SPINAL REFLEXES

Why is there a nervous system? The nervous system rapidly generates appropriate reactions to sensory stimuli.
**Reflex definition** - stereotyped motor response to a specific sensory stimulus

REFLEXES CAN FORM PART OF AUTOMATIC REACTIONS AND COMPLEX BEHAVIORS

SENSORY STIMULUS → MOTOR RESPONSE
Typical reflex arc: 1) sensory neuron - detects stimulus
2) interneurons - (most often) can be excitatory or inhibitory
3) motor neurons - produce muscle contraction, motor response

Reflexes often have effects on groups of motor neurons to different muscles, sometimes different joints or opposite limb
Example: FLEXOR REFLEX –
SENSORY STIMULUS - Stepping on nail causes pain
MOTOR RESPONSE - Lift leg

1) SENSORY NEURON – cutaneous afferent in sole of foot (A delta)
2) INTERNEURON(S)
3) MOTOR NEURON – to Flexor muscle

TYPICAL REFLEX

Knee Joint
FLEXOR MUSCLE – Hamstring flexes knee
NEURAL EXCITATION/INHIBITION IS CONDUCTED ALONG REFLEX PATHWAY BY DEFINED CELLULAR MECHANISMS

Typical reflex arc: 1) **sensory neuron** - detects stimulus
2) **interneurons** - (most often) can be excitatory or inhibitory
3) **motor neurons** - produce muscle contraction, motor response
REFLEX TESTING IS A POWERFUL CLINICAL TOOL

1. **STIMULUS**

2. **RESPONSE**

For reflex to occur all elements must be functional; pathways must be intact.

In clinical test apply **Stimulus 1** and see if get **Response 2**.
If absent, diagnose where pathway is interrupted.
If abnormal, diagnose where pathway is compromised.
EVALUATING REFLEXES

Reflex is evaluated according to:
1) amount (size, magnitude) of motor response,
2) latency (time to elicit motor response);
In some disease processes, damage can enhance reflex responses

<table>
<thead>
<tr>
<th>Grade</th>
<th>Deep Tendon Reflex Response</th>
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</thead>
<tbody>
<tr>
<td>0</td>
<td>No response</td>
</tr>
<tr>
<td>1+</td>
<td>Sluggish or diminished</td>
</tr>
<tr>
<td>2+</td>
<td>Active or expected response</td>
</tr>
<tr>
<td>3+</td>
<td>More brisk than expected, slightly hyperactive</td>
</tr>
<tr>
<td>4+</td>
<td>Brisk, hyperactive, with intermittent or transient clonus</td>
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SOME REFLEXES ARE CONSTANT

PUPILLARY LIGHT REFLEX - SHINE LIGHT IN EYE causes PUPILLARY CONSTRICTION; protective reflex that limits light entering eye.

1) STIMULUS (AFFERENT ARM) - OPTIC NERVE (CRANIAL NERVE II) detects light

2) RESPONSE (EFFERENT ARM) - OCULOMOTOR NERVE (CRANIAL NERVE III) innervates pupillary constrictor muscle

PROTECTIVE REFLEXES - limit amplitude of sensory stimulus, amount of light entering eye; connection is functional and present at all times.
SOME REFLEXES ARE CONSTANT UNDER SAME CIRCUMSTANCES

DEEP TENDON REFLEXES - stretch reflex activates muscle spindles

Patient positioned correctly, told to relax; focus patient's attention elsewhere (ex. tell patient to clench hands and try pulling apart). Reason: reflexes can be modulated by neural activities in CNS.
SPINAL REFLEXES FORM PART OF AUTOMATIC REACTIONS AND ADJUSTMENTS

1) **Maintaining balance when standing and walking**

2) **Regulating muscle tensions - not damage muscles or insertions**

3) **Stepping on a nail - avoid painful stimuli**

Muscle spindles

Golgi tendon organs

Cutaneous, nociceptive (pain) receptors

Note: Automatic reactions differ from reflexes in duration, complexity and can be influenced by different types of sensory inputs.
SOME 'REFLEXES' TRIGGER ACTIVITIES PRODUCED BY PATTERN GENERATORS

PALMAR GRASP

MORO REFLEX - arm extend

STEPPING 'REFLEX' - actually eliciting a motor pattern

PLANTAR GRASP

PLACING REFLEX

TONIC NECK REFLEX - extend ipsilateral arm flex opposite arm

PATTERN GENERATOR - groups of interneurons that are interconnected. Pattern generators produce activities in motor neurons and can generate rhythmic behaviors.
CLASSIC SPINAL REFLEXES

Three basic reflexes:

1) **Stretch reflex** - produced by activating muscle spindles - contributes to maintaining postural stability, countering sudden loads

2) **Autogenic inhibition** - produced by activating Golgi tendon organs - aids in regulating muscle tension, prevents damage to tendon, bone

3) **Flexion reflex** - produced by activating cutaneous, pain afferents - avoid obstacle or painful stimulus (stepping on nail)
TERMINOLOGY

IN A REFLEX:

HOMONYMOUS MUSCLE = muscle that contains sense organ

SYNERGIST MUSCLE = muscle that produces similar action

ANTAGONIST MUSCLE = muscle that produces opposite action

in diagram – ELBOW JOINT
BICEPS = homonymous (where spindle is located), flexes elbow
BRACHIALIS = synergist, also flexes elbow
TRICEPS = antagonist, extends elbow
REMEMBER: SENSORY NEURONS BRANCH AND CAN PROJECT TO MANY REGIONS IN CNS

SENSE ORGAN = Biceps Muscle Spindle Ia afferent

Ia afferent have a number of branches in CNS; some branches ascend dorsal columns
1) Stimulus - fast stretch of muscle

2) Sense organ excited - Muscle spindle la and II sensory neurons

3) Primary response - muscle that is stretched contracts rapidly
**Group Ia** - monosynaptic connections with alpha motor neurons (fastest reflex known, delay at synapse about 1 msec)

**Group II** - make 1) monosynaptic connections - direct to motor neuron and 2) polysynaptic connections to motor neurons (through interneuron)

*note: plus indicates excitatory connection*
OTHER COMPONENTS OF STRETCH REFLEX

1) Excite synergist muscles - spindle afferents also make excitatory monosynaptic connections with synergist muscles

2) Inhibit antagonist muscles - RECIPROCAL INHIBITION - Spindle activity also excites interneurons that make inhibitory synapses on motor neurons to antagonist muscles (polysynaptic)
MUSCLE TONUS

1- Because connection is monosynaptic, ongoing activity in muscle spindles is important in determining firing of alpha motoneurons at rest.
2- Increased activity of spindles can increase motor neuron firing producing increased tonus.

RESPONSE TO TENDON TAP

1- Tendon tap elicits twitch because it excites almost all muscle spindles simultaneously
2- Excitation converges upon motor neuron
STRETCH REFLEXES CAN BE MODULATED AND MODIFIED: CHANGE IN DAMAGE AND DISEASE

1- Reflexes can be modulated by pre-synaptic inhibition of Ia terminals; this can reduce the amount of transmitter release at the synapse upon motor neuron and dampen monosynaptic reflex.

2- Activities of motor neurons can be decreased by inhibitory inputs.

Changes in reflexes are symptomatic: In general, Decrease stretch reflexes can indicate Lower Motor Neuron Disorders, Increase Stretch reflexes can indicate Upper Motor Neuron Syndromes.
Activities of motor neurons can be modulated by Renshaw cells.

Axons of Alpha motor neurons have branches that synapse in the central nervous system; these branches are called Recurrent Branches.

Renshaw cells are interneurons that receive excitatory inputs from Recurrent branches of motor neurons and make inhibitory synapses upon the same motor neurons. These circuits can limit motor neuron firing; inhibition can dampen or reduce reflexes.
FUNCTION OF STRETCH REFLEX: MAINTAINING BALANCE WHEN STANDING

1) tilting forward stretches muscles on back of leg

2) muscles rapidly contract

Gastrocnemius excited first (consistent with monosynaptic reflex)

However, responses
1) are longer in duration than stretch reflex
2) activate extensor muscles of back
3) change when wearing a backpack; influenced by other sensory inputs.

TEST: STAND ON MOVING PLATFORM

STRETCH MUSCLE SPINDLES
MUSCLE SPINDLE FORMS NEGATIVE FEEDBACK LOOP

Why called NEGATIVE feedback? Perturbation produces INCREASE in length (stretch) which excites spindle, which excites motor neuron, which excites muscle which DECREASES length.
When stretch reflexes are active, unexpected perturbations that lead to stretch of any skeletal muscle will cause muscle to contract. Example from text: pouring fluid into glass increases weight, stretches biceps muscle.
AUTOGENIC INHIBITION

1) Stimulus - Large force exerted on muscle tendon

2) Sense organ excited - Golgi tendon organs

3) Primary response - muscle attached to tendon relaxes
AUTOGENIC INHIBITION

PRIMARY RESPONSE
Synapses - polysynaptic

1) Ib sensory neuron (GTO) makes excitatory synapse onto interneuron

2) Interneuron makes inhibitory synapse onto motor neuron; Motor neuron decreases firing

+ note: plus indicates excitatory connection

- note: minus indicates inhibitory connection
AUTOGENIC INHIBITION

Other effects

a. Inhibits synergist muscles -
GTO makes excitatory synapse on interneuron; interneuron makes inhibitory synapse on motor neurons to synergist muscle

b. Excites antagonist muscles -
GTO makes excitatory synapse on interneuron; interneuron makes excitatory synapse on motor neurons to antagonist muscles

CLASPED KNIFE REFLEX: in Upper motor neuron lesions, tonus increases, resistance to stretch increases; if sufficient force is applied, limb resistance suddenly decreases (like pocket knife snapping shut)
1- Regulating muscle tension - forces developed by contractions of muscles are automatically controlled so that they do not cause damage to tendons (ex. lifting heavy object).

2- Regulation of force during other behavior is more complex (ex. walking) – Connections for autogenic inhibition may be inactivated during walking. Effects of Golgi tendon organs can then become excitatory via other interneurons.
FLEXOR REFLEX

1) Stimulus - painful or noxious stimulus (stepping on nail)

2) Sense organ excited - Cutaneous receptors, Pain receptors (nociceptors)

3) Primary response - Protective withdrawal of limb
FLEXOR REFLEX: PATHWAYS

Synapses - Polysynaptic

1) Cutaneous afferent makes excitatory synapse onto Interneuron; Interneuron can synapse upon another interneuron

2) Interneuron makes excitatory synapse onto Flexor motor neuron
FLEXOR REFLEX: OTHER EFFECTS
ALL ARE POLYSYNAPTIC BY INTERNEURONS

1) Excite synergist muscles - excite other flexors in same leg (other joints)

2) Inhibit antagonist muscles - inhibit Extensors in same leg

3) CROSSED EXTENSION REFLEX - EXCITE EXTENSORS AND INHIBIT FLEXORS IN OPPOSITE LEG

FUNCTION: OTHER LEG PROVIDES SUPPORT WHEN FIRST LEG IS LIFTED
REFLEXES ARE MODULATED: SOME FLEXOR REFLEXES CAN CHANGE AFTER LESIONS, DISEASE PROCESSES

Babinski sign - seen after Upper Motor neuron lesion - direction of movement changes from flexing toes to extending and fanning (abductin) toes
SOME 'REFLEXES' ARE ACTUALLY INHERENT MOTOR PATTERNS THAT ARE ELICITED BY SENSORY STIMULI - MUCH MORE COMPLEX

PALMAR GRASP

PLANTAR GRASP

MORO REFLEX - arm extend

PLACING REFLEX

STEPPING 'REFLEX' - actually eliciting motor pattern

TONIC NECK REFLEX - extend ipsilateral arm, flex opposite arm
SPINAL CORD CONTAINS NETWORKS OF INTERNEURONS THAT GENERATE PATTERNED MOTOR ACTIVITIES

- networks are called PATTERN GENERATORS (composed of interneurons that are synaptically connected 1) to each other and 2) to motor neurons)
- right and left sides have inhibitory connections so when one leg is lifted, other side stays on ground (MUTUAL INHIBITION)
EVIDENCE FOR PATTERN GENERATOR FOR WALKING IN VERTEBRATES

AFTER SEVERING SPINAL CORD, MUSCLES OF HINDLEGS SHOW WALKING WHEN ANIMAL PLACED ON TREADMILL WITH BODY WEIGHT SUPPORTED

ISOLATED SPINAL CORDS OF NEONATAL RAT CAN SHOW SIMILAR BURSTING AFTER TREATMENT WITH EXCITATORY NEUROTRANSMITTERS
BABY HELD WITH WEIGHT SUPPORTED ABOVE TREADMILL

Note: Goo-Goo Person

MUSCLE ACTIVITIES IN WALKING ARE SIMILAR TO ADULT
BABY HELD WITH WEIGHT SUPPORTED ABOVE TREADMILL: Changes in direction similar to adult

Stepping 'reflex' probably represents activation of pattern generating neurons
### SUMMARY OF SPINAL REFLEXES

<table>
<thead>
<tr>
<th>REFLEX</th>
<th>STIMULUS (CLINICAL TEST)</th>
<th>RESPONSE</th>
<th>SENSORY RECEPTOR</th>
<th>SYNAPSES</th>
<th>EFFECT ON MUSCLE</th>
<th>OTHER EFFECTS</th>
<th>FUNCTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stretch (Myotatic) Reflex</td>
<td>Rapid Stretch of muscle (test: tap on muscle tendon)</td>
<td>Stretched muscle contracts rapidly (ex. knee jerk)</td>
<td>Muscle Spindle Primary (Ia) and Secondary (II) sensory neurons</td>
<td>Ia: Monosynaptic II: Monosynaptic (weak) and Polysynaptic</td>
<td>Excite Homonymous (same muscle) Also Excite synergist muscles; Inhibit antagonist muscles (Reciprocal Inhibition)</td>
<td>Aid in maintaining posture, counter sudden loads</td>
<td></td>
</tr>
<tr>
<td>Autogenic Inhibition (Inverse Myotatic Reflex)</td>
<td>Large force on tendon (pull on muscle when resisted)</td>
<td>Muscle tension decreases (Clasped knife reflex)</td>
<td>Golgi Tendon Organ (Ib)</td>
<td>Polysynaptic (via interneuron)</td>
<td>Inhibit Homonymous (same muscle) Also Inhibit synergist muscles; Excite antagonist muscles</td>
<td>Protective, prevent damage to tendon</td>
<td></td>
</tr>
<tr>
<td>Flexor Reflex</td>
<td>Sharp, painful stimulus (as in stepping on nail)</td>
<td>Limb is rapidly withdrawn from stimulus</td>
<td>Cutaneous (skin) and pain receptors</td>
<td>Polysynaptic (via interneuron)</td>
<td>Excite Flexor muscle</td>
<td>Also Inhibit extensor muscle of same limb; Excite extensor muscles and Inhibit flexors of opposite limb (Crossed Extensor Reflex)</td>
<td>Protective, withdraw from painful stimulus; Cross extension aids in maintaining posture when leg is lifted</td>
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Spinal reflexes are important tools; behaviors are more complex and can incorporate, change and adapt reflex connections.