PERIPHERAL NERVOUS SYSTEM (PNS)

- Links CNS to the environment (outside world).
- Includes all structures outside the CNS, including: sensory receptors, peripheral nerves & ganglia, and efferent motor endings (junctions).

I. OVERVIEW OF PNS

A) SENSORY RECEPTORS

- Pick up stimuli (changes in environment), and stimulate CSN
  * TRANSDUCTION: stimulus generates a nerve impulse (AP) on a sensory neuron.
  * SENSATION - awareness of stimuli. Sight, hearing, touch are sensations.
    ** Receptor must change permeability due to stimulus (see later section on “Stimulus type”).
  * PERCEPTION – CNS’s interpretation of meaning of stimulus. Pain, thirst, “what you see”, fear are all perceptions.

- Can be classified based on location, type of stimulation they receive, and structure of receptor.

  1) LOCATION

    (i) EXTEROCEPTORS - receives stimuli outside of body; located near body surface.
      * Touch, pain, pressure, temperature, special sense organs (eyes, ears, nose, etc.).

    (ii) INTEROCEPTORS - found w/in body; monitor internal environment.
      * found in viscera, blood vessels, etc.
      * Monitor chemical changes (pH, etc.), temperature, stretching, etc.
      * Most individual sensations are not conscious (blood pH, blood glucose levels, blood CO2 levels, etc.). Thirst, hunger = resulting perceptions.

    (iii) PROPRIOCEPTORS - (“one’s own”) monitor position of body parts to help CNS control movements. Also internal, but found in skeletal muscle, ligaments, tendons, etc. and monitor DEGREE OF STRETCH of these organs.
2) STIMULUS TYPE

(i) MECHANORECEPTORS generate nerve impulses when deformed by touch, pressure (including BP), vibration or stretch. Most common = HAIR CELLS.

(ii) THERMORECEPTORS - monitor changes in temperature.

(iii) PHOTORECEPTORS - generate impulses if stimulated by light energy.

(iv) CHEMORECEPTORS - monitor changes in chemical concentration. * includes taste & smell.

(v) NOCICEPTORS - generate impulses if stimulated by stimuli that can potentially cause tissue damage. Cause the sensation of PAIN.

***NOTE: THE OVERSTIMULATION OF ANY TYPE OF RECEPTOR CAUSES THE PERCEPTION OF PAIN BY THE CNS!!!!

Some examples of receptors based on stimulus type.
A = hair cell, B = chemoreceptor, C = Nociceptor
3) STRUCTURAL COMPLEXITY

(i) SIMPLE - “GENERAL SENSES”, majority of receptors.

* Skin, mucosae, muscles, connective tissue.
* modified dendritic ending of sensory neurons.
* 2 main types:

(a) FREE - 2 kinds:

* MERKEL’S DISKS - special flat epithelial cells attached to deep layers of epidermis that are LIGHT TOUCH RECEPTORS

* ROOT HAIR PLEXUSES - (plexus = “nerve net”) intertwine hair follicles to detect hair bending.

(b) ENCAPSULATED (“within a capsule”) -1 or more nerve fibers enclosed in a connective tissue capsule. Always are MECHANORECEPTORS.

- KNOW Meissner’s Corpuscles, Pacinian Corpuscles, Ruffini’s Corpuscles, Muscle Spindles, Golgi Tendon Apparatus, and Joint Kinesthetic Receptors. Know basics on where they are found, basic structure and what they do.

Ignore functional class.

There is an on-line video that helps you with this. Look in the PNS Lecture Series for the video “Receptors and Senses #2: Receptor Types and The General Senses”
(ii) SPECIAL SENSES - what most people think of when they hear the word “senses”. The senses that have specialized gross organs devoted to them:

* vision (the eye)
* hearing and balance (the ear, which includes the auditory system and vestibular system)
* smell (the nose)
* taste (the tongue)

* We will deal with vision, balance & hearing in their own special sections. Mostly covered in lab.

- No matter what the sense is, if they are simple or special senses, they all work pretty much the same! Aps going to CNS. There are no “vision” APs versus “touch APs” versus “pain APs”. So everything is PERCEPTION (INTERPRETATION) by the CNS.

CNS gives us a “thought” based on:

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From “Outline Video” found online:

a. modality: type of stimulus
   - CNS only knows “where it is coming from”. Interprets.
   ** “that is an afferent pressure signal coming from leg. You feel pressure on leg”

b. location
   - Receptive Field - sensory n. receives from and area
   can have dead spaces inbetween

c. duration
   - incr freq in AP OVER TIME
   "firing frequency"
   *phasic = high burst at first, then adapt
   **smell, hearing, taste = you stop after awhile
   *tonic - continually send impulses
   **proprioceptors in musc, tendons

d. intensity
   *more neurons stimulated = stronger = "spatial summation"
   *also, deeper neurons
   *very strong touch (or heat, or whatever)
   *lastly, some receptors given more priority than others
   - pulling hair in ear more painful than pulling hair on arm, simply because it is in the ear.

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* GENERATOR POTENTIAL = ion channels open, causes an ION FLUX, and summate these local potentials to cause an AP on an axon.

** Stronger signal = higher frequency of AP on the neuron.

* Receptor Potentials = GRADED POTENTIALS that vary with stimulus intensity (the harder MR. FINGER pushes down, the stronger the graded potential on the receptor). Also show a phenomenon (recall peripheral and central ADAPTATION of some sensory receptors):

  * If subjected to an UNCHANGING stimulus, receptors become less responsive over time; receptor potential declines or stops all together.

  **SO, you ignore sound, sight, touch, smell, etc. that is there all the time.

* One type of receptor that doesn’t adapt = PROPRIOCEPTORS. Always know where your body parts are!
B) Anatomy of the PNS: NERVES, AND ASSOCIATED GANGLIA

- NERVE - organ of PNS; parallel bundles of axons enclosed in a wrapping of connective tissue:
  * Divided into types based direction w/ respect to CNS: SENSORY (AFFERENT) & MOTOR (EFFERENT)

* Another classification: “what types of organs do they innervate?”:
  AUTONOMIC or VISCERAL (smooth muscle and gland) vs SOMATIC (muscles only)

** Therefore, can have the following types OF FIBERS:

SOMATIC AFFERENTS  VISCERAL AFFERENTS
SOMATIC EFFERENTS  VISCERAL EFFERENTS

* Also, can classify them based on where they originate:
  CRANIAL vs. SPINAL. See below.

- GANGLIA - collection of nerve bodies.

* If associated with afferent neurons, nerve bodies form the DORSAL ROOT GANGLION.

Afferent nerves enter spinal cord via dorsal root; their bodies are clumped together in a large ganglion (Dorsal Root Ganglion).

- Nerves are also classification based on where they emerge:

  1) CRANIAL NERVES – Some contain afferent fibers only, some are efferent fibers only, and some are mixed.

-12 pairs. Use roman numerals. Know order and basic function. See summary table next page.

1. OLFACTORY - (“smell”). Arise from the nasal mucosae to the olfactory bulb of brain.

2. OPTIC - (“eye”) considered a sensory nerve, but actually = an outgrowth of the brain. Crosses fibers at the optic chiasma.

* Damage to nerve results in blindness; damage posterior to optic chiasma results in partial loss of vision.
3. OCULOMOTOR - (“eye mover”) controls 4 of 5 extrinsic eye muscles.

4. TROCHLEAR - (“pulley”) purely motor function; no sensory neurons.
   * Trauma to trochlear nerve results in double vision & lowered ability to rotate eye

5. TRIGEMINAL - (“3 branches”) largest; sensory input from face & motor chewing control.
   * 3 divisions:
     - OPHTHALMIC: sensory input from forehead & nose region of face.
     - MAXILLARY: sensory input from mouth region.
     - MANDIBULAR: sensory of chin area & anterior tongue.

Trigeminal neuralgia is a chronic pain disorder that affects the trigeminal nerve.

The exact cause is unclear but believed to involve loss of the myelin around the trigeminal nerve.

6. ABDUCENS - ("abductor") controls abductor extrinsic eye muscles (lateral rectus muscle).

7. FACIAL - (“face”) facial expressions.
   * 5 divisions, each carrying motor output to the major regions:
     - TEMPORAL, ZYGOMATIC, BUCCAL, MANDIBULAR, CERVICAL.

BELL’S PALSY - paralysis of facial muscles; usually 1 side of face only. Rapid onset, often overnight. Cause unknown; probably inflammation of facial n. Droopy eyelid (ptosis), sagging mouth, eyes tear continuously.

8. VESTIBULOCOCHLEAR (AUDITORY) - (“from the vestibule & cochlea of the ear”) hearing & balance.
   * NERVE DEAFNESS - lesions of the cochlear nerve. If vestibular division is damaged, dizziness, nausea occurs.


10. VAGUS - extends into abdominal & thoracic cavities; visceral control of heart, respiration, etc.
    * innervates the jugular vein & carotid artery (major blood supply to the head), lung, heart, spleen, liver, stomach, kidney, small intestines & colon!!!!!!!

11. ACCESSORY - (“helper”) Synergist of the Vagus n.

12. HYPOGLOSSAL - (“under the tongue”) tongue mover.
<table>
<thead>
<tr>
<th>Cranial Nerve</th>
<th>Major Functions</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Olfactory</td>
<td>Sensory only: smell</td>
</tr>
<tr>
<td>II Optic</td>
<td>Sensory only: vision</td>
</tr>
<tr>
<td>III Oculomotor</td>
<td>Mainly Motor: eyelid and eyeball movement</td>
</tr>
<tr>
<td>IV Trochlear</td>
<td>Mainly Motor: eyeball movement</td>
</tr>
<tr>
<td>V Trigeminal</td>
<td>Motor &amp; Sensory: * most face &amp; mouth senses of touch &amp; pain</td>
</tr>
<tr>
<td></td>
<td>* (also chewing muscles)</td>
</tr>
<tr>
<td>VI Abducens</td>
<td>Mainly Motor: eyeball movement laterally</td>
</tr>
<tr>
<td>VII Facial</td>
<td>Motor &amp; Sensory: * controls most facial expressions</td>
</tr>
<tr>
<td></td>
<td>* (taste)</td>
</tr>
<tr>
<td>VIII Vestibulocochlear (auditory)</td>
<td>Mainly Sensory:</td>
</tr>
<tr>
<td></td>
<td>* hearing</td>
</tr>
<tr>
<td></td>
<td>* equilibrium sensation</td>
</tr>
<tr>
<td>IX Glossopharyngeal</td>
<td>Motor &amp; Sensory (only sense listed here):</td>
</tr>
<tr>
<td></td>
<td>* senses blood pressure</td>
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<tr>
<td></td>
<td>* (taste)</td>
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<tr>
<td>X Vagus</td>
<td>Motor &amp; Sensory: sets motor tone for most thoracic and abdominal visceral organs</td>
</tr>
<tr>
<td></td>
<td>* slows heart rate</td>
</tr>
<tr>
<td></td>
<td>* control peristalsis of gut</td>
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<tr>
<td></td>
<td>* controls respiratory rate</td>
</tr>
<tr>
<td></td>
<td>* etc., etc.!!!!!!</td>
</tr>
<tr>
<td>XI Accessory (spinal accessory)</td>
<td>Mainly Motor: controls swallowing movements</td>
</tr>
<tr>
<td>XII Hypoglossal</td>
<td>Mainly Motor: controls tongue movements</td>
</tr>
</tbody>
</table>
2) SPINAL NERVES

** MAJORITY OF SPINAL NERVES ARE "MIXED" - contain both afferent & efferent fibers!!!!**

- 31 pairs of nerves, each w/ thousands of fibers.
  - 8 cervical (C1 - C8)
  - 12 thoracic (T1 - T12)
  - 5 lumbar (L1 - L5)
  - 5 sacral (S1 - S5)
  - 1 coccygeal (C0)

- ROOTS AND RAMI
  * RECALL: spinal nerves are connected to the spinal cord through 2 roots: DORSAL ROOT (sensory or afferent n.) & VENTRAL ROOT (motor or efferent n.-"ANTERIOR HORN MOTOR NEURONS").

* Spinal nerves are very short (only ~ 1 mm in length). Immediately after leaving ventral root, branch into RAMI ("branches"); go to voluntary muscles & skin. 4 rami; each going to different areas of body.
  * student is not responsible for the individual rami.
  * NOTE: ROOTS = medial and form the spinal nerve; can be sensory or motor.
    RAMI = distal; form lateral branches of spinal nerves;
    also can be both sensory & motor.

- PLEXI (image next page) - branching network of intersecting nerves. Afferent & efferent fibers.

* We will be dealing with the innervations of spinal nerves in lab. However, do know the following:

(i) CERVICAL PLEXUS: major nerve is the PHRENIC, which controls breathing through innervation of the diaphragm. Hiccups are an irritation of this nerve. If destroyed, patient must use mechanical respiration.

(ii) BRACHIAL PLEXUS: know the 5 main arm nerves, general location (medial aspect, etc.), basically what they do (flex elbow, etc.). DO NOT go into detail about branchings, innervations, etc.

(iii) LUMBOSACRAL PLEXUS: lower limb. Know the FEMORAL NERVE.

(iv) SACRAL PLEXUS: Know the SCIATIC NERVE (hamstring innervation). Know the 3 main branches: TIBIAL, PERONEAL & POSTERIOR FEMORAL.

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### Median Nerve and Ulnar nerves:
Among other things:
- Move thumb
- Flex fingers
- Flex wrist
- Pronation
- Hand sensation

Radial nerve:
- Extend all joints below shoulder
- Supination

### Musculocutaneous Nerve:
- Innervated biceps and brachialis.
- Flex and supinate elbow.
- Forearm sensation.

### Axillary Nerve:
- Innervate deltoid (and more)
- Adduct at shoulder
- Shoulder sensation
**DEMATONES**

* Area of skin innervated by the cutaneous branches of individual spinal nerves. Numbness in these areas = diagnostic tool.

*all spinal nerves except C1 have dermatomes.

*map in figure in book separates them; but not this well separated in real life--much overlapping.

**some areas = 50% overlap. Therefore, you can completely destroy a spinal nerve w/out detecting complete numbness in a dermatome.

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**Sciatica**

The term "sciatica" describes a symptom — pain along the sciatic nerve pathway — rather than a specific condition, illness, or disease. Some use it to mean any pain starting in the lower back and going down the leg. Others use the term more specifically to mean a nerve dysfunction caused by compression of one or more lumbar or sacral nerve roots from a spinal disc herniation, though in this second use it is a medical diagnosis (i.e., it indicates a cause and effect diagnosed by an MD). Pain typically occurs in the distribution of a dermatome and goes below the knee to the foot.

Two common causes: spinal stenosis and piriformis syndrome.

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**C) MOTOR ENDINGS**

- Region of the motor neuron that activates the effector cells.

* If effector = voluntary muscle, motor ending = NEUROMUSCULAR JUNCTION.

* If effector = glandular, motor ending = NEUROGLANDULAR JUNCTION.

* End of axon branches into axon terminals, w/ a lot of mitochondria & ACh vesicles