like antagonistic muscle** so if you want to do some sort of movement and **contract** the **extensor** you have to **relax** the **flexors**, this is called **reciprocal innervation**
- So the **sensory signal** that **came** to the **spinal cord** will **branch** and **interact with** an **inhibitory interneuron** that will **supply** the **motor neuron supplying** the **antagonist muscle**
- Thus **reciprocal innervation** is **very important** to **prevent conflict between opposing muscle** and **vital in coordinating body movements**

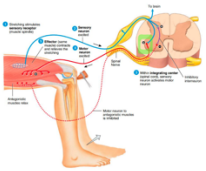
Stretch

Spindle

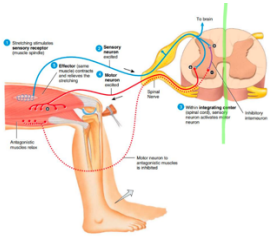


Stretch reflex arc

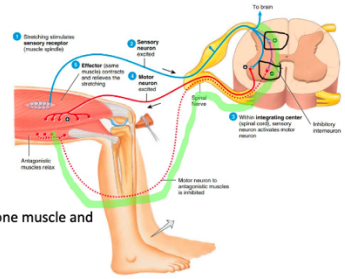
Monosynaptic



Ipsilateral

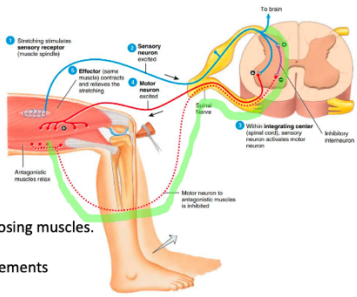


Reciprocal innervation



Simultaneous contraction of one muscle and relaxation of its antagonist.

Reciprocal innervation



Prevents conflict between opposing muscles.

Vital in coordinating body movements

Muscle stretch reflex

- The **stretch reflex** can be **divided into two components**:
  - The **dynamic stretch** reflex is **elicited** by **potent dynamic signals transmitted** from the **primary sensory endings** of the **muscle spindles**, caused by **rapid stretch** or **unstretch**.
    - That is, **when a muscle is suddenly stretched** or **unstretched**, a strong **signal is transmitted to the spinal cord**, which **causes** an **instantaneous strong reflex contraction** (or **decrease in contraction**) of the **same muscle** from **which the signal originated**.
    - Thus, the **reflex functions** to **oppose sudden changes in muscle length**.
  - The **dynamic stretch** reflex is **over within a fraction** of a **second after** the **muscle has** been **stretched** (**or unstretched**) to its **new length**, but then a **weaker static stretch reflex continues for a prolonged period thereafter**.
    - This **reflex** is **elicited by the continuous static receptor signals transmitted** by **both primary and secondary endings**.
    - The **importance** of the **static stretch reflex** is that it **causes the degree of muscle contraction** to **remain reasonably constant**, **except when** the **person's nervous system specifically wills otherwise**.

Role of muscle spindle in voluntary movements

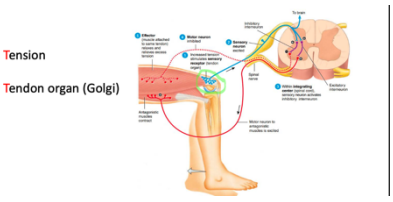
- **Whenever signals** are **transmitted from the motor cortex** or **from any other** area of the **brain** to the **alpha motor neurons**, in **most instances the gamma motor neurons** are **stimulated simultaneously**, an **effect called coactivation** of the **alpha** and **gamma motor neurons**.
- This **effect causes both the extrafusal skeletal muscle fibers** and the **muscle spindle intrafusal muscle fibers to contract at the same time**.
- **coactivation keeps** the **muscle spindle reflex from opposing** the **muscle contraction**.
- The **gamma efferent** system is **excited specifically by signals** from the **bulboreticular facilitatory region of the brain stem** and, **secondarily**, by **impulses transmitted into** the **bulboreticular area from the following**:
    - (1) the **cerebellum**;
    - (2) the **basal ganglia**;
    - (3) the **cerebral cortex**.

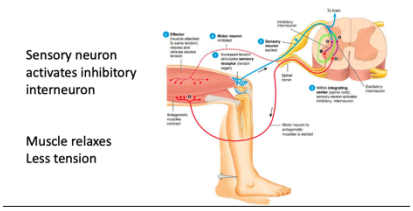
Clinical significance of stretch reflex

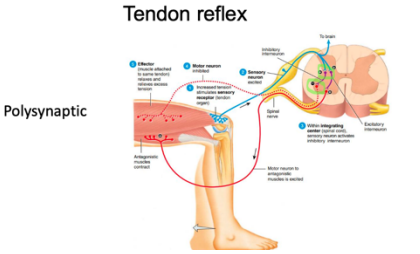
- The **muscle jerks** are **used** by **neurologists** to **assess** the **degree of facilitation** of **spinal cord centers.**
- When **large numbers of facilitatory impulses** are **being transmitted from the upper regions of** the **central nervous system** into the **cord**, the **muscle jerks are greatly exaggerated**.
- **Conversely**, if the **facilitatory impulses are depressed** or **abrogated**, the **muscle jerks are considerably weakened or absent.**
- These **reflexes** are **used most frequently in determining the presence or absence of muscle spasticity caused by lesions in the motor areas of the brain or diseases that excite the bulboreticular facilitatory** area of the **brain stem**
- Because the **stimulus** for the **stretch reflex is stretching** of **muscle**, this **reflex helps avert injury by preventing overstretching of muscles**.
- **The stretch reflex can also help maintain posture.**
    - For example, if a **standing person begins** to **lean forward**, the **gastrocnemius** and **other calf muscles are stretched**.
- **Consequently**, **stretch reflexes are initiated in these muscles**, which **cause them** to **contract** and **reestablish the body's upright posture**

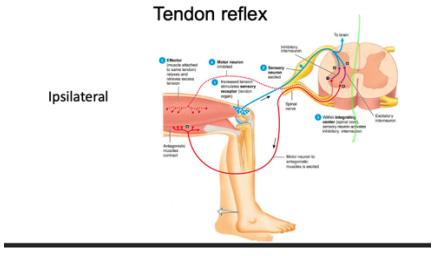
Tendon reflex

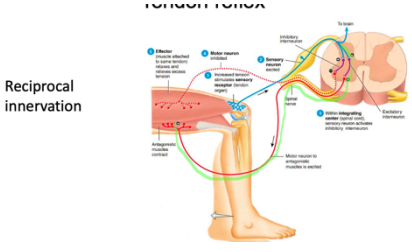
- The **sensory receptor** in the **reflex** is **called** the **golgi tendon organ located** in the **tendon** of the **skeletal muscles**
- It **detects** the **changes in the tension of the muscle**
- **Activation** of the **golgi tendon organ** by **increasing** the **tension** will **activate** the **sensory neuron** that will **go** to **the grey matter of** the **spinal cord synapsing with** the **interneuron** in the **spinal cord** that is **inhibitory which will** in **turn synapse** on the **anterior motor neuron resulting** in **relaxation** of this **muscle** and so it will decrease the **tension** of the **muscle** and **prevent injury** of the **muscle** by the **increased tension**
- **Similar** to the **spindle reflex** its also **can either be dynamic reflex** (**responding** to **sudden changes in** the **tension**) **or static** (**going on** for **prolonged time** giving the **importance** of **always informing** the **CNS about** the **situation** of the **tension**)
- You can also note that **this reflex** is **polysynaptic** because the **first synapse** is **between** the **sensory neuron** and the **interneuron while** the **second one synapses with** the **anterior motor neuron**
- Its an **ipsilateral reflex**
- **Just like** what we **explained in** the **muscle spindle reflex** here there is also **reciprocal innervation** (**branch going** to the **antagonistic muscle**, **but here** the **antagonistic muscle** will be **activated** and **contracted since** this **muscle is relaxed**)
- **Just like** the **spindle reflex** the **tendon reflex sensory fibers** will **give** branched **to** the **higher centers in the CNS** to the **cerebral cortex** the **motor area there** to the **cerebellum** and the **reticular formation**











Flexor (Withdrawl) reflex

- **Spinal reflexes aren't only stimulated by proprioceptive signals** they **may be stimulate** by **other cutaneous reflexes**
- For example **here** in the **flexor** reflex you **can** your **arm** and **leg** and **withdraw them from simple** or **light touch but most importantly** from **pain**
- Pain **stimuli activating** the **nociceptor** will **cause flexion** or **withdrawal from this** signal
- Note that this **flexor reflex** is **polysynaptic** so **interneurons** are **involved** in **this reflex**
- Its also **more complex than** the **previous two reflexes** because it **involves different types** of **neural circuits** like the **divergence circuit,** the **reciprocal circuit and** the **after discharge circuit**
- The **after discharge circuit** plays an **important role** to **keep** this kind of **withdrawal** from the **signal** to **prolong time until** the **CNS figures out what** to do **with this painful signal**
- Its **polysynaptic**
- Its **intersegmental** it has to **activate different skeletal muscles** on **different segments** of the **spinal cord**
- Its an **ipsilateral reflex**
- It **initiates** a **crossed extensor reflex affecting** the **opposite limb**
  - A **signal** on **one** side will also **activate** a **contralateral** or **across extensor reflex**, this is **important** to **maintain balance** in the **case** of the **lower limb** and **get away** from a **painful stimuli in the case of the upper limb**
- **Notice** that its a **complex intersegmental reflex** and **has many interneurons**