SOMATIC SENSATION

1. The somatosenses refer to the various sensory receptors that trigger the experiences we label as touch, pressure, warmth, cold, tickle, itch, and pain in the skin, joints, & tendons of the body.
2. Skin
    a. Composed of two basic parts:
        1. Epidermis (outer layer)
        2. Dermis (underlying layer)
    b. Contains a wide variety of sensory receptors classified into 3 basic types:
        1. Mechanoreceptors (respond to mechanical energy)
        2. Thermoreceptors (respond to changes in temperature)
        3. Nocioceptors (respond to painful stimuli)
    c. Receptors are either:
        1. Free nerve endings (relatively unmodified neurons)
            a. They are slowly adapting (i.e., they continue to respond as long as the appropriate stimulus is present)
            b. For the most part, they are only lightly myelinated or unmyelinated
            c. Two main categories recognized
                1. A-delta fibers
                2. C fibers
        2. Encapsulated receptors (receptors that contain some specialized structure)
            a. Adapt to stimulation very rapidly
            b. Axons are myelinated
            c. Skin receptors are bipolar neurons
                ** the cell bodies of these bipolar neurons are located in the dorsal root ganglion just outside the spinal cord
3. Somatosensory Pathways
    a. The axons of the receptors join together & enter the spinal cord as dorsal roots.
    b. Several different nerve tracts (talk about 2 largest)
        1. Anterolateral system
            a. Lightly myelinated axons --> conduct impulses at slower rates
            b. Receptors in this system synapse with neurons in the spinal cord & those axons ascend to one of these regions & synapse:
                1. Spinothalamic tract
                2. Spinoreticular tract
                3. Spinotectal tract
        2. Dorsal column system
            a. More heavily myelinated axons
            b. Synapse in the medulla, then with the thalamus, then with the various somatosensory areas in the parietal lobe.

        *** Both the anterolateral and dorsal column systems cross over to the contralateral side of the nervous system --> sensations on the left side of the body are due to activation of neurons in the right cerebral hemisphere (& vice versa)

4. Somatosensory Neocortex
    a. Several different areas receive somatosensory input, but primary areas are in the anterior part of the parietal lobe
    b. Organizing principle apparent in the neocortical areas = those regions of the body most richly supplied with sensory receptors have the largest number of neurons in the related areas of the neocortex (somatosensory homunculus)

MUSCLES & MOVEMENT

1. Must transduce the energy from neural impulses into a mechanical energy that will move our muscles & bones.
2. The control of movement includes many circuits, including:
    a. Reflex mechanisms in the spinal cord
    b. Neural circuits in the neocortex, cerebellum, basal ganglia, & other brain structures

Muscles

1. Types:
    a. Skeletal ("striped")
    b. Smooth
    c. Cardiac (heart)
2. Skeletal muscles
    a. Basic unit in skeletal muscle tissue is the muscle fiber
    b. Outstanding feature of muscle tissue is its ability to contract
    c. 3 basic types:
        1. Fast
            a. Paler than slow muscles because they contain less blood and less myoglobin
            b. Can use energy in a process that does not require oxygen (i.e., anaerobic processes)
        2. Slow
            a. Reddish because of a higher concentration of myoglobin & a richer blood supply
            b. Rely primarily on aerobic processes
            c. To a small extent, slow muscles can also use anaerobic processes for energy, as in marathon running
        3. Mixed -- contain both fast (pale) and slow (red) muscle types
3. Motor units
    a. Muscles are activated by **motor neurons**
    b. An individual motor neuron typically goes to more than one muscle fiber

1. Low innervation ratio (1:3) = precision
2. High innervation ratio (1:200) = force

c. A motor neuron and its associated muscle fibers make up a **motor unit**

d. Muscle fibers repond in one way -- contracting

4. Activation of muscles
   a. Muscle fibers contract in response to the release of neurotransmitters by the motor neuron
      1. Acetylcholine
      2. Neuromuscular Junction
      3. C in voltage across the cell membrane when the muscle is stimulated by acetyl.
      4. Acetylcholine binds with its postsynaptic receptor & opens ion channels that allow Na & K to cross the cell membrane of the muscle cell
         a. The action potential recorded across the cell membrane of the muscle cell is a depolarization of the cell membrane (more Na going in than K going out)
         b. What actually triggers the contractions of the myofibrils within the muscle cell is the release of Ca ions from stores within the sarcoplasmic reticulum of the muscle fiber
         c. Increase in Ca within the muscle cell causes the actin-complex proteins to slide past the myosin
         d. The muscle fibers then contract as the myofibrils become shorter, and the muscles then move the bone to which they are attached.

Motor Centers

1. Spinal cord & reflexes
   a. The cell bodies of motor neurons are located in the ventral horn of the spinal cord
   b. Reflexes
      1. Automatic movements triggered by stimuli in the skin or joints
      2. Stretch reflex
      3. Monosynaptic reflex
      4. Polysynaptic reflex
   c. Muscle spindle organs
      1. Extrafusal muscles
         a. Alpha motor neurons innervate the extrafusal muscle fibers
      2. Intrafusal muscles
         a. Gamma motor neurons innervate the intrafusal muscle fibers
      3. Stretch receptors make excitatory synapses with the motor neurons that activate the large extrafusal muscles & intrafusal muscles are connected in parallel with the large extrafusal muscles

extrafusal muscles relaxed --> length of fibers increase --> intrafusal muscle fibers also stretched --> burst of nerve impulses is produced in afferents leaving the spindle organ --> motor neurons supplying the extrafusal muscles of the same fiber are excited --> motor neuron fires more rapidly --> extrafusal muscle fibers contract --> shortening of extrafusal fibers --> less stretch on the intrafusal fibers --> intrafusal fibers shorten --> afferent input from the stretch receptor afferents decreases --> excitation on motor neurons decreases --> muscle relaxes (lengthens) again

d. Golgi tendon organs
   1. Found in the tendons that attach skeletal muscles to bone
   2. Particularly sensitive to the degree of tension developed in a muscle when it contracts
   3. Axons enter the spinal cord where they form excitatory synapses on inhibitory interneurons (when activated, they decrease the firing rate of the alpha motor neurons --> lessening the contraction of the muscle & the degree of tension transmitted to the tendon

2. Brainstem centers
   a. Midbrain, pons, medulla all modulate spinal reflexes
   b. Cutting spinal cord = flaccid paralysis below
   c. Sometimes hyperreflexia due to disinhibition of postural reflexes
   d. Central motor programs
      1. Most movements are voluntary & some voluntary movements (e.g., walking, swallowing, running, facial grooming in rodents, erection, ejaculation) are thought to involve activation of central programs depending on the degree to which they can be elicited in isolation
      2. Control changes from cortex to subcortical areas
      3. Whole sequences of movements become units
      4. The motor program for walking appears to be located in the spinal cord;

3. Higher brain regions
   a. Motor Cortex
      1. Located just in front of the central sulcus of the brain in the frontal lobe
      2. In the motor cortex, the number of neurons devoted to movements of a particular region of the body is proportional to the precision of mvmts Shown by that region of the body part (motor homunculus)
      3. Motor cortex axons project to various parts of the brain (cerebellum, thalamus, caudate nucleus, & the reticular formation); one major output path is the corticospinal tract (a/k/a the pyramidal tract)
   b. Cerebellum -- coordination of movement components (especially rapid); maintenance of balance, and muscle tone
      1. Output of the cerebellum does not reach motor neurons directly; all outgoing messages from the cerebellum are designed to adjust or modulate signals from other components of the motor system, particularly

the neocortex and brain stem.

2. Some of the neurons in the corticospinal tract synapse on neurons in the brain stem which project to the cerebellum.
   a. Corollary discharge
   b. Related hypothesis that the cerebellum compares intended movement (corollary discharge) with actual performance
   c. Another hypothesis is that the cerebellum is involved in the production of what are termed ballistic movements

c. Basal ganglia
   1. Structures included:
      a. Caudate nucleus
      b. Globus pallidus
      c. Putamen
   2. Connected with the motor cortex, thalamus, & brain stem structures in a series of complex neural loops
   3. Basic function= initiation and regulation of movement (especially slow);

Types of Movement

1. Maintaining posture and balance
2. Locomotion
3. Complex
   a. Fixed action patterns (i.e., unlearned, innate) = grooming, mating, nesting, courtship
   b. Acquired skills = playing piano, tennis, speech, brushing teeth

PAIN

1. Purpose of pain
2. 2 basic aspects of pain:
   a. A discriminative aspect
   b. An emotional aspect
3. Pain Receptors
   a. Free nerve endings
   b. Can be stimulated by pressure, heat, and various chemical substances
   c. A rise in extracellular potassium activates free nerve endings
   d. Prostaglandins
   e. Substance P
4. Pain pathways
   a. Axons of free nerve endings responsible for pain perception --> spinal cord --> branch --> synapse with relay neurons in the dorsal horn --> relay neurons

ascend to the brain via the anterolateral system (recall 3 components) --> ?

b. Possible that neural circuits in the neocortex help to put painful sensations into a meaningful context

c. Pain impulses are also sent to the cingulate neocortex (usually considered part of the limbic system), which may be important for mediating the affective component of pain

5. Surgery to relieve chronic pain (all has to do w/ CLBP)
    a. Cutting the axons of the anterolateral system
    b. Surgery that removes tissue at higher levels of the brain
    c. Lesion the cingulate neocortex (again, mixed results)
    c. Surgery may interrupt the descending modulatory systems normally involved in the inhibition of pain impulses
6. Endogenous opiates
    a. Stress-induced analgesia (SIA)
    b. Hughes & Kosterlitz (Univ. Of Aberdeen) -- discovered 2 endogenous opiates in the brains of experimental animals (called them enkephalins)
    c. Functions -- not yet known; pain suppression during emergencies still considered their primary function; two major lines of research offer considerable support for this hypothesis though:
        1. Stimulation-Produced Analgesia
            a. Best analgesia comes from stimulation of the periaqueductal gray matter & nearby regions of the brainstem
            b. Also have found that stimulation of the ventral posterior lateral nucleus of the thalamus
        2. Stress-Induced Analgesia