Andrew Rosen - Chapter 3: The Brain and Nervous System

**Intro:**

- Brain is made up of numerous, complex parts
  - Frontal lobes by forehead are the brain’s executive center
  - Parietal lobes wave sensory information together (maps feeling on body)
  - Temporal lobes interpret sound and speech
  - Occipital lobes interpret visual information from eyes
- Neurons are cells that make up the nervous system

**The Organism as a Machine:**

- Descartes - Behaviors, thoughts, and feelings are a product of the brain
  - Every action is the response to an event in the world (said soul controlled the pathways that the nervous responses took)
    - Reflex - Something excites a sense which excites a nerve to the brain which diverts excitation to a muscle making it contract

**Building Blocks of the Nervous System:**

- Neuroscience – Understanding the nature, function, and origins of the nervous system
- Neurons – Individual cells that act as the main information processors of the nervous system (100 billion)
- Glia cells – Another brain cell outnumbering neurons 10:1
- Nerve impulse – Means through which individual neurons communicate with one another

**Neurons:**

- Neuron – A cell that specializes in sending and receiving information
  - Consist of dendrites, cell body (soma), and axon
  - Dendrites (input) receive signals from many other neurons and are branched
  - Cell body contains the nucleus and elements needed for metabolic activity
  - Axon (output) extends outward and forks
- Motor neurons have the largest axons
- Efferent neurons – Allows the brain to control the muscles by carrying information from the brain to a destination outside of the brain (Away from CNS)
- Afferent neurons carry information towards the brain and keeps the nervous system informed about the external and internal environments (Toward CNS)
  - Have receptor cells that transduce physical stimuli into electrical changes which triggers other nerve impulses
- 99% of nerve cells in the brain are neither afferent or efferent and make connections within the CNS
  - Projection neurons – Link one area of the CNS to another area with long axons
  - Interneurons – Make local connections within the nervous system with short (or no) axons

**Glia:**

- Holds neurons in place and supplies (and control) them with nutrients and oxygen
- Convert glucose into lactate that feeds the neurons
- Sensitive to activity level in each neuron and increase blood flow whenever the neurons in one area become more active
- Control brain development
- When new neurons are made during development, they migrate from one position to another, and this is controlled by glia
  - Glia produce chemicals to shut down neural growth when necessary
- Increase speed of neuronal communication
  - Composed of a lot of myelin
  - Glia wrap themselves around axons (especially longer ones)
    - This composes the myelin sheath
    - Leaves behind gaps that are known as the nodes of Ranvier
    - This combination speeds up nerve impulses on myelinated axons
- White matter – Myelinated axons
- Gray matter – Cell bodies, dendrites, and unmyelinated axons
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- Might help regulate strength of connections between adjacent neurons
- Can release chemicals that increase reactivity of neurons

Communication among Neurons:

- Communication within the neuron requires electrical signals
- Communication between neurons requires chemical signals

Activity and Communication within the Neuron:

- Stimulating a neuron can cause an electrical signal called an action potential
- Action potential – a signal sent from one end of the neuron to another that is the main response to input and is the fundamental information carrier of the nervous system
- There is always a voltage difference between the inside of the neuron and the outside
- The inside of the axon is electrically negative (-70mV) compared to the outside
- If the pulse is strong enough to push the voltage difference past a critical excitation threshold, the voltage difference collapses to zero and reverses itself
  - Inside of the membrane becomes positive (up to +40mV)
  - Resting potential is restored within a msec or so

Explaining the Action Potential:

- Ions have positive or negative electrical charges
- When a neuron is at rest, the inside of the cell contains positive and negative ions (same is true for the fluid outside it)
- Ion pumps control ion concentrations
  - Move sodium ions out of the cell and potassium ions into the cell (3 Na⁺ out for every 2 K⁺ in)
- Ion channels are actual passageways through the membrane that allow certain ions to pass through
- When a neuron is at rest, sodium ions are barely able to pass through the channels but potassium ions can move freely
- There is more potassium inside the cell than outside (not necessarily concentration though)
- Dominant movement of potassium ions is outward due to diffusion
  - Creates a surplus of positive ions outside of the cell, and this is the main source of the resting potential
- New ion channels open upon stimulation that allow sodium to pass and flood into the cell leading to an excess of positive charges inside the cell membrane but immediately returns to initial state with the sodium channels “slamming shut”
- Refractory period – The time after an action potential during which the cell membrane is unprepared for the next action potential due to an imbalance of ions
- Depolarization – When sodium channels open and membrane potential becomes more positive
- Repolarization – After the sodium channels close and the membrane potential becomes less positive

Propagation of the Action Potential:

- Depolarization at one point on the membrane causes other nearby ion channels to open and the depolarization spreads because sodium rushes into the cell in these spots also
- This sequence is known as propagation of the action potential
- It does not go on for forever because of the refractory period at each area of the membrane
  - Because of this, the action potential only goes in one direction down the axon
- Propagation of the action potential is slow, especially compared to the movement of ions
- If an axon is myelinated, ions can move into or out of the axon only at the nodes of Ranvier
  - In other areas, The axon is enclosed within the myelin wrapper
  - The action potential must skip from node to node, which makes it much faster
  - Multiple sclerosis is a disease in which the body’s immune system mistakenly regards the myelin as an intruder and attacks it

All-or-None Law:

- When an action potential is produced, the neuron is deemed to be fired
- The action potential is the same size and is propagated at the same speed no matter if the impulse meets or exceeds the threshold
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- This is known as the all-or-none law (neuron either fires or it doesn’t)
- More intense stimuli excited a greater number of neurons since neurons have various threshold levels
  - With a sustained stimulus, it is a repeated cycle of destabilization and restabilization
- Neurons can vary the rate of their firing in the “volley” and can increase to a certain maximum rate

The Synapse:

- Neural communication relies on a succession of neurons
- There are gaps within the succession between adjacent neurons
  - Neural signal has to move down the axon, jump the gap, and trigger the next neuron’s response, etc.
  - This gap is called a synapse
    - It’s slower than communication within the neuron due to the synapse, but it has many benefits
  - Each neuron receives information (has synapses with) many other neurons
    - Allows receiving neuron to integrate information from many sources
    - Can amplify a weak signal
    - Synaptic communication is adjustable
      - The strength of a synaptic connection can be altered by experience

The Synaptic Mechanism:

- The neuron on the sending side of the synapse releases chemicals that drift across the synapse and trigger a response on the receiving end
- Presynaptic neuron – The cell that sends the message
  - Axon terminals – Location of actual transmission process in presynaptic neurons
  - Synaptic vesicles – Located in axon terminals that are filled with neurotransmitters that will influence other neurons
- When a presynaptic neuron fires, some vesicles burst and release chemicals into the gap
- Postsynaptic neuron – Cell that receives the message
  - Receptors on the membrane of a postsynaptic cell receive the neurotransmitter message
    - Causes certain ion channels to open or close
- Neurotransmitters that open channels to sodium ions decrease the voltage difference
  - If the change is small, the membrane can restore it to resting potential
- Since a postsynaptic cell likely receives signals from many presynaptic cells, the accumulation of opened sodium ion channels can make the neuron fire and will release neurotransmitters of its own
- Neurotransmitters can make a cell less likely to fire, too, due to an increased voltage difference
  - Can happen if the transmitters cause the opening of Cl⁻ channels
  - Hyperpolarization – Movement even further away from the action potential
- Some neurotransmitters are inactivated after discharge due to enzymes
  - They are typically reused though
    - This is called synaptic reuptake
    - Neurotransmitters are ejected from receptors and molecular pumps pump them back into the presynaptic axon terminals where they are repackaged into new synaptic vesicles

Neurotransmitters:

- Individual neurons are selective with the type of neurotransmitters they respond to
- Receptors have certain shapes that allow only certain neurotransmitters to be activated
  - This is the Lock-and-key model

Drugs and Neurotransmitters:

- Agonists – Chemicals that enhance a transmitter’s activity
  - Some agonists mimic the transmitter and can act on their own
  - Other agonists block the reuptake of the transmitter into the presynaptic cell
  - Other agonists counteract the cleanup enzyme that breaks down transmitters
  - Other agonists promote the production of the transmitter by increasing a component of the transmitter
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- This all increase the transmitter’s opportunity to influence the postsynaptic membrane

- **Antagonists** – Chemicals that impede such activity
  - Work the same way as agonists but completely the opposite

- **Endogenous substances** - produced naturally that provide a way for the nervous system to modify and control its own functioning
  - Antagonists and agonists depend on this many times
  - Example: endorphins and pain reception

- **Exogenous agonists/antagonists** – Chemicals introduced from outside of the body that modify neurotransmission

- **Blood-brain barrier** – Protects the cells that make up the nervous system from toxins
  - Layer of tightly packed cells that surround blood vessels in the brain
    - Downside: Blocks many medications

**Communication through the Bloodstream:**

- Blood delivers oxygen and nutrients and carries away waste products
- **Endocrine system** – Means of sending signals throughout the body
  - Glands release hormones into the bloodstream that affect areas away from the place of the hormone’s origin
  - Hormones travel throughout the entire body but are only detected by specialized receptors
  - Oftentimes chemicals serve as hormones and neurotransmitters
    - Possible common origin in ancestral signaling system

**Methods for Studying the Nervous System:**

**Recording from Individual Neurons:**

- Single-cell recording – Monitoring of moment-by-moment activity of individual neurons in the brain while placing various stimuli in front of the eyes
  - Some cells function as motion detectors and only fire when an object is in motion
  - Some cells function as shape detectors that fire when a form is in view
- Multi-unit recording – Procedure using microelectrodes to record the activity of individual cells and then relies on computer analysis to examine patterns of activity across the entire collection of cells
  - Collects single-cell data from many neurons at the same time
  - Useful in understanding limb control due to monitoring of the aggregate

**Studying the Effects of Brain Damage:**

- Brain lesion – Damage to brain cells
- Transection – Cutting relevant pathways and observing the result
- Neuropsychology – The effort to gain insights into the brain’s function by examining individuals that have suffered some form of brain damage
- Aphasia – Disruption of language use caused by brain damage
- **Transcranial Magnetic Stimulation (TMS)** – Causes temporary brain disruption with a series of strong magnetic pulses at particular location on the scalp
  - At certain intensities and frequencies they can stimulate a brain region
  - At other intensities it can turn off certain brain mechanisms for a brief period
  - Only influences structures close to the surface of the brain

**Recording from the Whole Brain:**

- Electroencephalography – Recording of voltage changes occurring at the scalp that reflects activity in the brain underneath
  - Produces an electroencephalogram (EEG)
    - Often a rhythm in the brain’s electrical activity
- **Event-Related Potential (ERP)** – Used for finding the brain’s response at a particular moment by measuring the changes in the EEG before, during, and after the event
  - Presenting the stimulus over and over and averaging the results can help cancel out all of the brain’s background activities and isolate the brain’s response to the desired signal
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- Neuroimaging techniques – Provide three-dimensional portraits of the brain’s anatomy and functioning
- Computerized Tomography (CT) Scan/Computerized Axial Tomography (CAT) Scan – Series of X-ray pictures of the brain from different angles that a computer puts together
- Magnetic Resonance Imaging (MRI) – Aligns the spinning of nuclei of atoms that make up brain tissue, send a brief electromagnetic energy pulse to disrupt the spins, and records the energy given off by the nuclei as they realign their spins
- Positron Emission Tomography (PET) Scans – Participant is injected with a radioisotope that the PET scan keeps track of how it’s distributed across the brain
  - Can monitor moment-by-moment functioning
- Functional MRI (fMRI) Scanning – Adapts MRI procedures to study brain activity
  - Relies on the fact that hemoglobin is less sensitive to magnetism when it is transporting oxygen molecules than when it’s not
  - Yields the blood-oxygenation-level-dependent signal (BOLD)
    - Tracking this measures activity in the brain
    - Provides measurements across a few seconds so it can be used to analyze activities within a time window, which makes fMRI scans better than PET scans for the most part
- These scans measure increases beyond the constant state of activity