I. ORGANIZATION OF THE NERVOUS SYSTEM

- master control & communication. Control behavior of other tissues (increase or decrease activity) in order to maintain homeostasis.

  *along with endocrine system, which acts slower but has longer effects.

- monitor changes, take info to CNS via an afferent pathway, CNS makes a decision, send out an efferent command to an effector.

  *sensory input, integration, and motor output

  *transduction: take stimulus, turn it into an impulse (AP).

  *propagation: move the impulse down a neuron

  *synapse: special connection with another cell, which allows AP to pass to another organ (effectors: muscle, gland or other neuron).

  *innervation: tissue is synapsed with nervous tissue.
A. Structural Classification

   - brain
   - spinal cord

2. Peripheral Nervous System (PNS): Nerves and sensory apparatus, along with connections (synapses). Subdivided into:
   - spinal nerves: leave spinal cord
   - cranial nerves: leave brain

B. Functional Classification

- PNS only. CNS is just broken down into brain & spinal cord, but they work on very similar principles.

1. Sensory (Afferent) Division (towards the CNS; respond to stimuli, and take info to CNS). Although there are classification of sensory receptors, they all will work in a similar manner.
2. Motor (Efferent) Division (away from CNS; take command to effectors). Further divided, depending on the effectors it innervates. Broken down into:

- Somatic Nervous System: innervates skeletal (striated) muscle tissue.

- Autonomic Nervous System (ANS): innervates smooth muscle, cardiac muscle, and glands. Further subdivided, based on overall effect on the effectors, into:

  * Parasympathetic System: “Rest & Relaxation” system. Organs are set at a set rate. Minimized energy usage.

  * Sympathetic System: “Fight or Flight” system, used under stress/emergency. Lower some organs activity, while increasing others.

II. NERVOUS TISSUE: STRUCTURE AND FUNCTION

A. Supporting Cells

- neuroglia; do not transmit impulses.

- Some found in CNS:

1. Astrocytes: form blood-brain barrier. Neurons are fragile; changes in blood pH, etc. would kill them. Do not come in contact with blood. Astrocytes form a “bridge”.

2. Microglia: CNS does not have immune cells; otherwise, would be open to autoimmune disorders, but neurons are amitotic, so damage is forever. Microglia = specialized nerve cells acting as phagocytes.

3. Ependymal cells: CNS is hollow, filled with Cerebrospinal fluid (CSF) which acts at a circulating fluid for CNS (analogous to blood). Ependymal cells line part of the cavity and make CSF.

4. Oligodendrites: wrap cytoplasm around neurons, forming “myelin sheaths” which insulate the neurons.
- Some found in PNS:

1. Schwann cells: analogous to Oligodendrites found in CNS.


B. Neurons

1. Anatomy:

   - body (perikaryon)

   - neurilemma: the PM of neurons. Special, because they can transmit an impulse (AP). That is, they are excitable (they can conduct electricity).

   - processes, which include:

      i. axon: transmit impulse. Often have myelin sheaths, which act to insulate the neurons and speed up the transmitting of impulses.

      ii. dendrite: receive stimulus, carry info to body.

      iii. axons end in an axon terminal, which contains vesicles filled with neurotransmitters (chemical that will allow the neuron to pass the impulse (information) to the next tissue, whether it is another neuron, muscle or gland).

   - synapse: specialized connection between cells. Specialized for transferring information (AP or impulse) from 1 cell to the next. Includes the end bulb of the neuron and the membrane of the “receiving” cell.

*vesicles with neurotransmitters: sacs with a chemical that can cause an impulse (AP) on the receiving cell

*cleft or gap: a short gap between the neuron and the receiving cell.
2. Classification

i. Sensory (Afferent):

- Neurons cell bodies are found in a ganglion.

- Structurally, they are unipolar (“one pole” or “one process”, with the body hanging off).

- Synapse with a receptor cell at one end and an Interneuron on the other end. Type of sensors:

  *cutaneous: many types. Simplest are the free nerve endings (which detect pain). Also: Chemoreceptors (chemicals), Pressoreceptors (“hair cells” that detect touch or movement), Baroreceptors (pressure), Heat detectors.

  *proprioreceptors: detect stretch of muscles and tendons, so you never over-stretch them.

  *special senses: complex organs that make up what you think of as your “senses”: hearing, vision, taste, smell, etc.

ii. Association Neurons (Interneurons):

- Found in the CNS. Usually short, multiple branches.

- They do integration.

- They synapse with each other and a motor neuron (next on list).
- Structurally, they are “multipolar” (“many processes”), where all the processes are short and branching ... difficult to tell an axon from a dendrite.

iii. Motor (Efferent) Neurons :

- carry the information (AP) to an effector organ/tissue (muscle or gland).

- Structurally, they are also multipolar, although one process is very long (the axon). This is what takes the info to the effector.

3. Physiology

a) Nerve Impulses - occur on the neurilemma of the axon. Carry & transfer information. They are electrical current.

Putting electrical current in context of what the system does:
There are 5 aspects to them:

i. **Resting Membrane Potential**: you must first have a polarity, before you can generate electrical current.

* At rest, the neurilemma has a positive charge on the outside (extracellular fluid) due to a high [sodium].

* The inside has a negative charge, due to the presence of proteins (which tend to be negatively charged). \(-70\text{mV}\).

This polarity (difference in charges) is called the **Resting Membrane Potential**.

ii. You must detect a stimulus: **Depolarization**
* The neurilemma has special channels, called gates, that allow sodium into the cell if they are opened. If they are opened, the neurilemma depolarizes ... that is, changes the polarity.

* Then, potassium (K+) gates open, and K+ flows outward, into the extracellular fluid. This repolarizes the neurilemma.

**Excitable** = these channels can open, if they are stimulated in the correct way. If they are stimulated enough, the neurilemma depolarizes so much that it has an electrical impulse (the AP - the next step!).

* neurons, muscles & glands have these channels, and are therefore excitable. However, the PM of muscles and glands have a different name (see later chapters).

* what is the stimulus?

For the receptors, it is the presence of chemicals, heat, pressure, etc. (that is...whatever it is they are detecting).

iii. If the stimulus is strong enough that a signal must go to the brain, alerting it: Electrical Current (**Propagation of an Action Potential (AP)**)

* If the depolarization is strong enough, enough sodium will enter the cell to cause a “switch” in the polarity. This point is called “**THRESHOLD**”

* If this happens, it will open the sodium gate next to it. It will then depolarize, and the signal will switch.
ACTION POTENTIAL: a series of “switches in polarity” down the cell!

* which will cause the same thing to happen at the next gate down the line!!!!

** This is a signal for something to occur at the end of the cell!

(all excitable tissues can do this!)

*Propagation of the AP: Now, we must move the AP down the axon to wherever it need to go!

- But that is not a problem, because an AP on one spot causes an AP on the next spot of the neurilemma, as it opens gates on the neighboring section, which allows Na+ in, etc.
- This will continue all the way down the axon....this is the electrical current! Therefore, APs are called “All or Nothing”, because if you have enough stimulus to have one AP, you’ll have them all the way down the axon.

- myelin sheaths, formed by the Schwann Cells in the PNS, insulate the neurons and speed up this propagation of APs. This is called “Saltatory Conduction” (“Jumping Conduction”).

  *myelin is white .... therefore anything myelinated is “white matter”, like your nerves, and parts of your brain and spinal cord. Non-myelinated tissues are grey .... like the grey matter of your brain.

Iv.. Also...you must have a way to deaden the neuron so you can turn it off, or make sure the signal doesn’t go the wrong way!

**Hyperpolarization** ("more polarized" = turning it off) : anything I do to the neurilemma that would make it “more polarized” will make it harder to depolarize in the first place, basically “deadening” the neuron.

  - If I interfere with the sodium channels so neurotransmitters can’t open them, or if I increase K+ permeability.

  - this is called “inhibition”. Some chemicals in your body are “inhibitory”, and act to turn off your neurons.

    *NOTE: Anything that lowers Na+ permeability or increases K+ permeability can deaden your neurons! Anaesthetics, toxins, pain relievers, alcohol, snake venom, etc.

    * ALSO: anything that changes the [ ] of these electrolytes in the body's fluids will interfere with the electrical system! Twitching, spasms, sweating are all signs of electrolyte imbalance.

v. Transmit the signal to another tissue: **The Synapse & Neurotransmitter**

  * something crosses from 1 cell to the next and controls it’s behavior (turn it on or off). It is a chemical called a neurotransmitter, which will bind to the sodium gates and opens them for a moment.

    - This is how the synapse passes the info from one nervous cell to another.
- Therefore, it is an "electrochemical event"!

* excitatory neurotransmitter: causes and AP on the next cell.

** Acetycholine (ACh) is the most common

* inhibitory neurotransmitter: causes and AP on the next cell.

** Some tissues (cardiac and smooth muscle) are "self-generating" ... that is, the gates open by themselves, in a timed manner, so the tissue doesn't have to have a stimulus to depolarize and have an AP (your heart will beat for awhile even outside of your body).

** this will be important in the Heart and Digestive chapters, for example.

* ALSO: notice that integration within the CNS is the multiple inputs from several inputs at the same time.

** The response is a "decision" based on several inputs.

** This is what some people mean when they say your CNS (brain) is like a computer...however, this is an over-simplification.
b) Reflex Arc The system has to do more than just pass along APs ... it must do it in an organized way that gets a job done!!

reflex arcs have a receptor, 1 (or just a few) afferent n., just 1 or a few synapses within the Interneurons of the CNS, and just 1 or a few motor outputs. They are fast, predictable responses to a stimulus. They can be learned, however!

i. Autonomic Reflexes: control heart (cardiac muscle), gland, smooth muscle. Heart rate, elimination, digestion, blood pressure, etc. Examples: salivation & peristalsis.

ii. Somatic Reflexes: skeletal muscle. Pulling your hand away from a hot object, knee jerk (patellar), flexor.
III PERIPHERAL NERVOUS SYSTEM: NOTE: in book, found at the end of the chapter.

- the nerves and ganglia found outside the CNS, including synapses.

A. Structure of a Nerve

- nerve = bundle of neurons, plus blood vessels. Carry APs to/from the CNS. Wrapped in connective tissue for protection & insulation. Endoneurium around the whole nerve, perineurium around a fascicle ("bundle") within the nerve, and an endoneurium around an individual neuron.

* ALS: gradual destruction of myelin sheaths. Genetic component. Patient loses control of skeletal muscle. Death often comes from suffocation, as they can't control pharynx or diaphragm.

- spinal nerves leave/enter the spinal cord, cranial nerves leave/enter the brain.

1. Mixed Nerves: both afferent & efferent fibers. All spinal nerves are mixed.

2. Sensory (Afferent) Nerves: some cranial nerves.


B. Cranial Nerves

- 12 nerves entering/leaving brain. Some mixed, some afferent, some efferent.

Olfactory
Optic
Oculomotor
Trochlear
Trigeminal
Abducens
Facial
Vestibulocochlear
Glossopharyngeal
Vagus
Accessory
Hypoglossal
C. Spinal Nerves and Nerve Plexuses

- 31 pairs. All = mixed. Very short, branch almost immediately into rami, which then branch into plexi (plexus = singular, “web”). Ventral and Dorsal Rami. Cervical, Brachial, lumbar and Sacral plexus. Know the names of the important nerves leaving each plexus see on table 7.2.

D. Autonomic Nervous System

- “involuntary” system.

- 2 sensory neurons: pre-ganglionic and post-ganglionic.

1. Comparison of the Somatic and Autonomic Nervous Systems:

- somatic nerves innervate skeletal muscle; they are all the same. No subdivisions. Main neurotransmitter = ACh.

- autonomic nerves control “automatic” responses. Several neurotransmitters: ACh and the “adrenalines” (epinephrine, norepinephrine) can be used, depending on whether the CNS wants to speed them up (excitatory) or slow them down (inhibition). So ... all these organs have 2 autonomic innervations: parasympathetic (“resting state”) and sympathetic (“emergency state”).

2. Anatomy of the Sympathetic Division: “Fight or Flight” system; also called the “thoracolumbar” because this is where the nerves originate from spinal cord.

- Ganglia are close to the spinal cord (= short pre-ganglionic), forming the sympathetic trunk.

- Epinephrine & Norepinephrine control the effectors.

3. Anatomy of the Parasympathetic Division: “Rest and Relax” system; also called the “craniosacral” because this is where the nerves originate from spinal cord.

- Vagus nerve is an important member of this group. Fibers originate in the medulla oblongata (see later) of the brain, it innervates almost all visceral organs, setting a “vagal tone” (resting rate).

- Ganglia are far from the spinal cord (= long pre-ganglionic), no trunk formed.

- ACh controls the effectors.
4. Autonomic Functioning: sometime a given neurotransmitter will speed up an organ (excite), whereas the same neurotransmitter will slow down another (inhibit).

- Example: the parasympathetic system slows down the heart rate, but speeds up peristalsis in the gut. The sympathetic innervation speeds up heart rate, but slows down the gut.

*On This Diagram: Dark arrows “speed up”, lighter arrows “slow down”*

- see table 7.3 for more examples. However, student should be able to figure it out, if they remember that the parasympathetic system is conserving ATP for the muscles and other important organs for fighting or running ... everything else is inhibited.

- the effects of many drugs can be explained as their effects on these 2 systems. Some make you drowsy; others make you nervous, sweat, weight loss, etc. These drugs mimic these neurotransmitters, often sitting on the same receptors that would be normally used by the neurotransmitters themselves.
IV. CENTRAL NERVOUS SYSTEM: NOTE: Different organization than the book

- receives incoming info, interprets and integrates, and sends motor output.

- Interneurons = grey matter.

- Terminology:
  * tracts = bundles of neurons, like nerves in the PNS.
  * nuclei = collections of bodies, like ganglia in PNS.

- NOTE: there are lots of other neurotransmitters besides those mentioned. Many are chemicals that affect certain regions of the CNS in different ways. These include dopamine, serotonin, nitrous oxide, opiates, among many others.

A. Spinal Cord

- dense cord of neural tissue, protected by the vertebral column, blood-brain barrier, and the meninges (protective sheets ... see later). Found in the dorsal cavity. Interneurons. White matter outside, grey inner core = integration (non-myelinated interneurons).

- center = hollow central canal, filled with CSF (circulating fluid, made by Ependymal cells).

B. Gray Matter of the Spinal Cords, White Matter Columns and Spinal Roots

1. Grey matter: center = grey matter = integration. Surrounded by white matter = speedy transmission of impulses up & down (no integration; just take sensory info up to brain, carry commands or motor output down). PNS nerves enter/leave the spinal cord via roots, the PNS neurons synapse with interneurons in the grey.
2. Roots: although PNS nerves are mixed, they split up as they enter the spinal cord: motors leave dorsally (dorsal root, which has a motor root ganglion), the sensory enter ventrally (no ganglion; recall the discussion of pre-ganglionic and post-ganglionic neurons earlier).

*polio myelitis: virus that can attack the dorsal root, causing paralysis. If attacks upper part of spinal cord, may affect the splenic nerve, patient can't breath (use the diaphragm muscle). Iron lungs.

3. White Matter of the Spinal Cord: myelinated, in bundles (“tracts”) going up & down through structures called “columns”. Sensory tracts go up, motor tracts go down. Many motor tracts are posterior columns, which is why damage to back of spinal cord can cause paralysis but patient still has “feeling”.

*spastic paralysis: transection of spinal cord leads to paralysis. Neurons = amitotic, so it is permanent. In spastic paralysis, muscle is not lost, as spinal reflexes still exist, so muscles still receives stimulation.

*atrophy: permanent loss of muscle via fibrosis, if spinal reflexes are lost.

*Paraplegia: thoracic transection; 2 limbs (legs) lost

*Quadriplegia: cervical transection; 4 limbs lost.

C. Functional Anatomy of the Brain

- brain is an enlargement of CNS at head. About 3 pounds.

- central canal also enlarges into 4 ventricles, filled with CSF.

- Functions:

1. accept sensory input, interpret meaning, make a decision, and send motor output.

2. Coordinate muscular activities. Communicate and coordinate with the spinal cord.

3. Make hormones that control visceral functioning, and set a constant “tone” for those visceral organs that need it (lungs, heart, gut, etc.).
- Tissues basically the same as spinal cord, but major difference = grey outside, white inside.

- “Ridges” give more surface area for functioning.

- 4 major regions, each with individual structures and surrounding the ventricles.
Each region has its own function:

1. Cerebrum with Cerebral Hemispheres: Accept sensory info, make decision, send motor output.

- grey matter cortex, with white matter structures inside.

- cortex:

  * 2 separate hemispheres, separated by the longitudinal fissure.

  * Each has lobes, fissures, sulci and gyri. Notice the lobes are named for the bones that overlay and protect them.

  * Certain spots in grey matter have functions (visual cortex, auditory cortex, gustatory cortex, primary motor cortex, etc.).

  * Functional distribution:

    i. everything anterior to the central sulcus is motor output (including personality and cognition)

    ii. everything posterior is sensory input, memory (for the most part) is on the sides.

- White matter tracts tie the individual structures together to integrate.

  * Association* areas of the cortex tie sensory and motor cortices.

  * Some structures provide communicate/coordination between hemispheres (corpus callosum (white matter “bridge”))

  * Some structures provide communication/coordination with the next section of the brain (cerebral nuclei connect with the diencephalon).

**Parkinson’s disorder: problem at basal nuclei with deficiency of neurotransmitter dopamine. Tremors, interspersed with catatonia.
2. Diencephalon: many parts, most dealing with hormone secretion or transferring information:

- Thalamus: surrounds 3rd ventricle. Ependymal cells make CSF. Really up to sensory cortex.

- Hypothalamus: has the pituitary gland, which secretes many hormones involved in visceral homeostasis. Also, important part of the limbic system, which is the emotional brain.

- Pineal gland: melatonin secretion, controls wake/sleep cycle.

3. Brain Stem: controls visceral “tone” by containing several nuclei (respiratory, cardiac, etc.). Contains the Reticular Activatin System, which gives you consciousness (damaging the reticular formation leads to coma). # major structures:

- Midbrain: relay sensory up and motor down. Also, involved in hearing and vision reflexes (corpora quadrigemina).

- Pons: relay with spinal cord and respiratory reflexes.

- Medulla Oblongata: many nuclei controlling vital visceral activities, heart rate, breathing, blood pressure, swallowing, vomiting, etc. Many fibers of the vagus nerve originate here..

4. Cerebellum: coordinate muscular activities, but monitoring info from proprioceptors, and motor output by the cerebrum.
D. Protection of the Central Nervous System

Meninges

Meningitis and Encephalitis

Cerebrospinal Fluid

Hydrocephalus

The Blood-Brain Barrier

E. Brain Dysfunctions

Traumatic Brain Injuries

Degenerative Brain Diseases

Cerebrovascular Accidents

Alzheimer's Disease