JC

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Goal: to learn as much as possible about BCI today.

(Note: I take notes by directly writing down stuff word by word and skipping words occasionally.)

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wack questions and thoughts and todos

- can we do reverse EEG? if we can, can we do at a similar price point? what does it entail?
- imagine if we could measure the signal of every signal individually
- there are so many extra factors to eeg that we don't know about
- how to read schematics/electric circuits
- how to read bit operations

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what we are doing

replicate this board, at a cheaper price board and with more processing channels

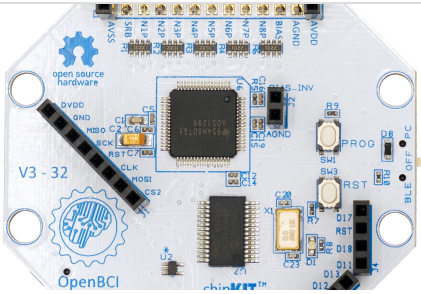
week 1 is designing the pcb and getting it shipped (with onboard?)

week 2 is interfacing with the pcb through software to actually get a cool demo: play a game using the mind

Cyton Biosensing Board (8-channels)

The Cyton Board is a scientifically-validated research tool

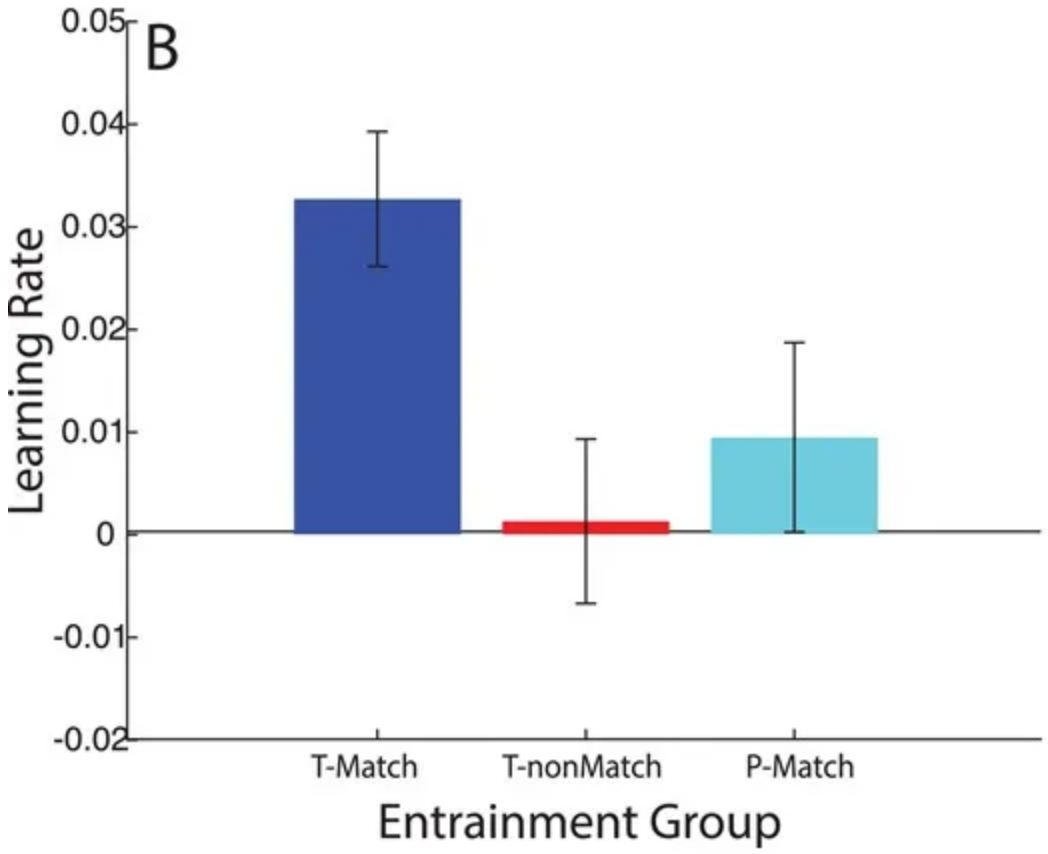
https://shop.openbci.com/products/cyton-biosensing-board-8-channel



what we can do

#1 of https://www.astralcodexten.com/p/quests-and-requests?publication_id=89120&post_id=138508657&isFreemail=true&r=2g0jvb

in 2022, a team at cambridge found that experimental subjects learned faster stimuli were presented at their brain's unique alpha rhythm. the scientists monitored their brain waves to figure out exactly what each subject's alpha rhythm was (usually a pattern of flashes about a dozen times per second), then), then presented a flashing pattern that hit the trough of each alpha wave, then asked subjects to solve tough visual recognition problems. they found the alpha entrainment helped them learn faster:



consumer-grade eeg headbands could potentially be used to replicate this result… but someone should figure out whether this can be used for the sorts of things normal people want to learn.

they might be able to figure it out by reading the original research carefully with a good neuroscience background and understanding its implications,, or use an eeg to do the experiment and see.

https://jacobshapiro.substack.com/p/teaching-at-the-brains-tempo

^ more on the flashing lights thing

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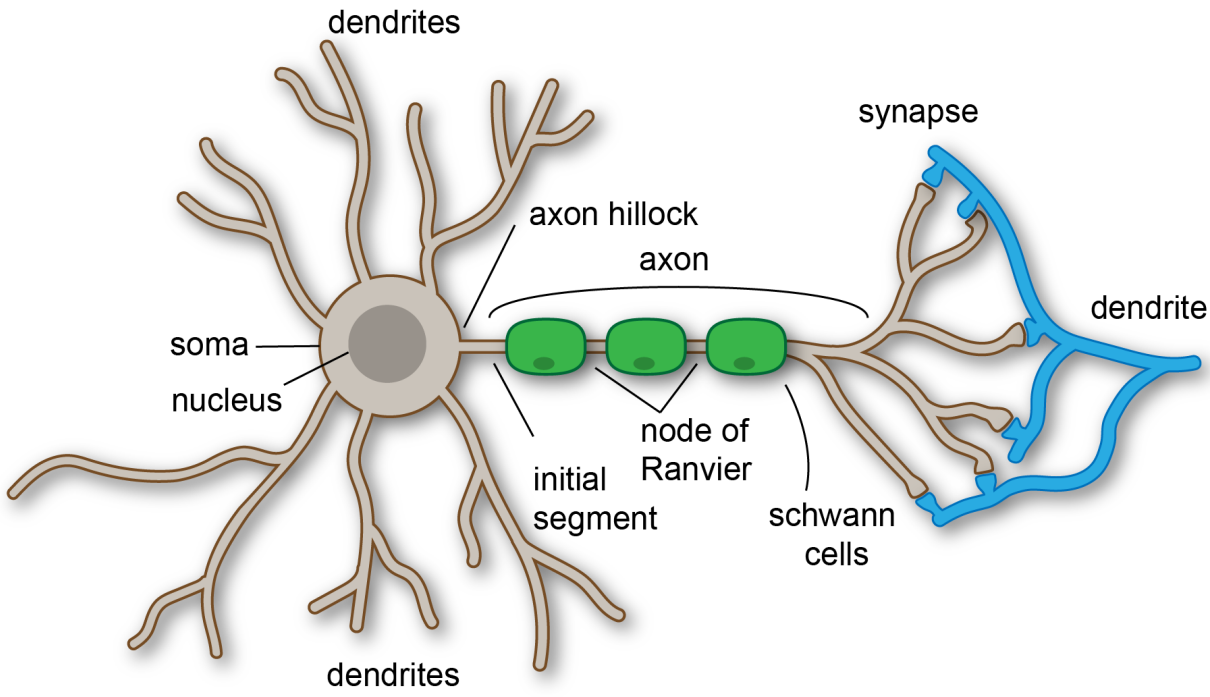
what does the eeg signal measure?

- measures aggregate electrical activity across millions of cells but there are many complexities
- brain is made up of two primary cell types called neurons and glia that together form the jelly like folded tissue of our brain. all this brain tissue is sitting in a very small

volume of cerebrospinal fluid (CSF), which is basically salt water (NaCl), but has other ionic salts = good conductor of electricity

- neurons = active conductors, extending out long cables called axons that form connections with other neurons, along which they can propagate and electric signal non-attenuating manner. they do so by a process of exchanging rapid spikes of charge with the CSF down ts lenght. when the signal or spike has reached the end of the cable where the neuron connects with another neuron (the synapse), it triggers a release of chemicals
- the cables that receive signals: dendrites



- constructed differently from axons. they don't have the insulating material needed for fast spike propagation. these currents on the receiving end - called synaptic and dendritic currents - are much slower and longer
- while the electrical activity of neurons is probably the most studied aspect of brain activity, it may only be part of the story. glial cells can sense the levels of activity in the milieu and modulate it by changing how much or how neurons can communicate with one another. +, they outnumber neurons in the brain 4:1 and may have far more of a story to tell than we know.

- csf also plays a factor that we don’t know about!
- in eeg we are not measuring activity of individual cells but the aggregate spikes and synaptic currents generated by whole swathes of tissue that contain millions of cells.

> this could be thought of as analogous to tracking the aggregate flow of activity on the internet, where you can’t read any individual email but can see macro traffic patterns

- tldr: not only neurons generate electrical signals. we are still learning about the various factors of eeg

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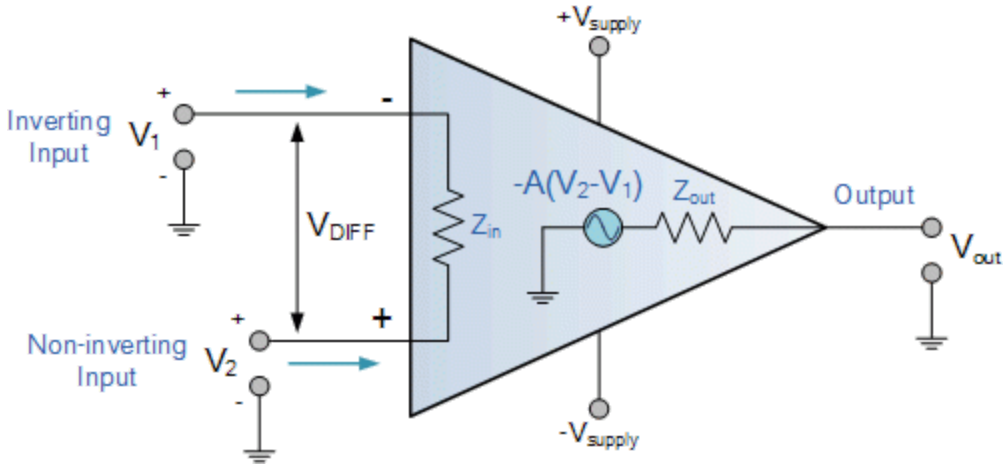
diy eeg circuit

https://www.instructables.com/DIY-EEG-and-ECG-Circuit/

this tutorial is an in-depth guide on how to make your own simple eeg circuit. the circuit will use 3 electrode - 2 to measure a voltage difference across your scalp, and one as a reference to ground. depending on how many parts you already have, the circuit could only set you back $10

- instrumentation amplifier: what is an instrumentation amplifier?
- 2x quad op-amp
- capacitors:

▼ what is an op-amp?



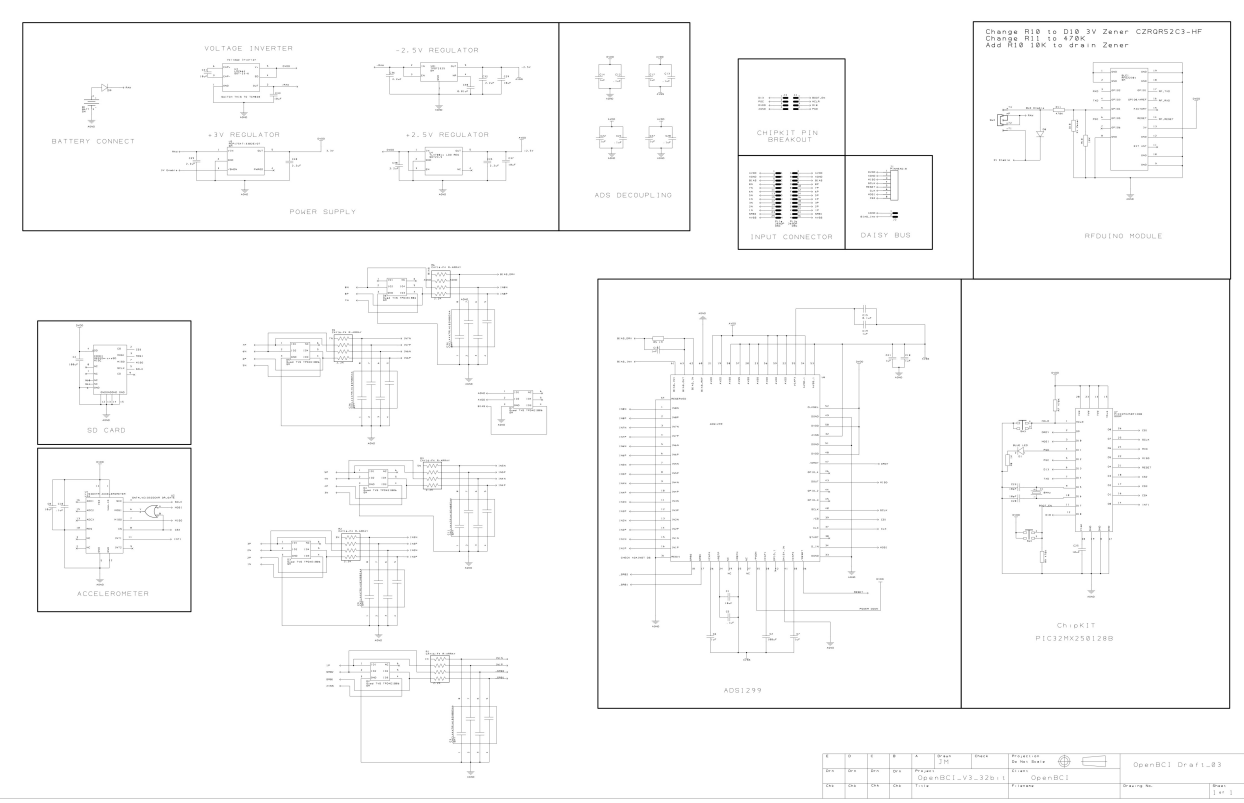
- an operational amplifier, or op-amp for short, is fundamentally a voltage amplifying device designed to be used with external feedback components such as resistors and capacitors between its output and input terminals
- these feedback components determine the resulting function or “operation” and by virtu

after sync

- [ ] read schematic and understand it
  - [ ] battery connect
  - [ ] voltage inverter
  - [ ] +3v regulator
  - [ ] -2.5v regulator
  - [ ] +2.5v regulator
  - [ ] ads decoupling
  - [x] ~~sd card (just a IC)~~
  - [ ] accelerometer
  - [ ] ads1299
  - [ ] rfduino module
- [ ] list of parts on digikey and lcsc

- basically: electrodes → [black box currently] → ads1229 [also black box currently] → microcontroller (in this case, rfduino) → computer
- rfduino: https://github.com/RFduino/RFduino

studying the schematic



1. start out with individual components first

how electricity works

the universe as we know it is governed by four fundamental forces: the strong nuclear force (which holds subatomic particles together inside atoms), the weak nuclear force (which guides some types of radioactivity), gravity, and electromagnetism (which governs the intrinsically linked concepts of electricity and magnetism).

one of electromagnetism's key tenets is that the subatoic particles that make up the cosmos can have either a positive or negative change. electricity = the movement of

negatively charged electrons.

electrons need conductors, materials which have loose electrons that can be knocked away to keep the current going

analogy: electricity = water streaming through a pipe. the volume of water passing through a pipe section at a given tie compares to the number of electrons flowing through a particular strand of wire = amps. the water pressure that's pushing the fluid through = voltage. amps * volts = power in watts.

based on the law of electromagnetism, if a wire is caught in a magnetic field and the magnetic field shifts, it induces an electric current in the wire. this is why most of the world's electricity is born from generators.

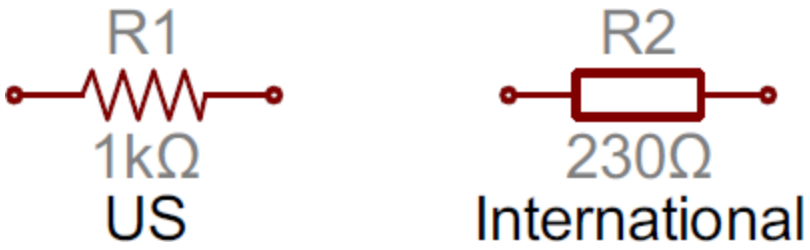
current doesn't flow one way - instead, it constantly switches direction back and forth, which engineers call alternating current. in north america, wires flip 60 times / second.

how to read schematics

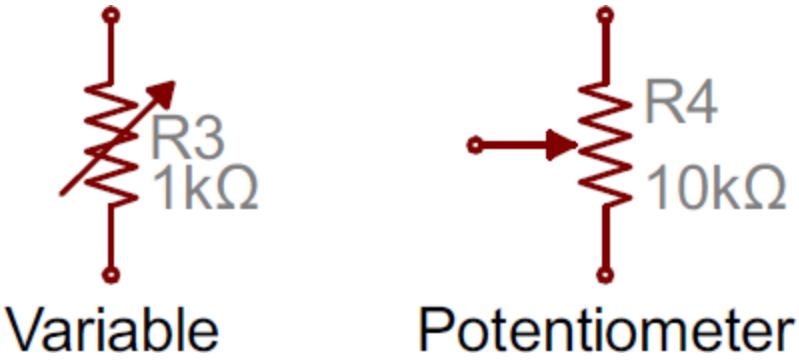
https://learn.sparkfun.com/tutorials/how-to-read-a-schematic/all

schematics are our map to designing, building, and troubleshooting circuits. understanding how to read and follow schematics is an important skill.

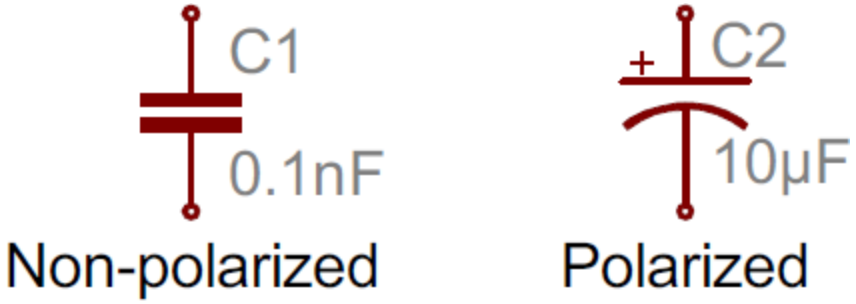
- resistor: most fundamental of circuit components and symbols



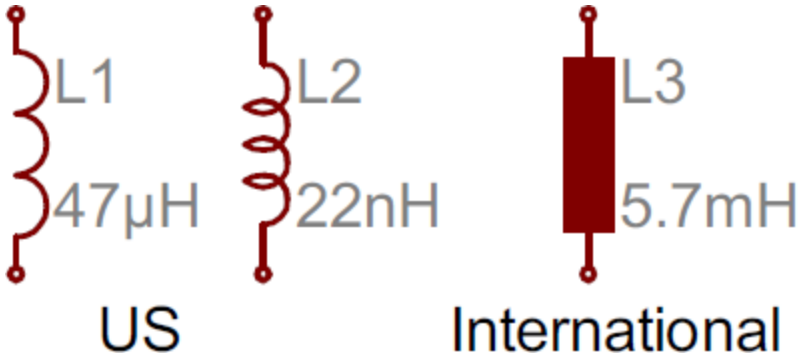
- potentiometers and variable resistors



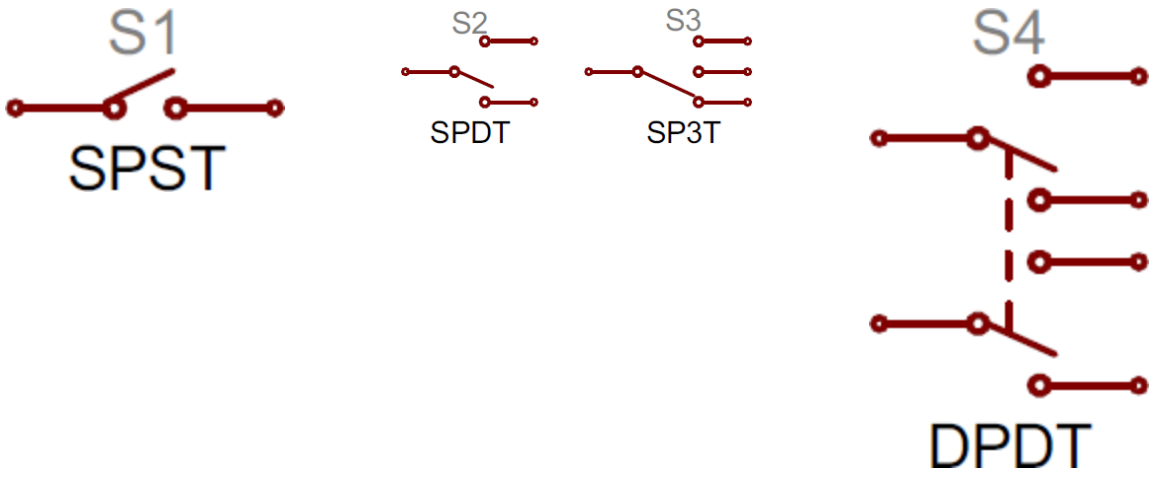
- capacitors: can store power and then release as needed. one symbol usually represents a polarized (one voltage direction) capacitor, and the other is for non-polarized capacitors.



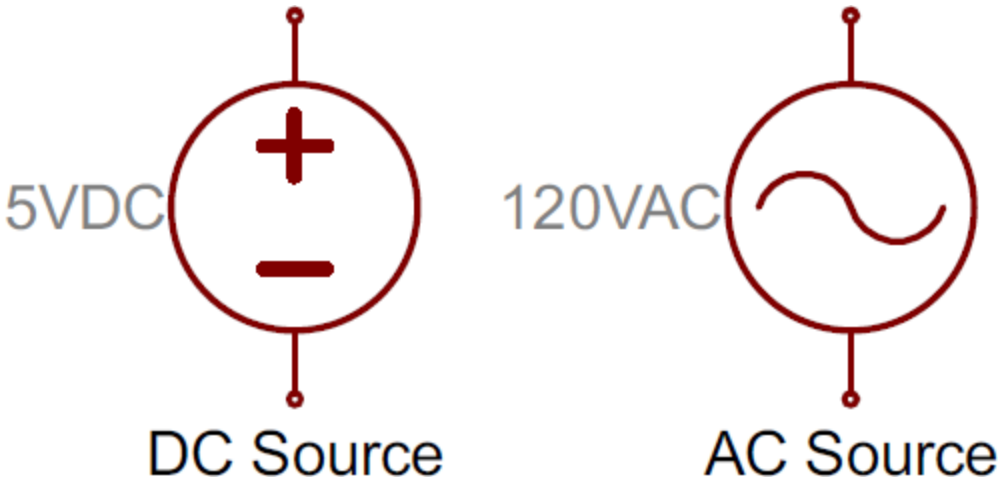
- inductors: passive two-terminal electrical component that stores energy in a magnetic field when electric current flows through it



- switches: most basic switch: a single-pole/single-throw (SPST), is two terminals with a half-connected line representing the actuator. there are also switches with more throws:

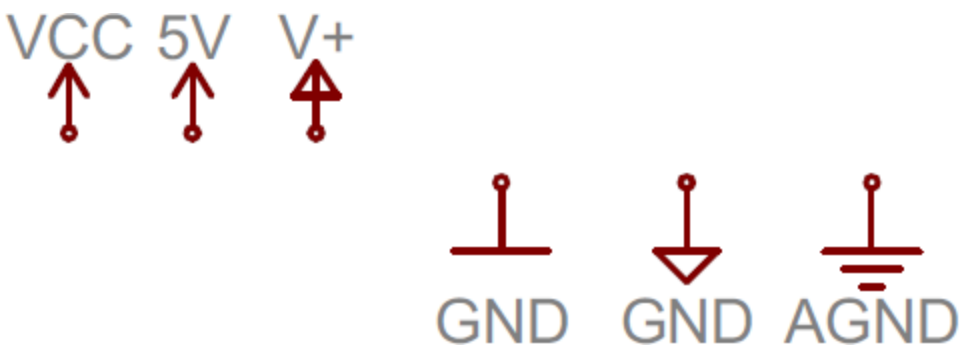


- power sources

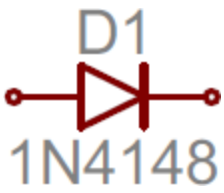


- batteries

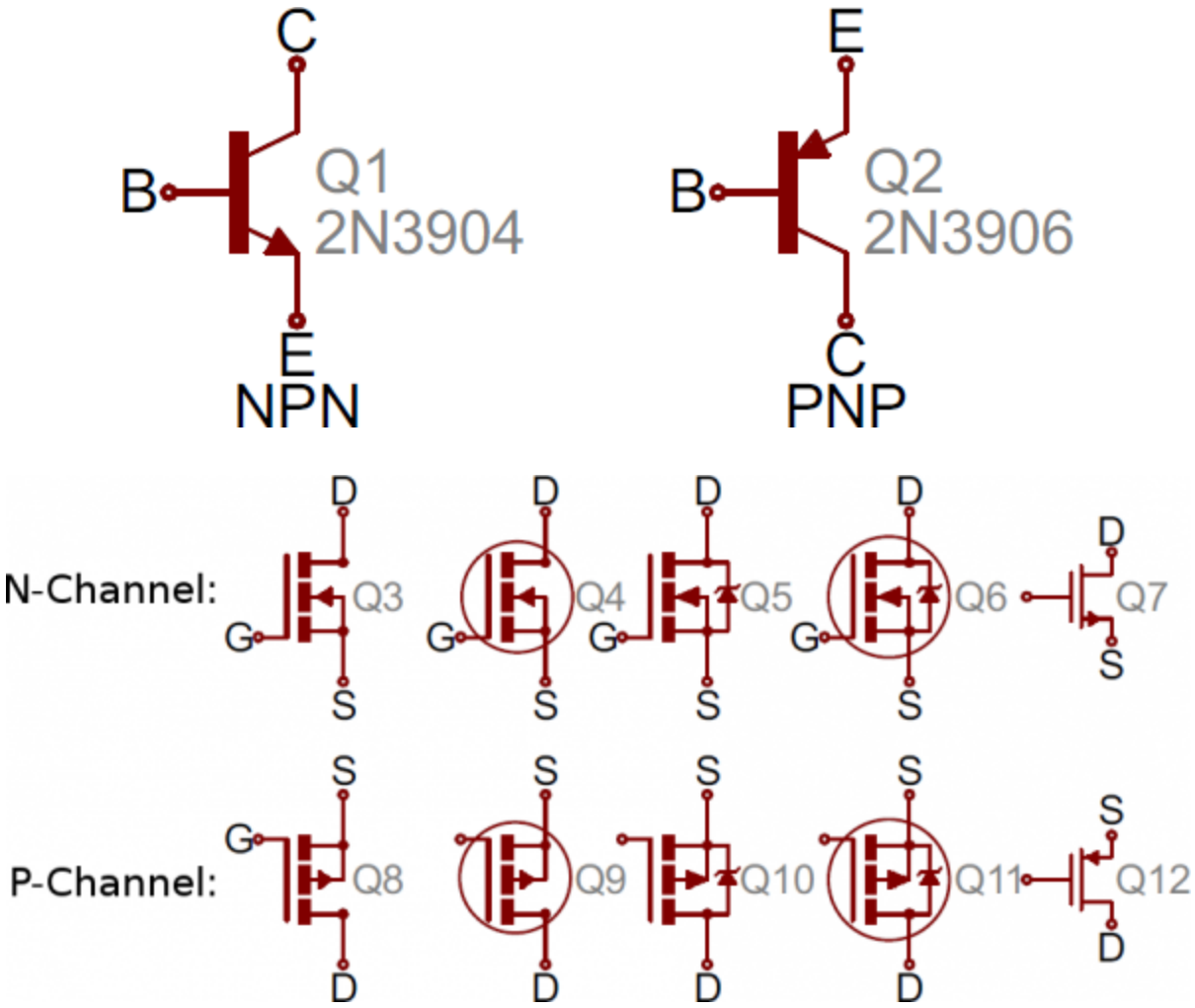
- sometimes - on really busy schematics especially - you can assign special symbols to node voltages. you can connect devices to these one-terminal symbols, and it'll be tied directly.



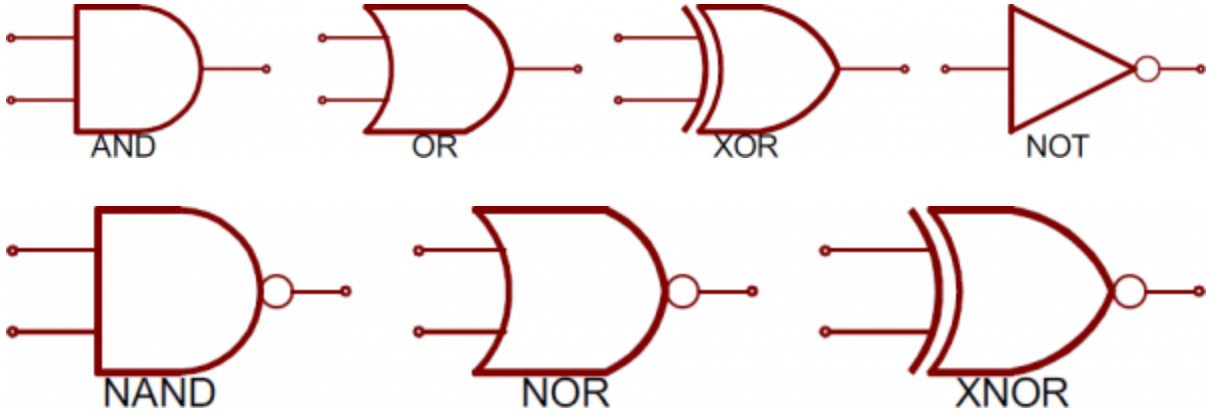
- diodes are two terminal electronic components that conduct electricity in one dir. diodes are usually represented with a triangle pressed up against a line.
- diodes are also polarized, so each of the two terminals require distinguishing identifiers. the positive, anode is the terminal running into the flat edge of the triangle. the negative, cathode extends out of the line in the symbol



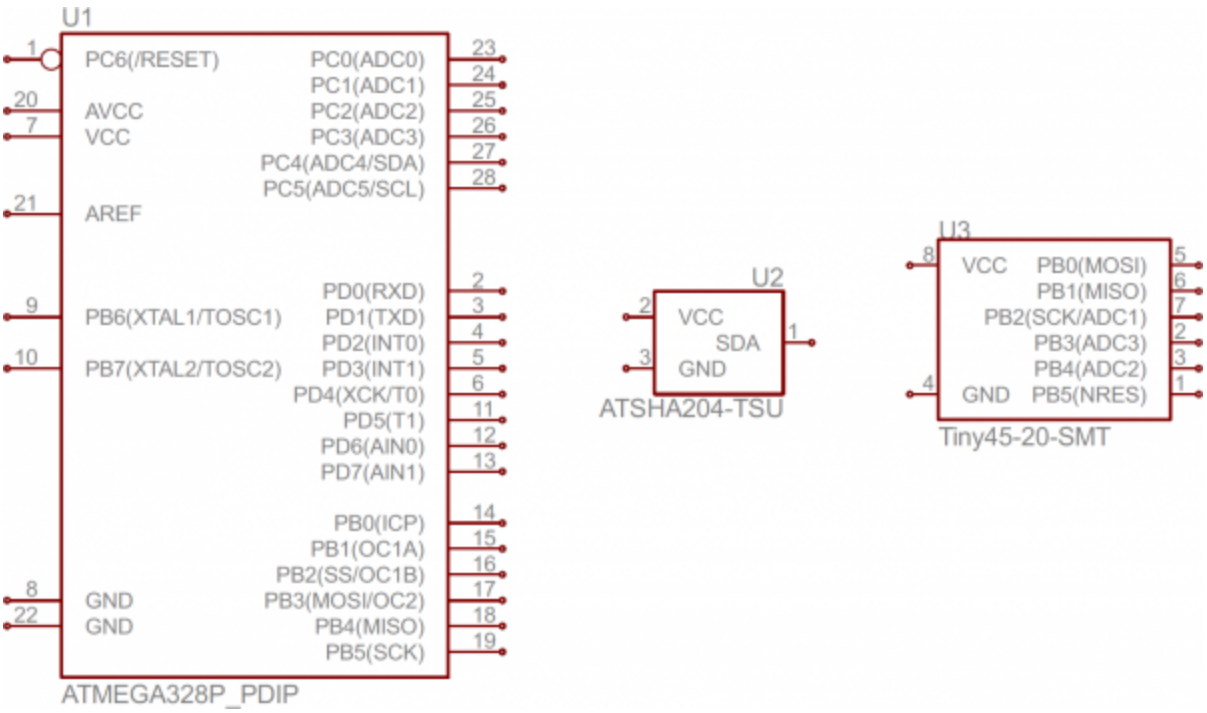
- there are all sorts of different types of diodes, each of which has a special riff on the standard diode symbol. e.g leds augment the diode symbol with a couple lines pointing away. (google)
- transistors are semiconductors used to amplify electrical signals. whether they're BJTs or MOSFETs can exist in two configurations: positively doped or negatively doped. so for each of these types of transistor, there are at least two ways to draw it.



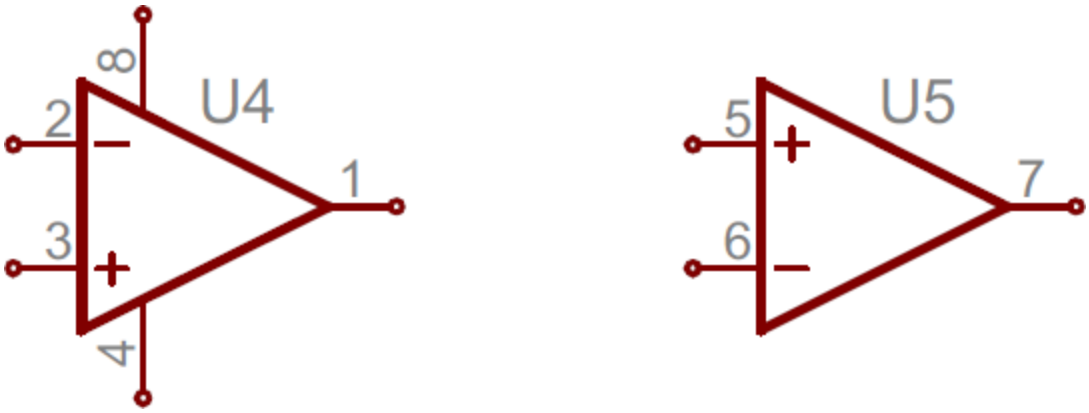
- digital logic gate: our standard logic functions - AND, OR, NOT, and XOR - all have unique schematic symbols, and adding a bubble to the output negates the function, creating NANDs, NORs, and XNORs:



- ICs accomplish such unique tasks, and are so numerous, that they don't really get a unique circuit symbol



- ^ schematic sybols for an ATmega328 microcontroller (commonly found on Arduinos), an ATSHA204 encryption IC, and an ATtiny45 MCU
- there are couple of common ICs that do get a unique circuit symbol. you'll usually e op amps laid out like below, with 5 total terminals: a non-inverting input (+), inverting input (-), output, and two power inputs.



- often, there will be two op amps built into one IC package requiring only one pin for power and one for ground, which is why the one on the right only has three pins.

name designators and value

- one of the biggest keys to being schematic-literate is being able to recognize which components are which.
- values help define exactly what a component is = most important characteristic.
- component names are usually a combination of one or two letters and a number & there are some common prefixes:
  - R = resistor
  - C = capacitors
  - L = inductors
  - S = switches
  - D = diodes
  - Q = transistors
  - U = ICs
  - Y = crystals and oscillators
- (although sometimes you have to use your best judgment!)

reading schematics

- nets, nodes, and labels
- schematic nets tell you how components are wired together in a circuit
- nets are represented as lines between component terminals
- wires can connect two terminals together, or they can connect dozens. when a wire splits into two directions, it creates a junction. we represent junctions on schematics with nodes, little dots placed at the intersection of the wires
- absence of a node at a junction means two separate wires are just passing by
- sometimes, to make schematics more legible, we'll give a net a name and label it, rather than routing a wire all over the schematic. nets with the same are assumed to be connected, even though there isn't a visible wire connecting them.

schematic reading tips (bc i need these!)

- identify blocks
- recognize voltage nodes
- if there’s something on a schematic that just doesn’t make sense, try finding a datasheet for the most important component

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wave terminology

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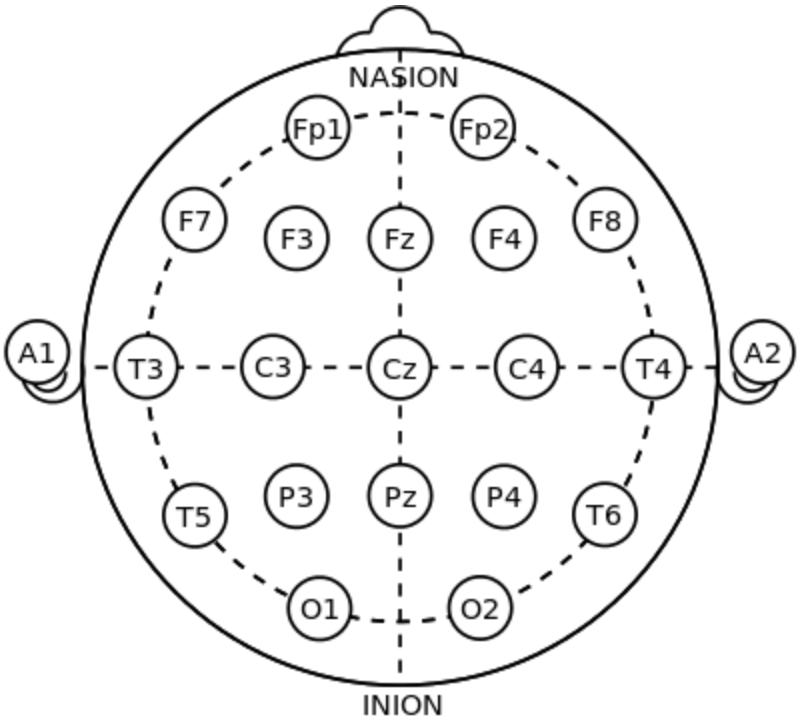
electroencephalography

https://en.wikipedia.org/wiki/10–20_system_(EEG)

- EEG is a method to record an electrogram of the spontaneous electrical activity of the brain.
- Biosignals detected by EEG have been shown to represent the postsynaptic potentials
- Non invasive, electrodes are placed along the scalp (we have kit alr, commonly called “scalp EEG”)
  - ▼ Using the international 10-20 system
    - internationally recognized method to describe and apply the location of scalp electrodes
    - the “10” and “20” refer to the fact that the actual distances between adjacent electrodes are either 10% or 20% of the total front-back or right-left distance of the skull
    - for example, a measurement is taken across the top of the head, from the nasion (it marks the midpoint) to inion ()
    - electrod labeling: each electrode placement site has a letter to identify the lobe, or area of the brain it reading from:
    - FP = pre-frontal
    - F = frontal

- T = temporal
- P = parietal
- O = occipital
- C = central (C)… note that there is no “central lobe”; due to their placement, and depending on the individual, the “C” electrodes can exhibit/represent EEG activity more typical of frontal, temporal, and some parietal-occipital activity
- there are also (Z) sites, present mostly for reference/measurement points
- even-numbered electrodes (2, 4, 6, 8) refer to electrode placement on the right side of the head, whereas odd number refer to those on the left (applies to most ee- stuff)
- the A or M refers to the prominent bone process usually found just behind the outer ear



measurement

- specific anatomical landmarks are used for the essential measuring and positioning of the eeg electrodes. these are found with a tape measure, and often marked with

a grease pencil, or “china marker”.

- nasion to inion: the nasion is the distinctly depressed area between the eyes, just above the bridge of the nose, and the inion, is the crest point of back of the skull

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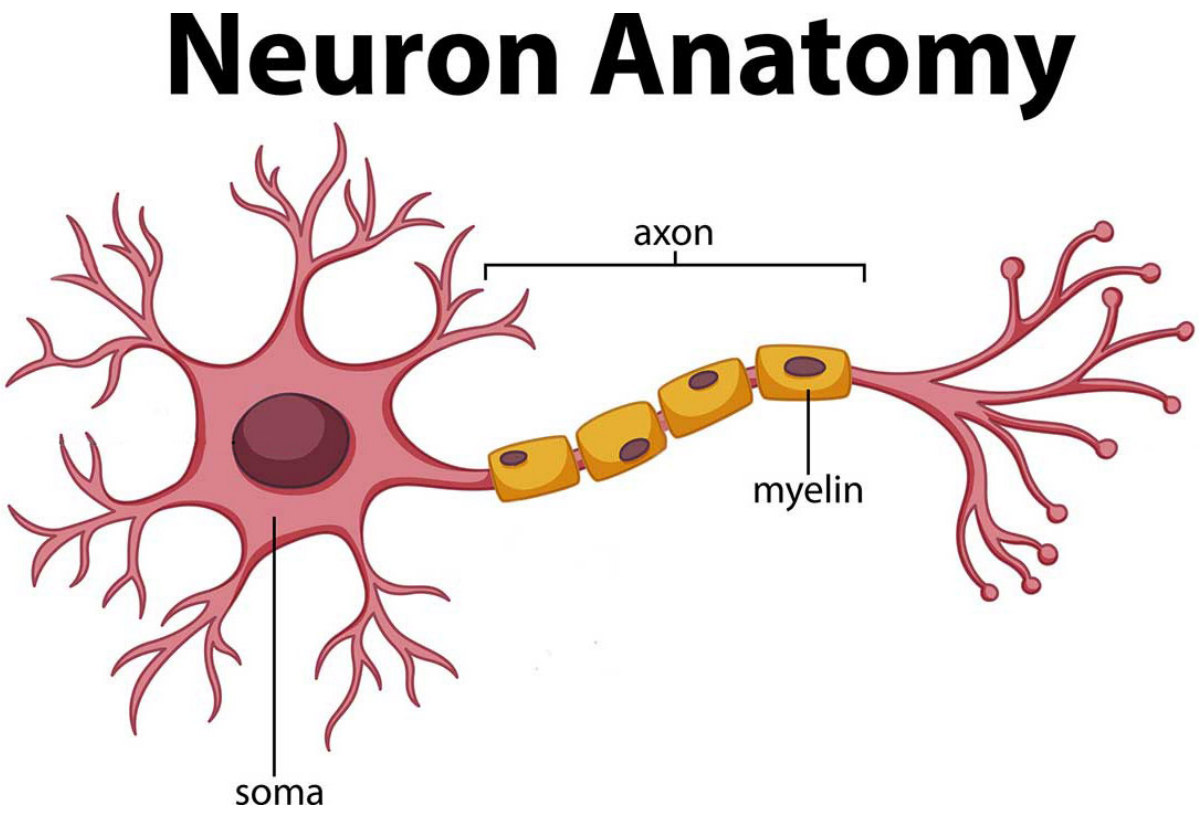
parts of the brain

just trying to generally understand the brain; ref for when i need to match smth up

https://www.hopkinsmedicine.org/health/conditions-and-diseases/anatomy-of-the-brain

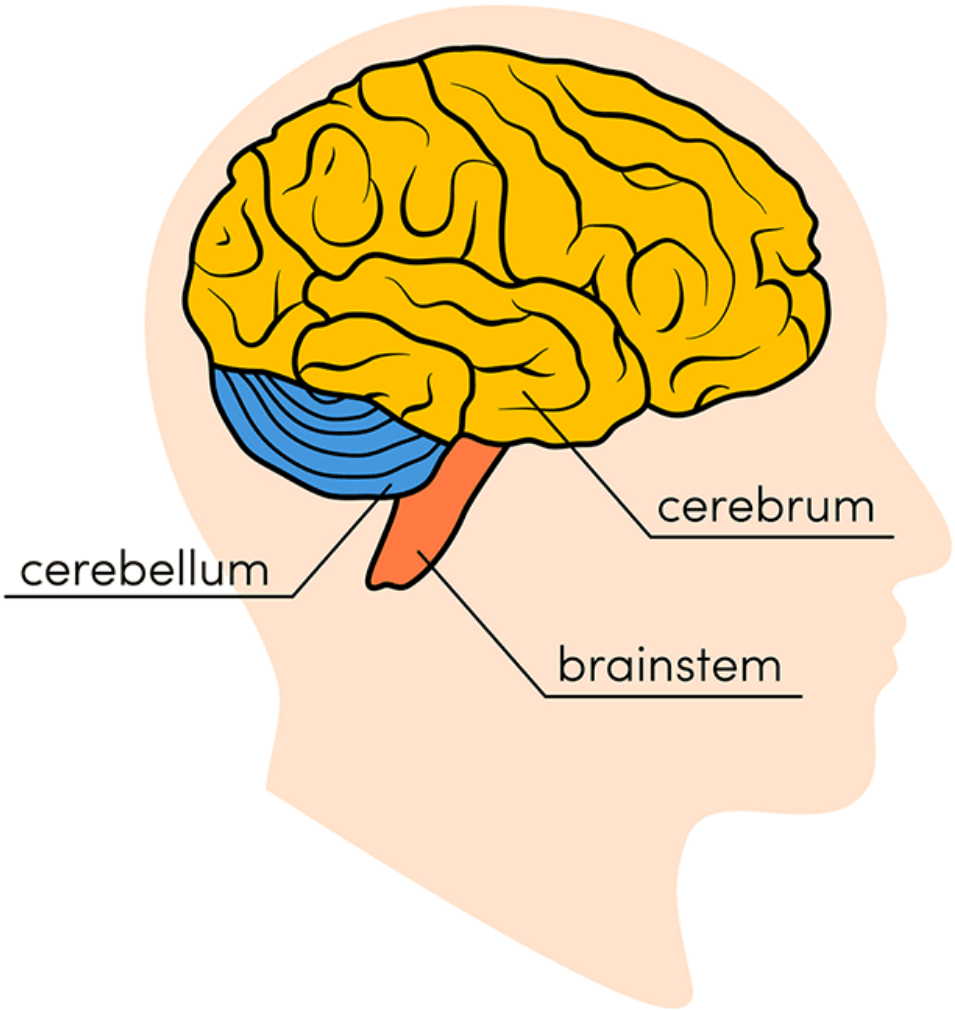
- weight about 3 pounds
- gray and white matter are two different regions of the central nervous system. in the brain, gray matter refers to the darker, outer portion, while white matter describes the lighter, inner section underneath
- gray matter mostly neuron somas (round central cell bodies), white matter is mostly axons (the long stems that connects neurons together) wrapped in myelin (protective coating)



- each region = diff role
- brain sens and receives chemical and electrical signals
- different signals control diff processes
- eeg read signals

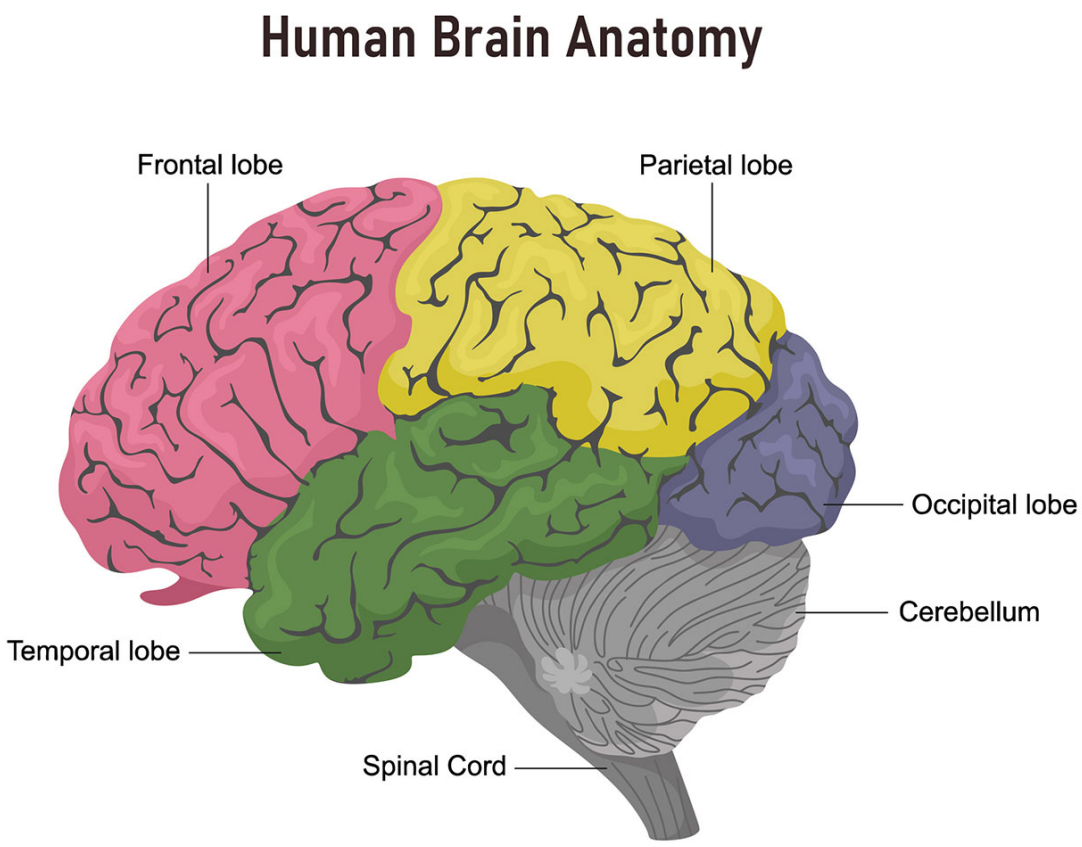
main parts of the brain and their functions

high level: brain can be divided into the cerebrum, brainstem, and cerebellum.



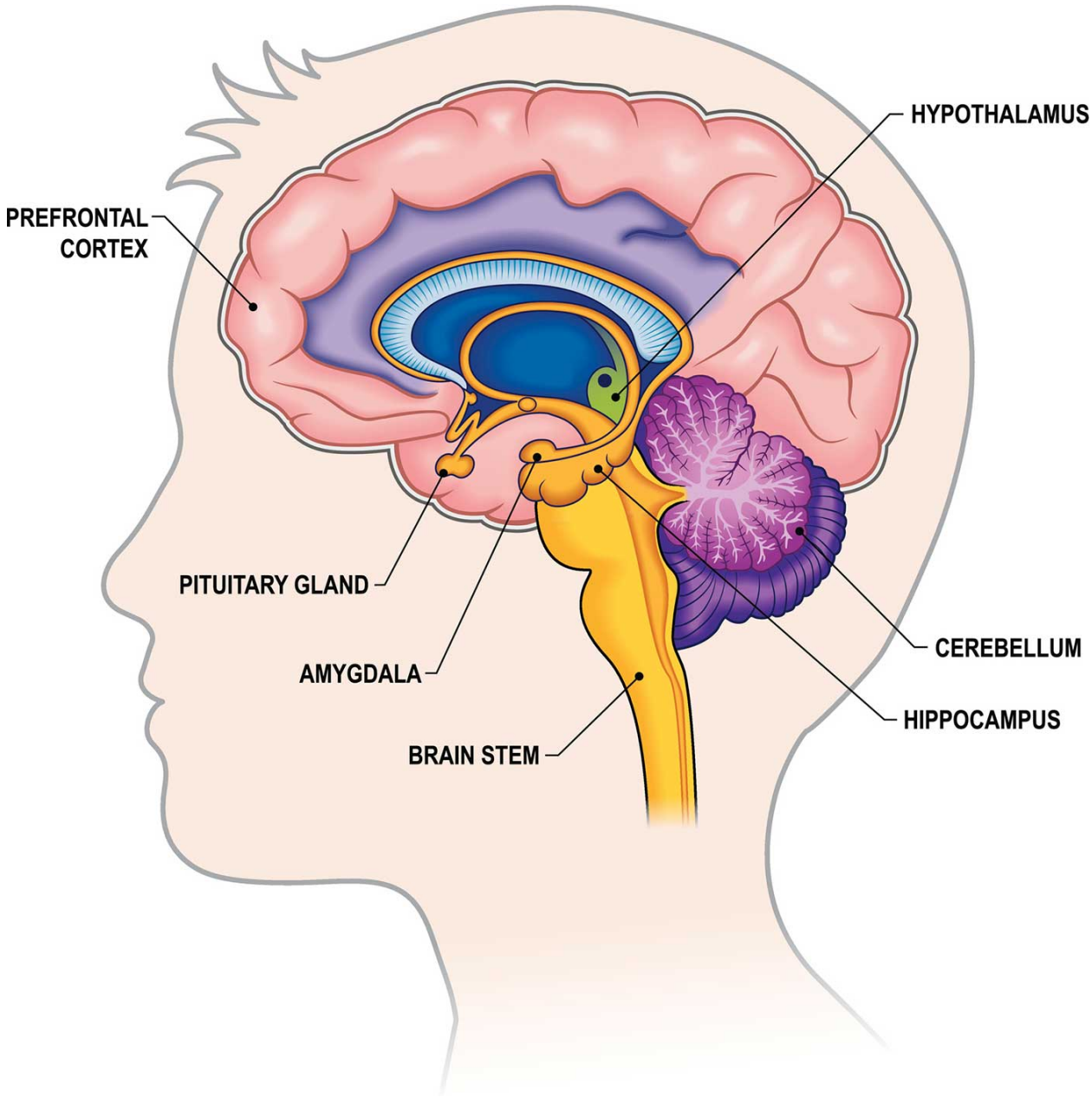
- the crebrum (front of brain) comprises gray matter (the cerebral cortex) and white matter at its center. it is the largest part of the brain & initiates and coordinates movement and regulates temp
    - other areas enable speech, judgment, thinking and reasoning, emotions and leanring… senses
    - cerebral cortex
        - large surface area due to its folds
        - divided into two halves, or hemispheres
        - covered with ridges (gyri) and folds (sulci)
        - join at a large, deep sulcus (interhemispheric fissure, aka the medial longitudinal fissue)
        - right controls left, left contrls right
        - communicate through a large, c-shaped structure of white matter in center of the cerebrum called corpus callosum
    - brainstem
        - connects the cerebrum with the spinal cord. the brainstem includes the midbrain, the pons and the medulla.
        - midbrain: very complex structure with a range of different neuron clusters (nuclei and colliculi), neural pathways. functions: hearing, movement, calculating responses/environmental changes
        - pons: origin for 4 of the 12 cranial nerves. functions: tear production, chewing, blinking, focusing vision, balance, hearing and facial expression
        - medulla: bottom of brainstem, connects to spinal cord. essential to survival as it regulates many bodily activities
    - cerebellum is a fist-sized portion of the brain lcoated below the temporal and occipital lobesand has two hemispheres. outer portion contains neurons, inner area communicates with the cerebral cortex. its function is to coordinate voluntary muscle movements
    - three layers of portective covering (meninges)

- lobes of the brain: each brain hemisphere (cerebrum) has four sections, called lobes:



- frontal lobe: personality characteristics, decision making, movement
- parietal lobe: helps a person identify objects and spatial relationships
- occipital love: vision
- temporal lobe: short-term memory

deeper structures within the brain



- pituitary gland: sometimes called the “master gland”, the pituitary gland is a pea-sized structure found deep in the in the brain behind the bridge of the nose. hormones
- hypothalamus: sends pituitary gland chemical messages that control its functions: regulates body temp, synchronizes sleep patterns, controls hunger and thirst
- amygdala: one located under each half of the brain, regulate emotion and memory

- hippocampus: a curved seahorse-shaped organ on the underside of each temporal lobe, supports memory, learning, navigation
- pineal gland: located deep in the brain and attached by a stalk to the top of the third ventricle: sleep