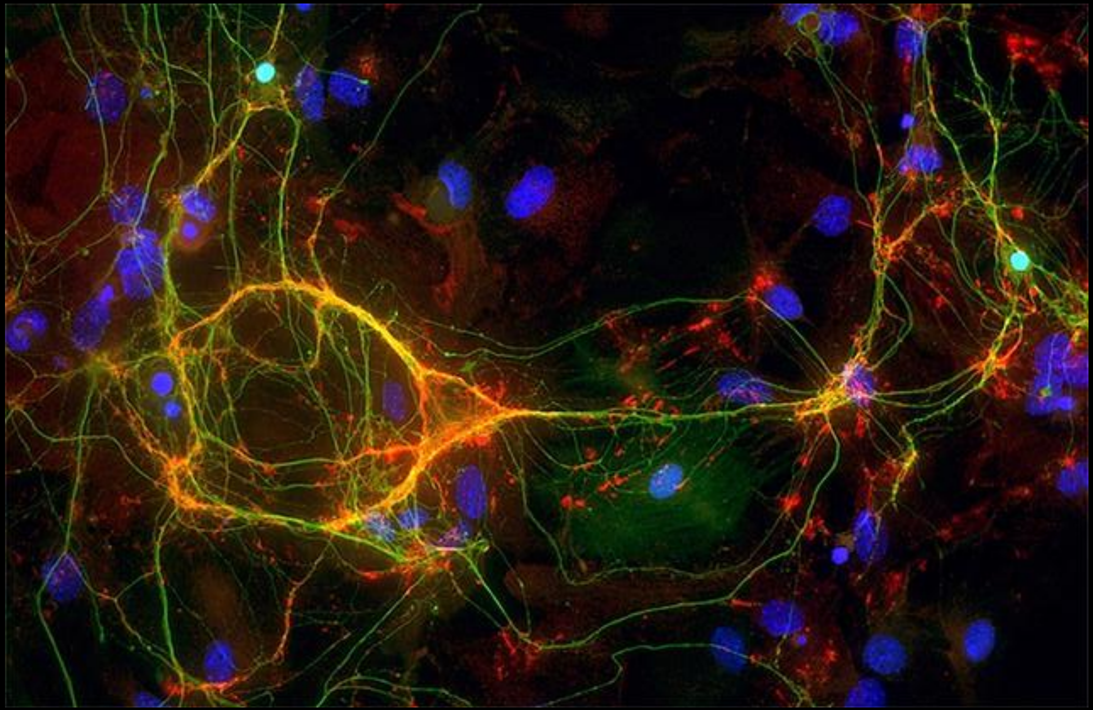
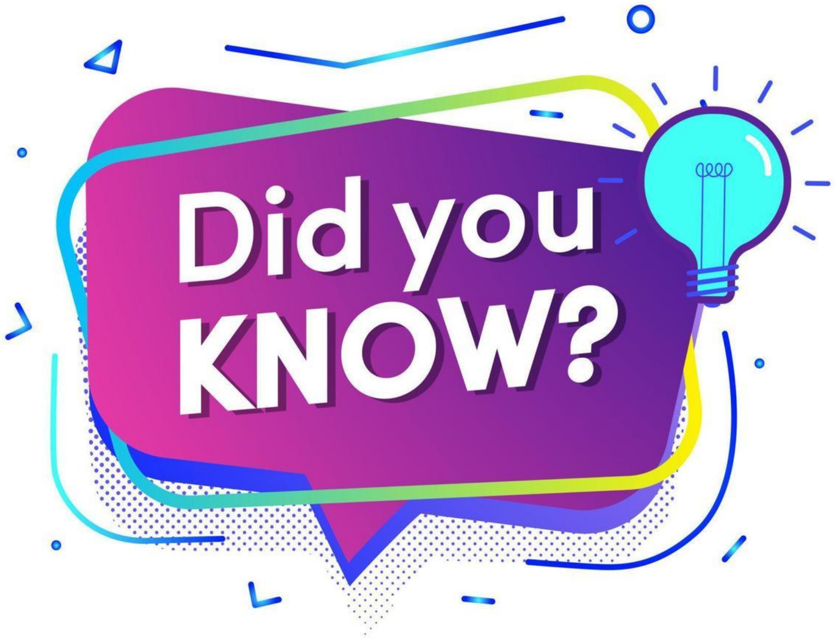
Knowledge Category 2

Neurotransmission, Development, and Imaging





We are born with about 100 billion neurons

We lose about 10,000 per day

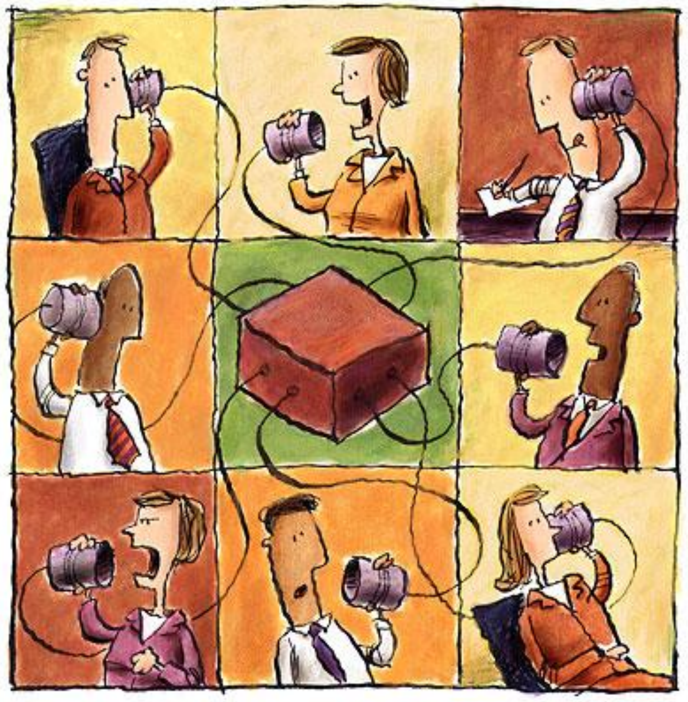
By age 70, we’ve only lost about 2%

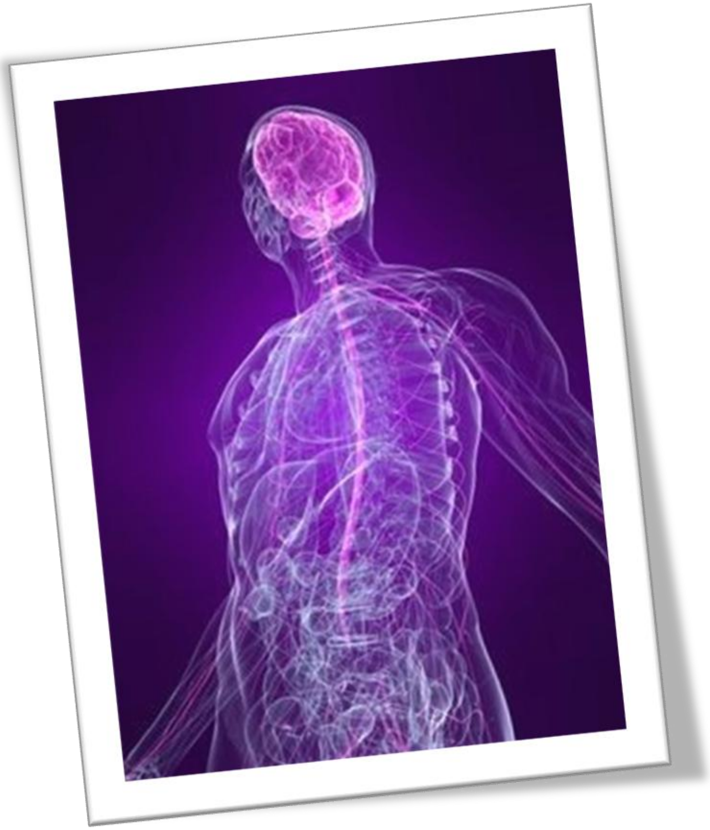
Neurons can regenerate in the hippocampus & caudate n.

Scientists estimate that humans have 100 trillion synaptic connections

Each neuron can have a few to over 200,000 synapses

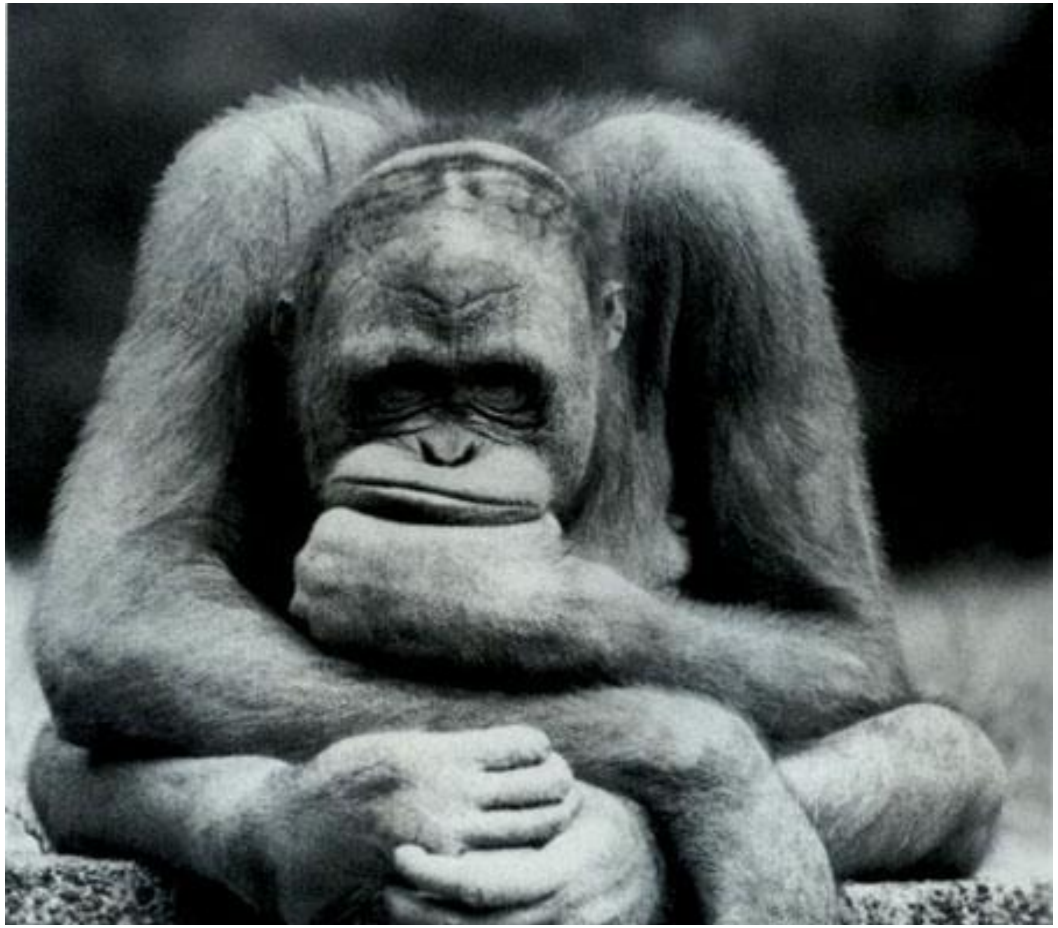
How do the different parts of our body COMMUNICATE?





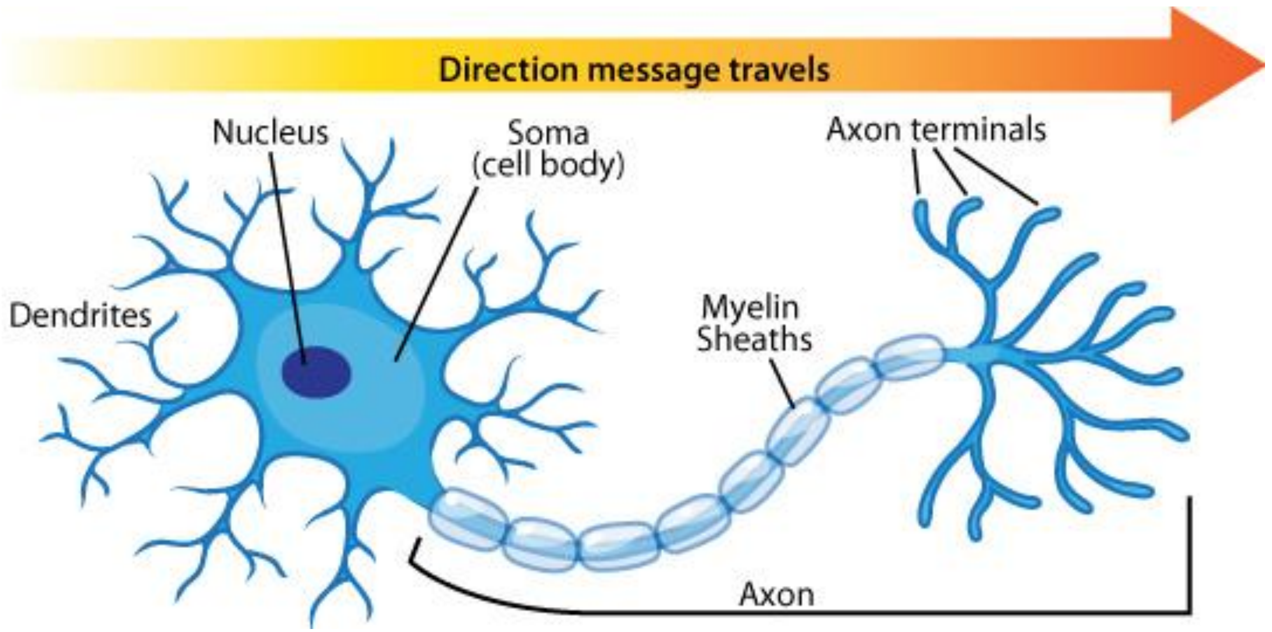
ANSWER: via the endocrine and nervous systems

Why is it important for us to understand how cellular communication works?



Two cell types in the NS: 10% Neurons & 90% Glial Cells

A "typical" motor neuron is multipolar

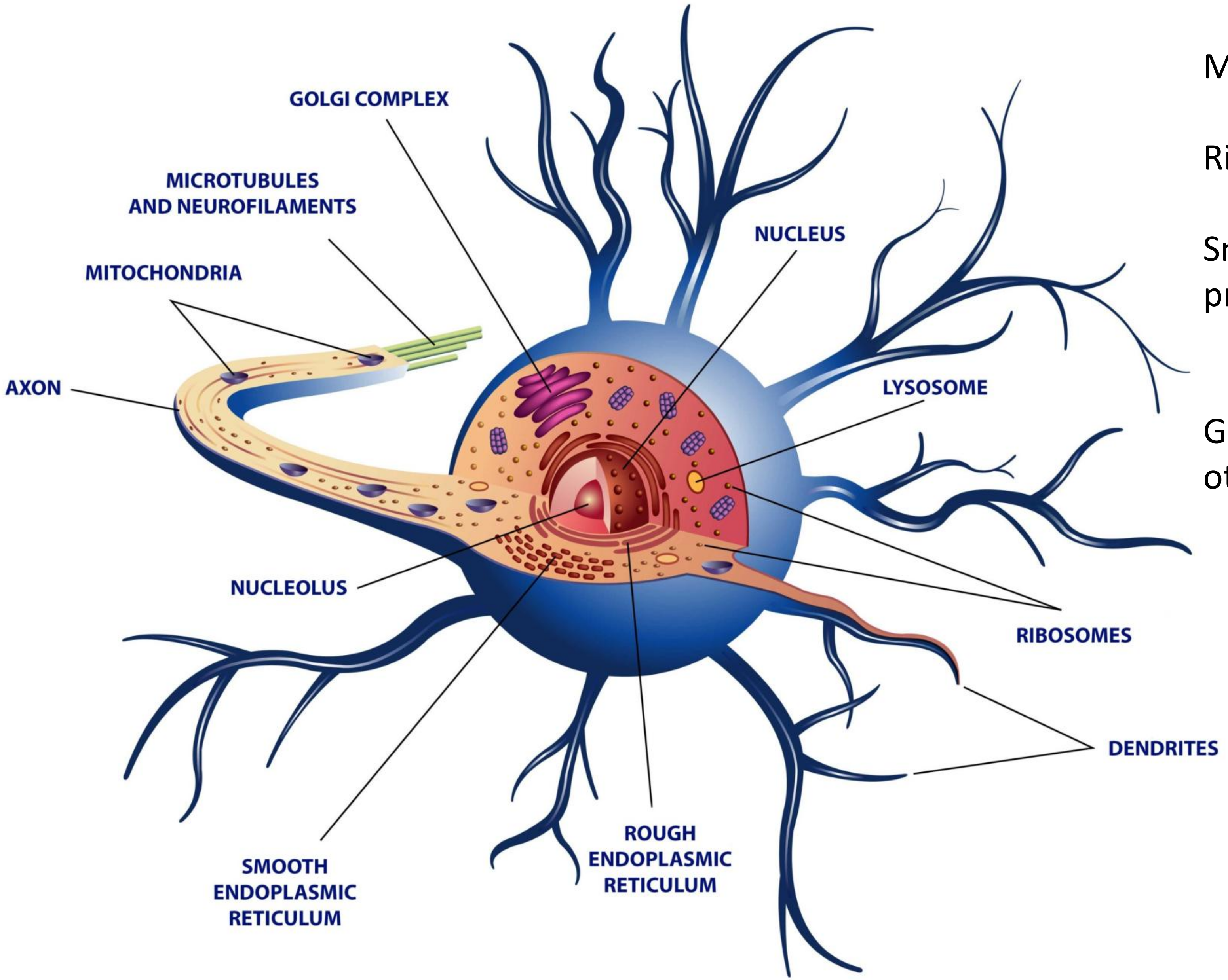


Cell body (soma) is the "life hub" mediates cell metabolism, growth, division, contains DNA

Axons are specialized to send information to other neurons

Dendrites are specialized to receive information from other cells

The Cell Body – Up Close and Personal



Mitochondria = metabolic activities

Ribosomes = code new proteins

Smooth endoplasmic reticulum = transport proteins to other cell locations

Golgi complex = prep neurotransmitters and other substances for excretion

All neurons have potential energy – this builds up until it EXPLODES and generates an action potential.

Electrochemical communication between neurons

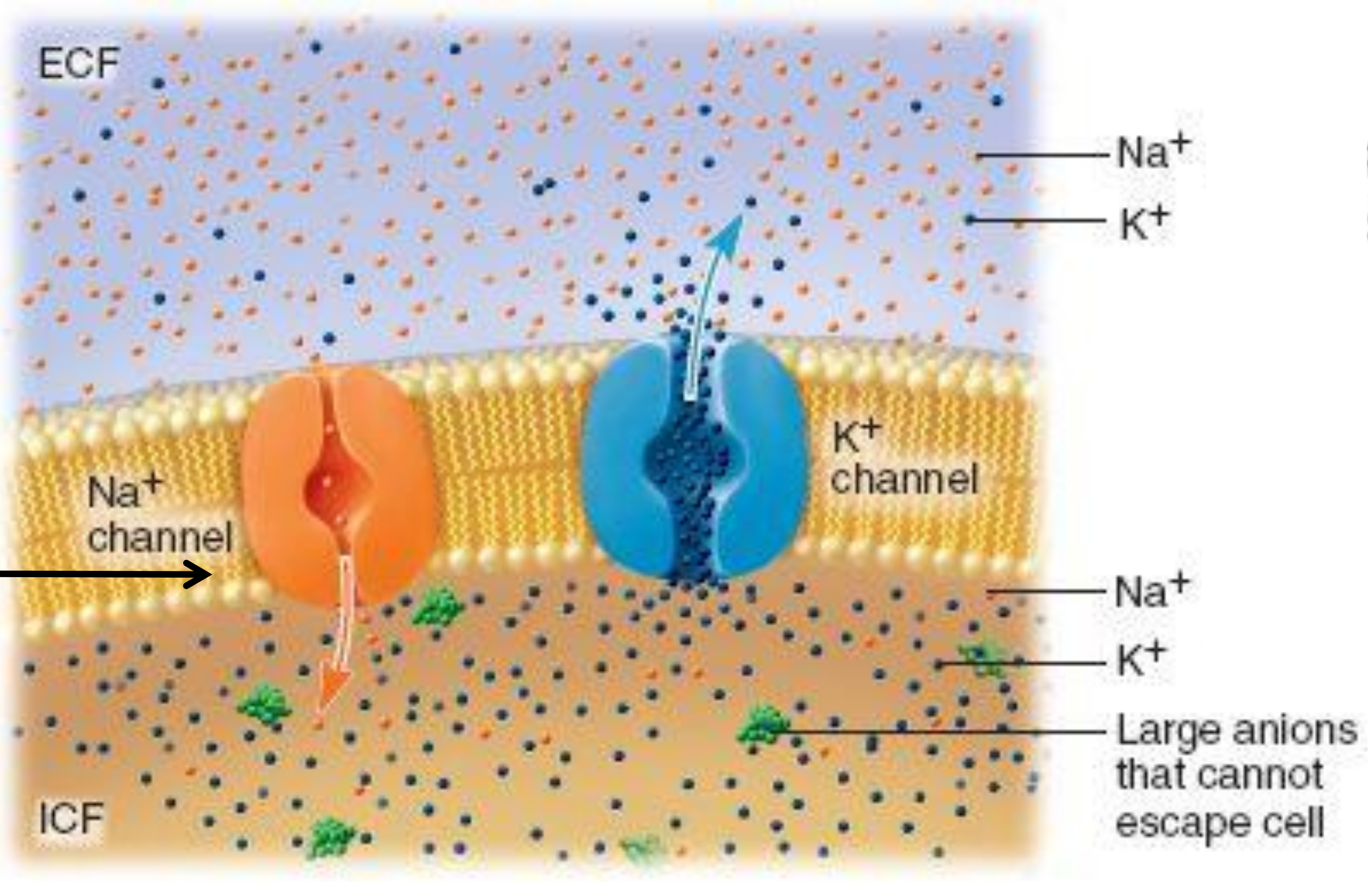
Step 1: the neuron at rest (polarized) Inside is more negative than outside. -70mV

Outside has more Sodium (+) and Chloride (-)

lipid molecules

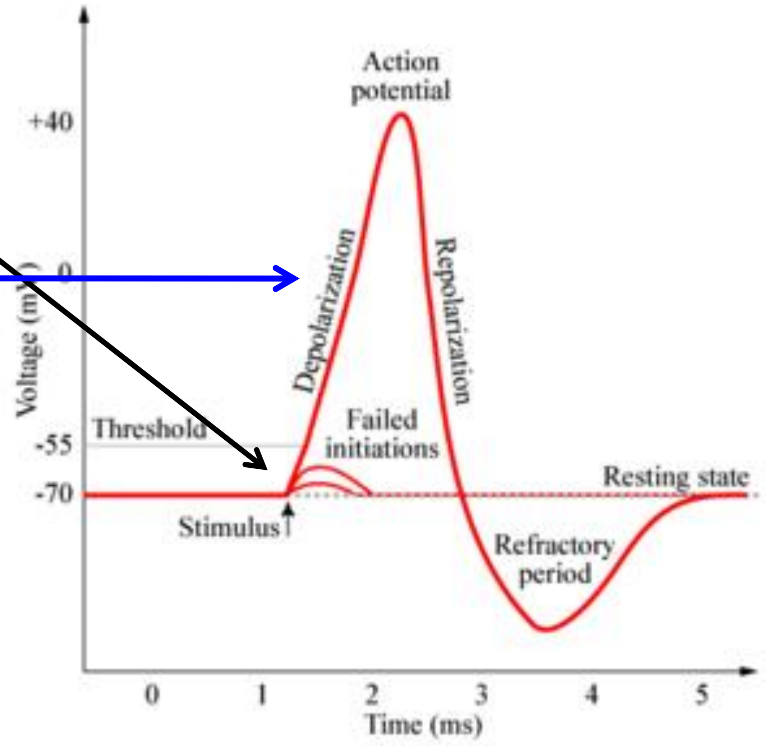
Ion channels

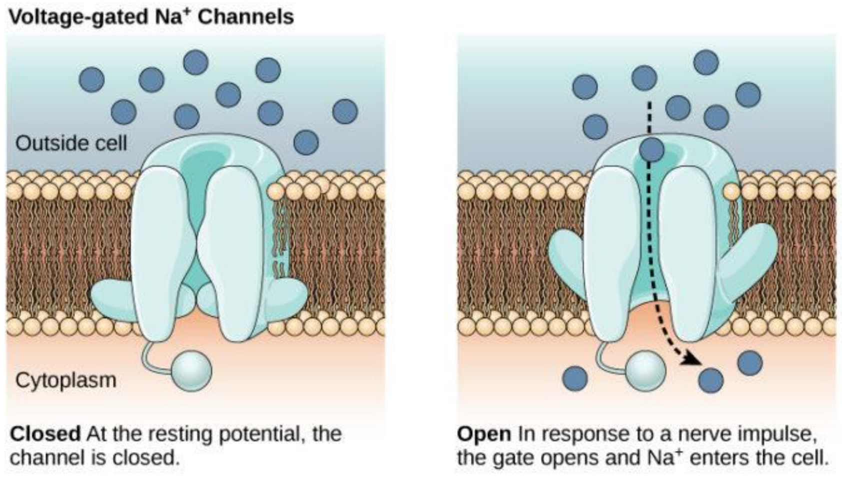
Inside has more Potassium (+) and anions (-)



Step 2: the neuron's membrane potential begins to depolarize (inside becomes less neg.)

If neighboring cells stimulate *our* neuron, sodium (+) will rush into the cell, making it less and less negative.

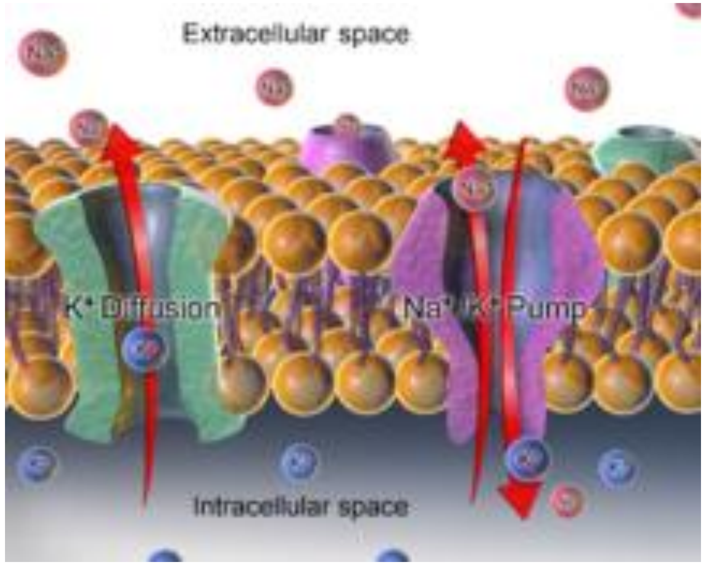


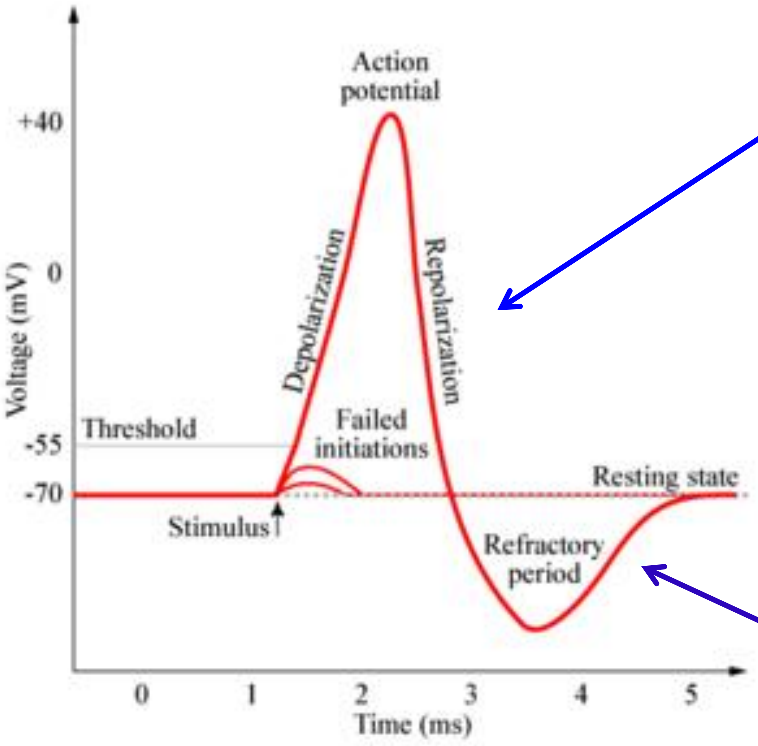


If it reaches approximately -55mV, our neuron will *fire = action potential!*

Step 3: the neuron's membrane potential begins to repolarize (inside becomes more neg.)

Eventually, the cell reaches its positive peak, sodium gates close, and potassium (+) gates open



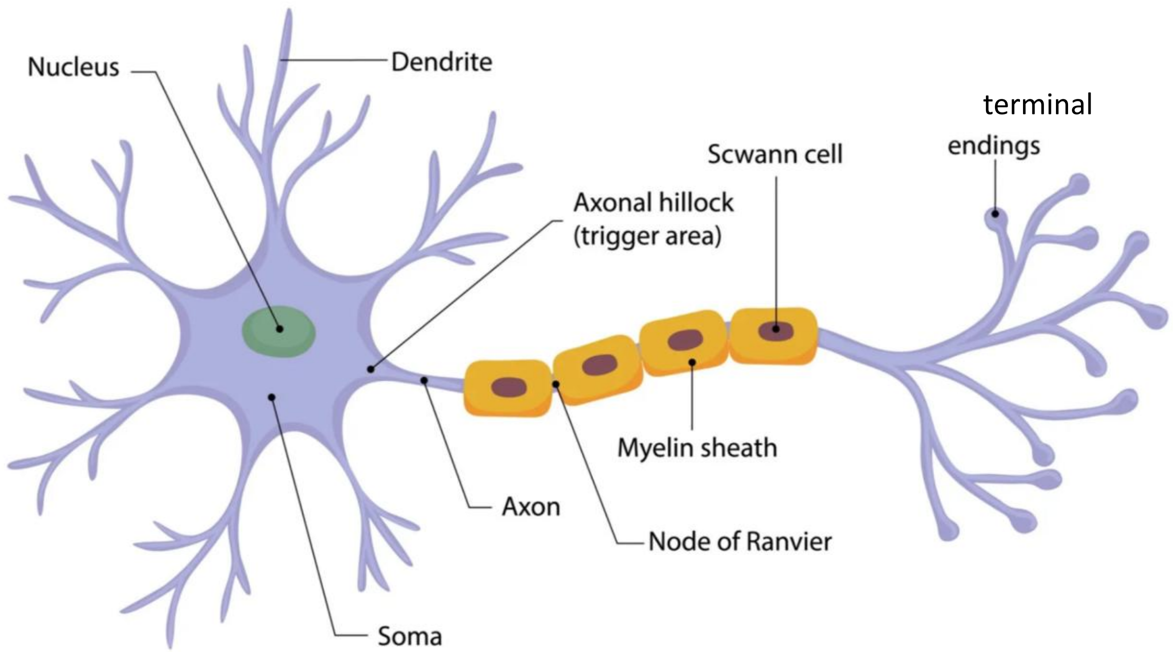


K+ rushes out, returning the cell to negative

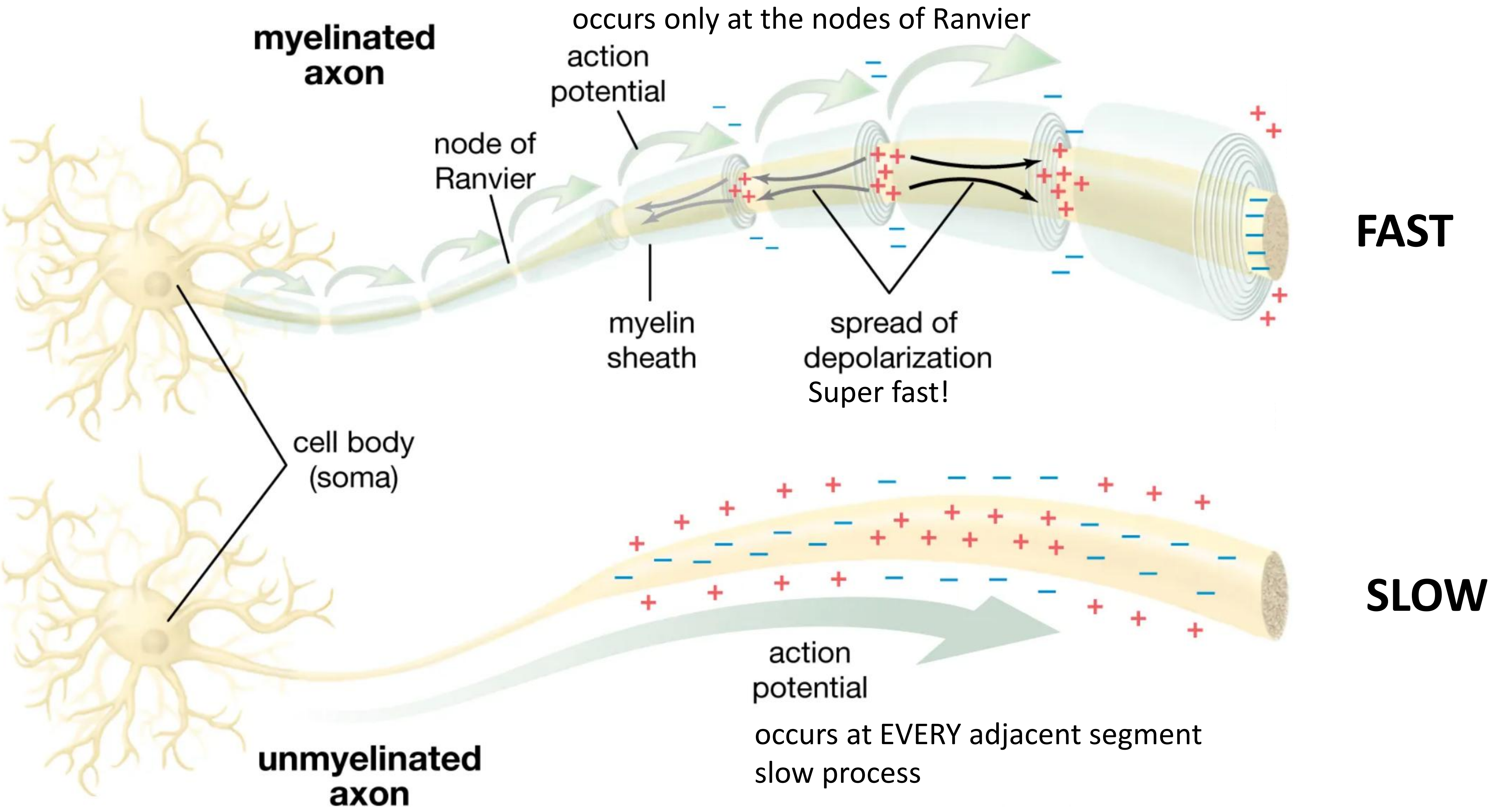
Oops! Too far! No worries, the Na – K pump will bring us back to normal ☺

Step 4: the action potential starts at the axon hillock and then sweeps down the axon

The first action potential begins at the AXON HILLOCK



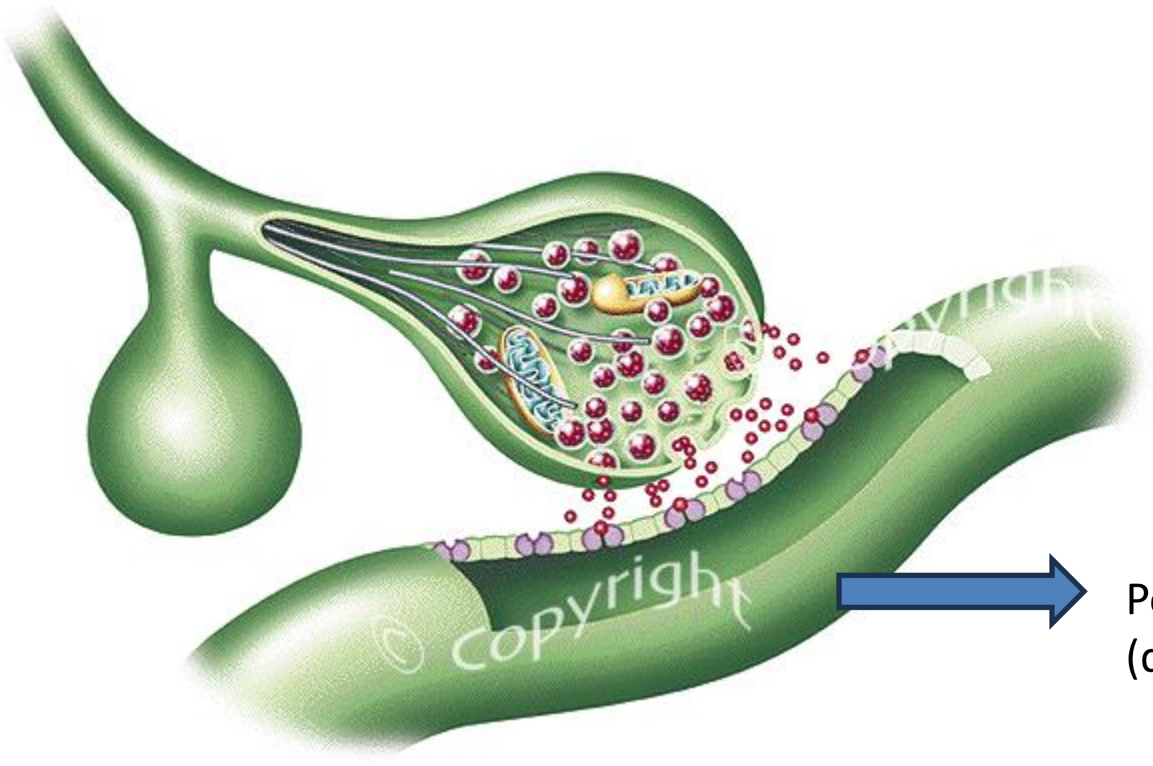
This creates a dominos effect of action potentials which end at the axon terminals


occurs only at the nodes of Ranvier
myelinated axon
action potential
node of Ranvier
myelin sheath
spread of depolarization
Super fast!
FAST
cell body (soma)
SLOW
action potential
occurs at EVERY adjacent segment
slow process
unmyelinated axon

Step 5 : neurotransmitters are released and bind to receptors on the postsynaptic cell

When the action potential reaches the terminal button, calcium in the synaptic space (cleft) enters the terminal button and NT's are released

Vesicles fuse with the cell membrane, break open and NT Spill out



Postsynaptic cell
(dendrite or soma)

Once NT’s bind to receptors on the post-synaptic cell, what then?

Step 6 : neurotransmitters on receptors generate a GRADED POST-SYNAPTIC POTENTIAL

Graded potentials are either inhibitory or excitatory

IPSP’s make the cell more negative, decreasing the probability that the cell will fire

EPSP’s make the cell less negative, increasing the probability that the cell will fire

PSP’s are “local potentials” which are distinct from action potentials

Local potentials vs. action potentials

Analogous to a gentle nudge vs. a explosive push

Local potentials

Decremental

Graded

Initiated in dendrite or soma

Action potential

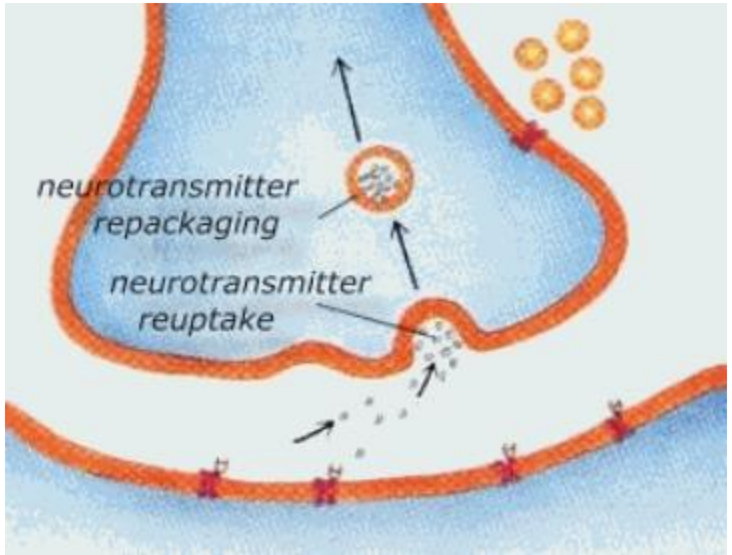
Non-decremental

All-or-none

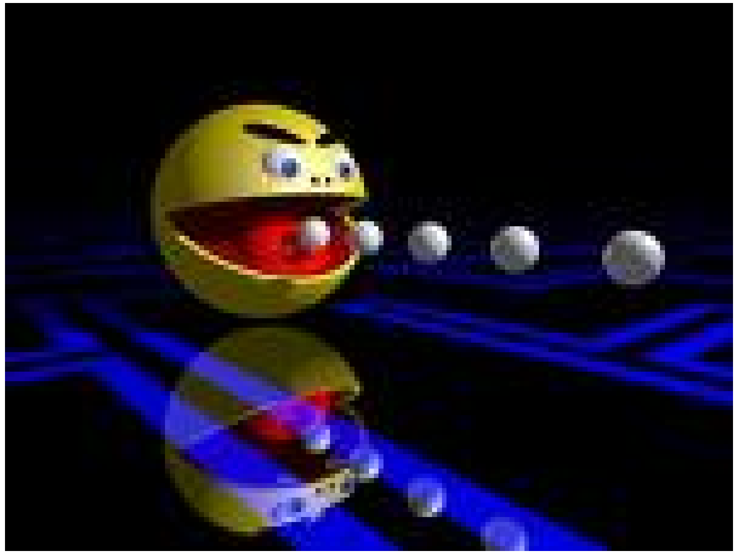
initiated at the axon hillock

Terminating synaptic activity

Re-uptake



Enzyme degradation



NEUROTRANSMITTERS

Acetylcholine Ach

Dopamine DA

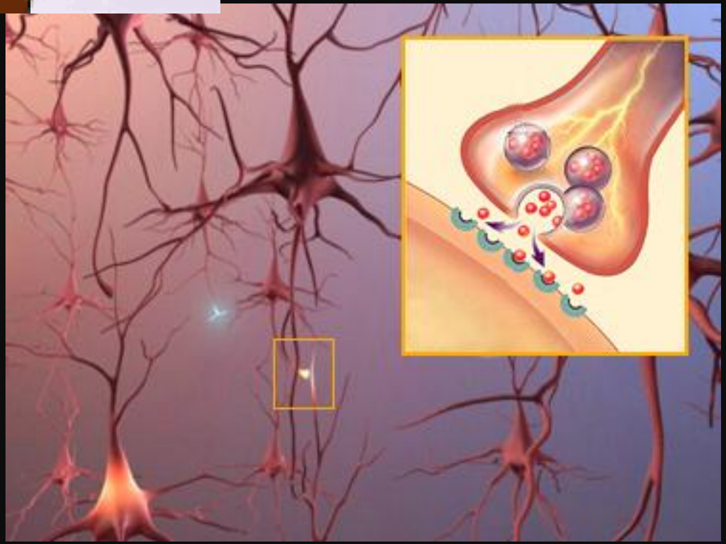
Norepinephrine NE

Serotonin 5-HT

Gamma-Aminobutyric Acid GABA

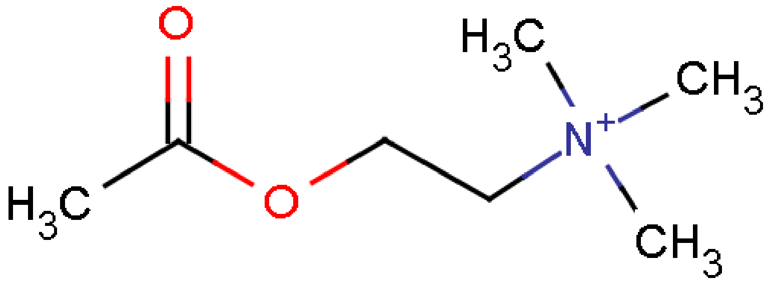
Glutamate

Endorphins



Acetylcholine

binds to muscarinic & nicotinic receptors



Peripheral nervous system ACH causes muscles to contract

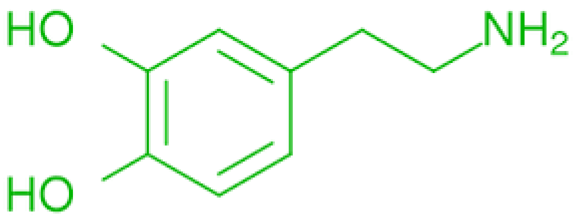
Central nervous system ACH involved in REM sleep, sleep-wake cycle, learning & memory
too little Ach in entorhinal cortex may mediate memory loss in Alzheimer's
cholinesterase (enzyme that breaks down Ach) inhibitors may slow memory loss
e.g. tacrine (Cognex), donepezil (Aricept), galantamine (Reminyl), rivastigmine (Exelon)

Dopamine

binds to DA1 through DA5 receptors

personality, mood, memory, movement, sleep, reward and pleasure

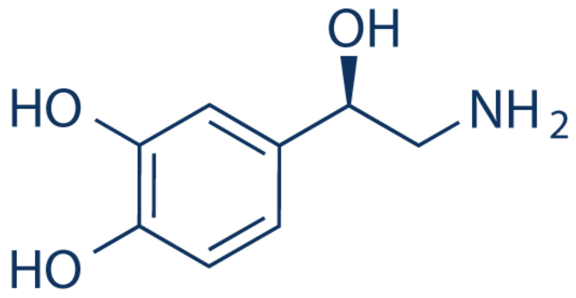
Found in peripheral and central nervous systems



Note: DA belongs to a class of NT called catecholamine along with Epinephrine and Norepinephrine

Norepinephrine

binds to alpha and beta-adrenergic receptors



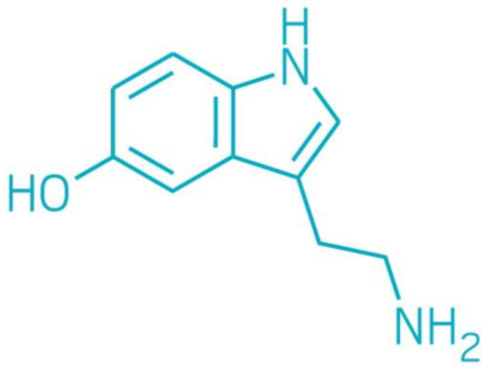
Central Nervous System: mood, attention, dreaming, learning

Peripheral nervous system: part of the stress response (autonomic nervous system)

Serotonin

binds to 5-HT1 through 5-HT7 receptors

mostly inhibitory



Found in peripheral and central nervous systems

mood, hunger, temperature regulation, sexual activity, arousal, sleep, aggression, migraines

GABA

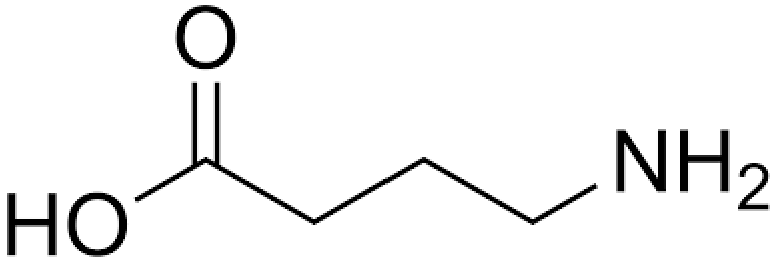
binds to GABAergic receptors

brain’s most prevalent inhibitory NT

found in Peripheral and central nervous systems

Eating, motor control, vision, sleep, anxiety

Benzodiazepines increase GABA binding



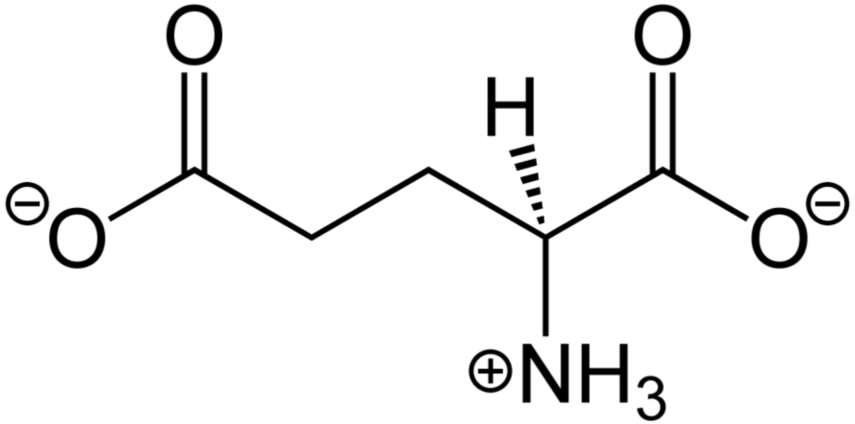
Glutamate

binds to NMDA receptors, AMPA receptors, and kainate receptors

brain’s most prevalent excitatory NT

found in peripheral and central nervous systems

learning and memory (long-term potentiation)



Endorphins

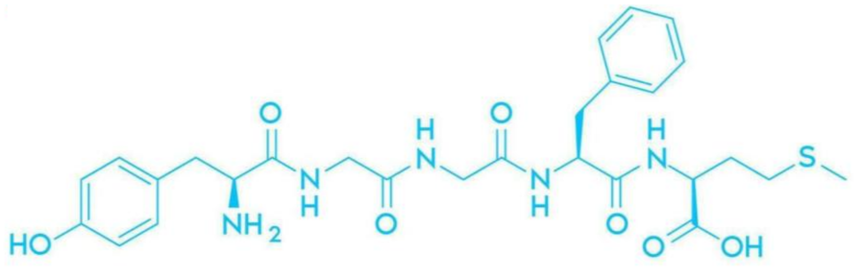
binds to opioid receptors

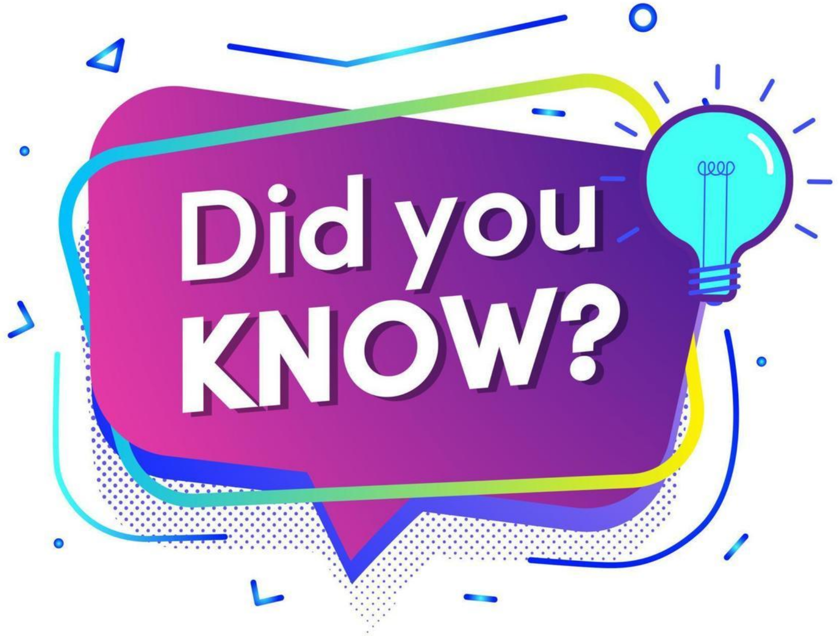
brain's natural painkiller

found in Peripheral and central nervous systems

emotions, memory, learning, sexual behavior, "runner's high"

may produce analgesic effects by blocking release of "Substance P" which transmits noxious info



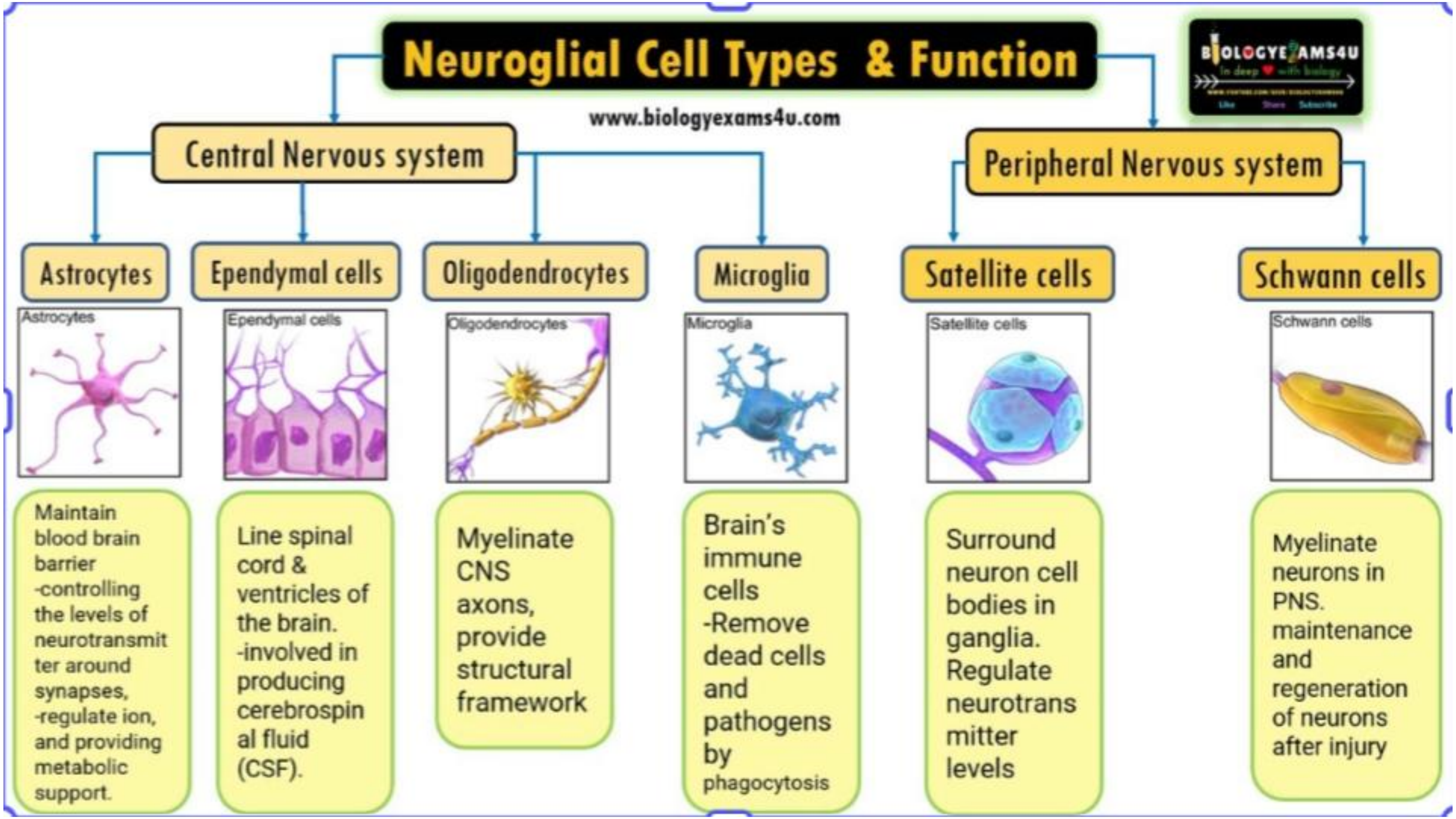


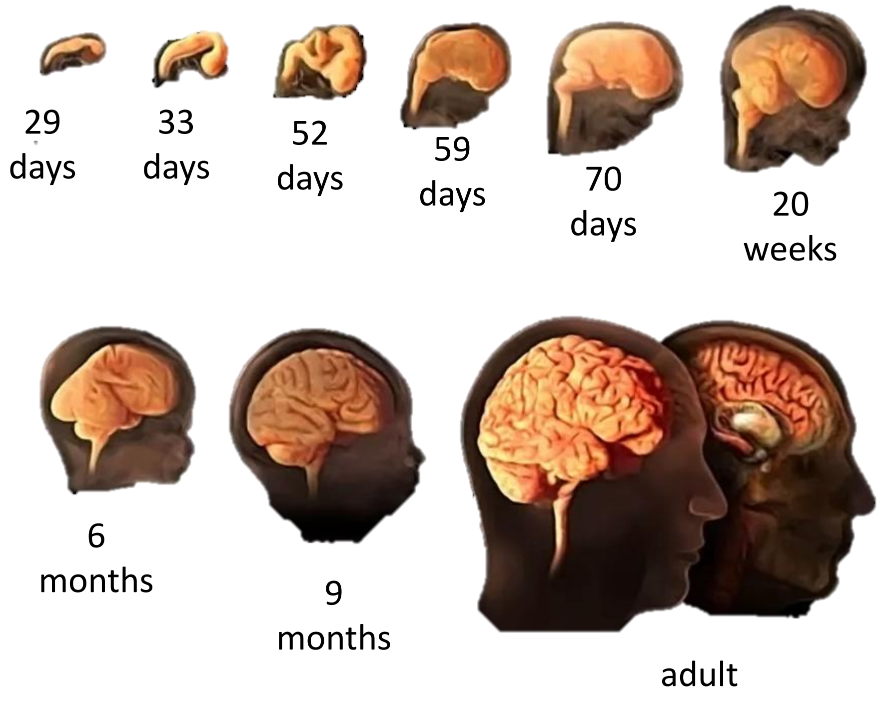
ALL these neurotransmitters are produced by gut microbes!

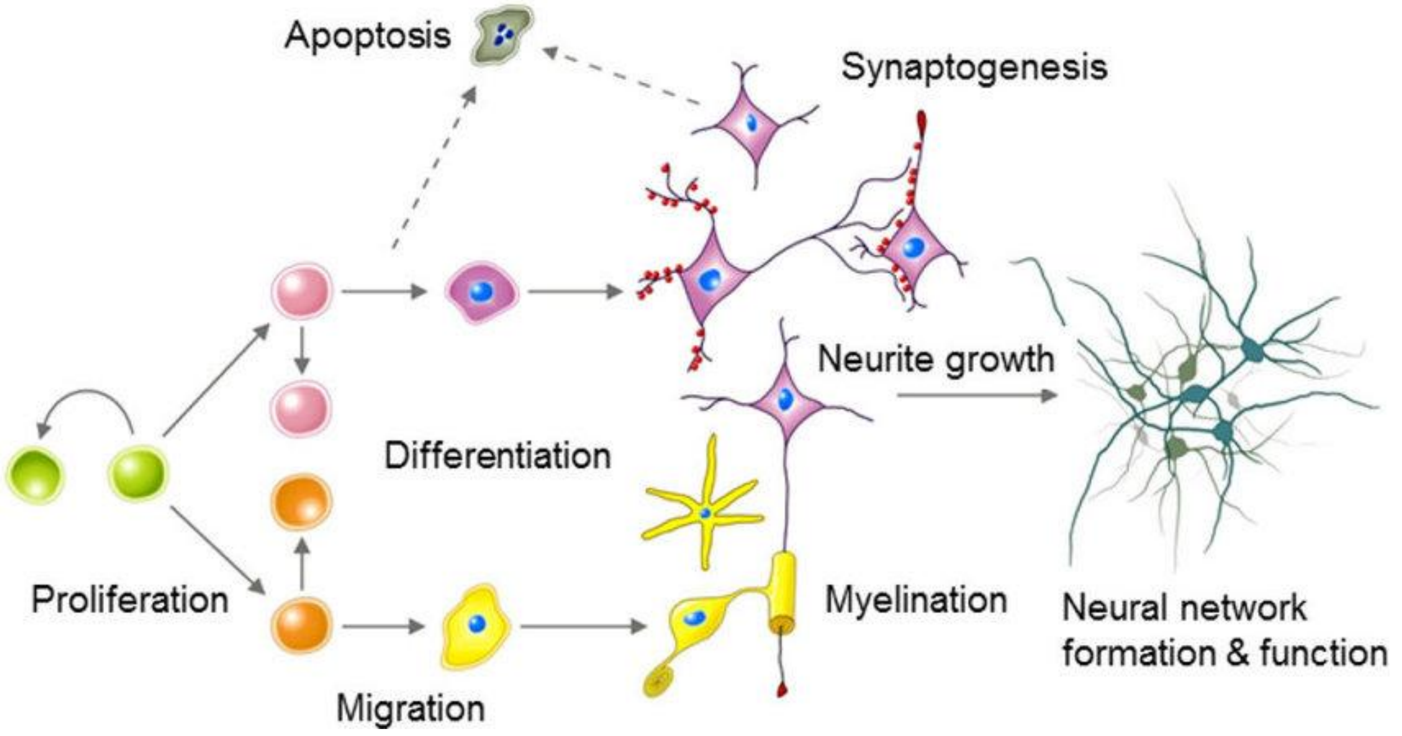
Some, like 5-HT are mainly produced there (90-95%)

What about Glial Cells in the nervous system?

Warning: Memorizing all this may be hazardous to your heath







1. **Proliferation:** new cells grow in the neural tube at about 2.5 weeks old

2. **Migration:** immature neurons travel to their final destination and cluster with other cells to form structures – begins at about 8 weeks

3. **Differentiation:** cells develop axons and dendrites

4. **Myelination:** glial cells begin to myelinate some axons much occurs after birth

5. **Synaptogenesis:** synapses form – timing depends on where in the brain, genetics, and experiential factors – much occurs after birth

Apoptosis: pruning to fine-tune development – pre & post birth

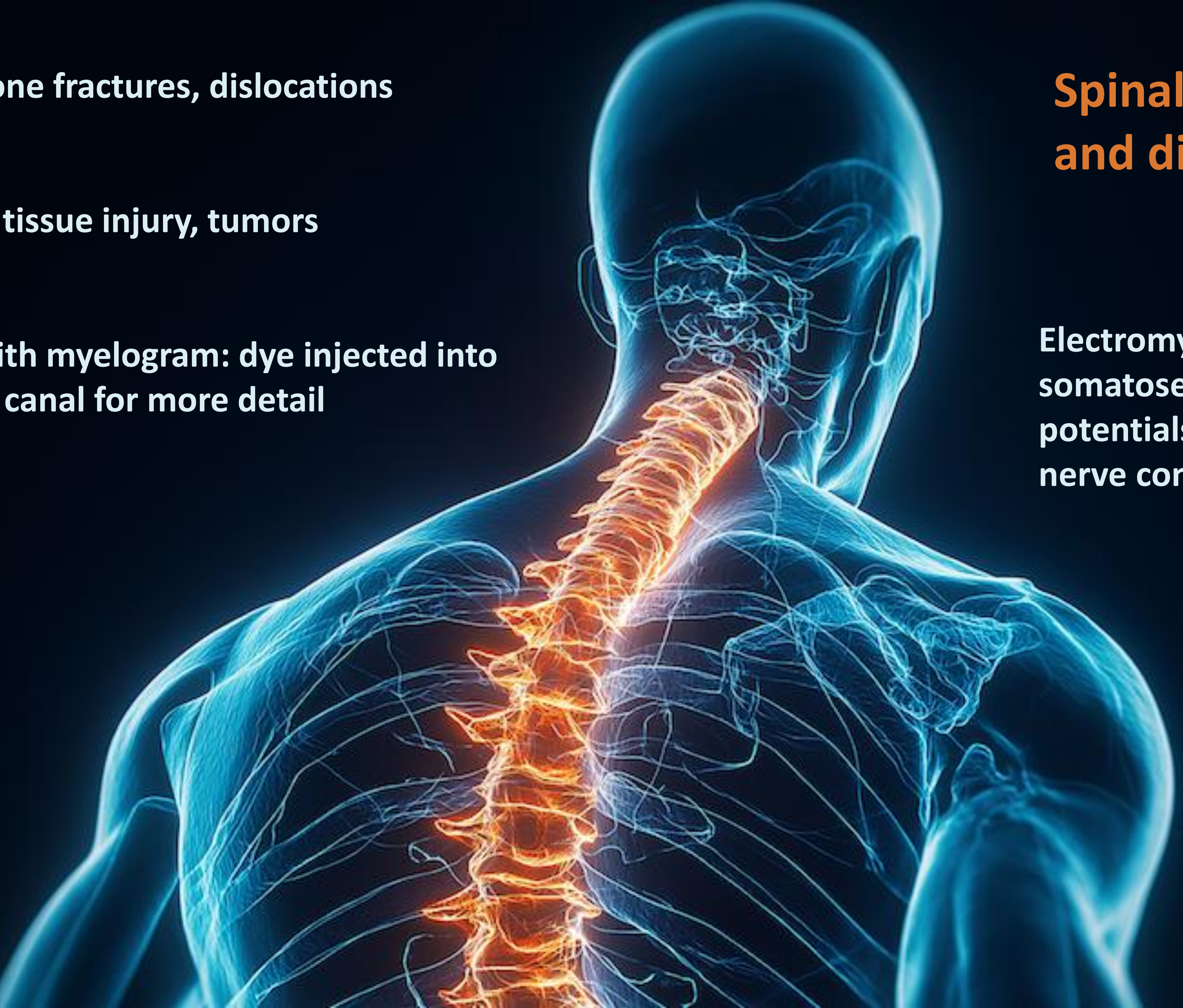
Spinal cord injury and disease

X-rays: bone fractures, dislocations

MRI: soft tissue injury, tumors

CT scan with myelogram: dye injected into the spinal canal for more detail

Electromyography (EMG) and somatosensory evoked potentials (SSEP): to assess nerve conduction



Structural Brain Imaging

deals with the structure of the brain and the diagnosis of large-scale intracranial disease e.g. tumor and/or injury

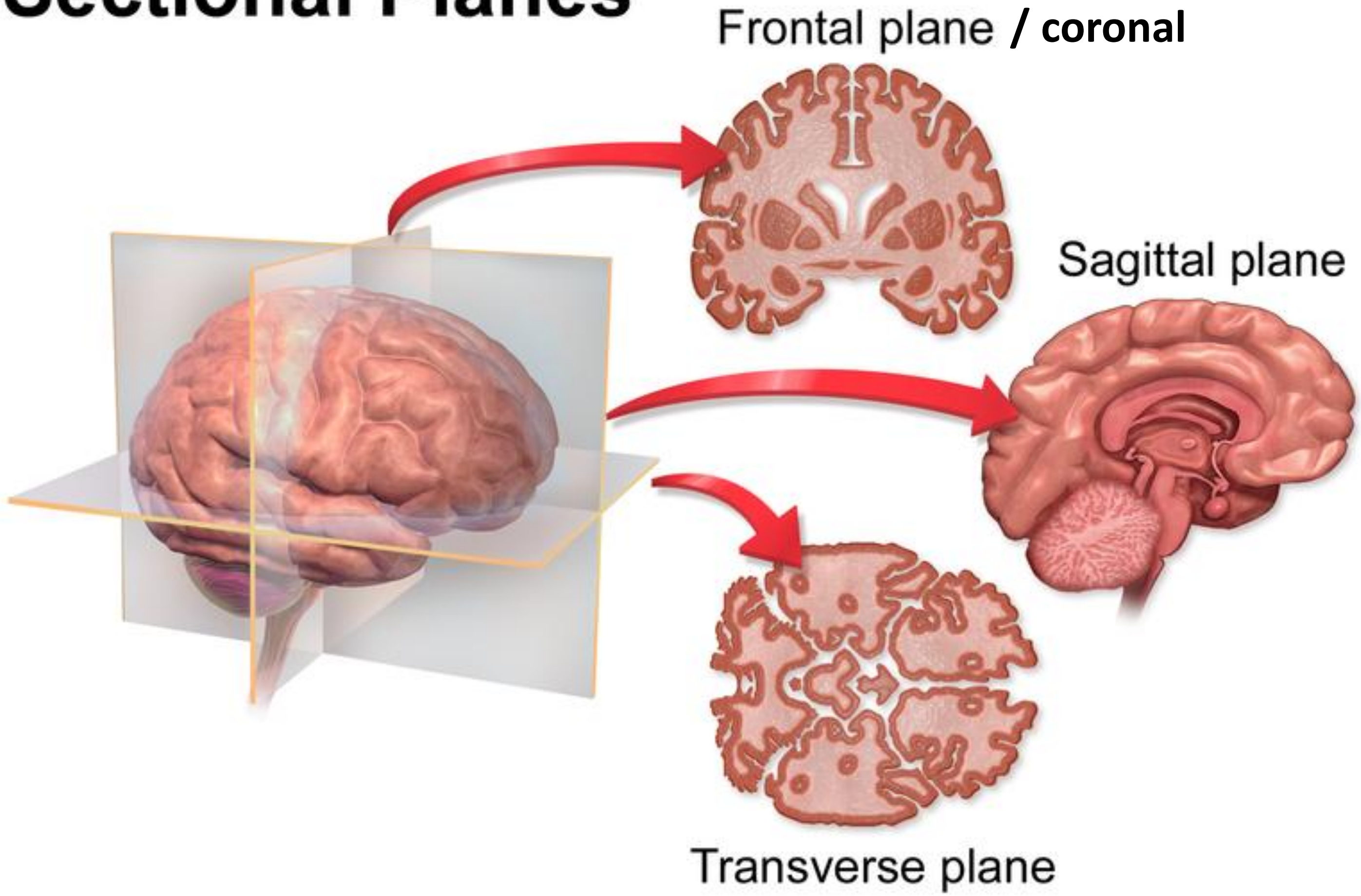
CT, MRI, Diffusion Tensor Imaging

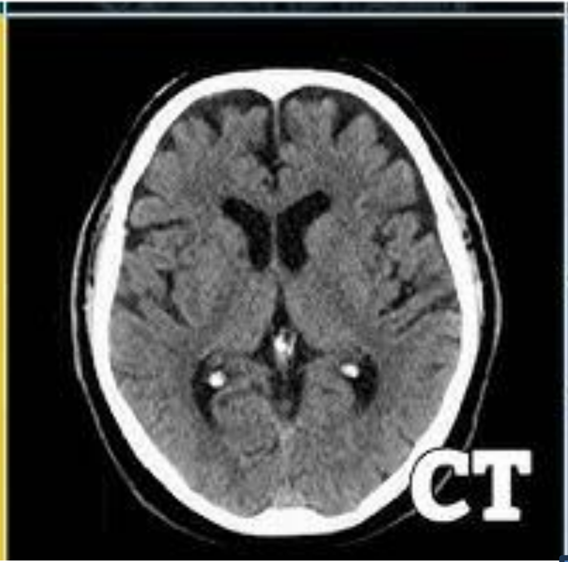
Functional Brain Imaging

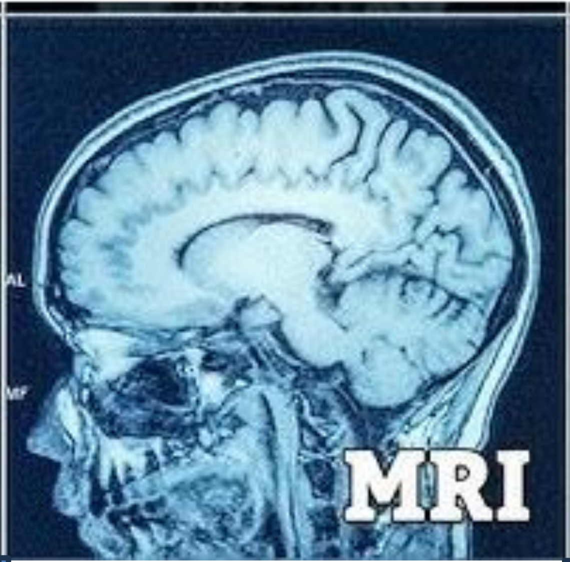
measures brain activity to understand relationships between activity in certain brain areas and specific mental functions

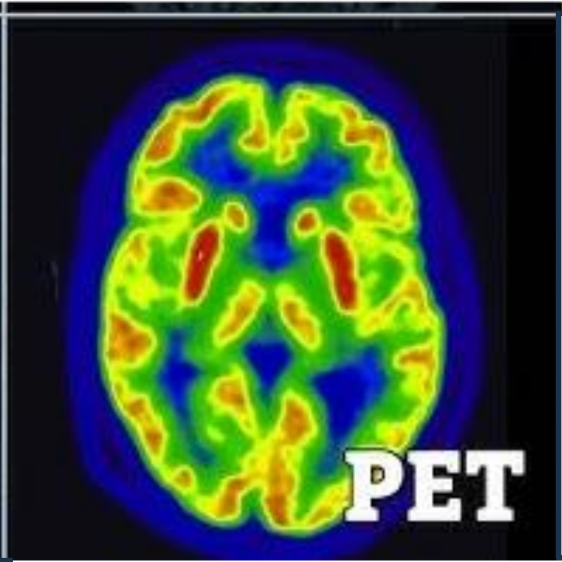
PET, fMRI, EEG

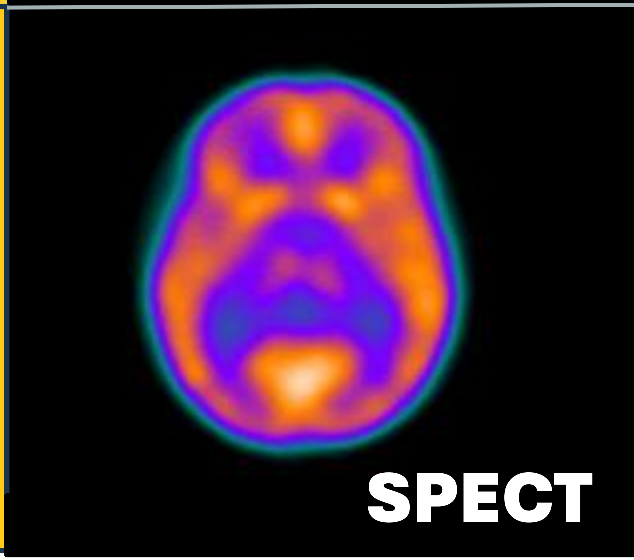
Sectional Planes











Computed Tomography or Computerized Axial Tomography (CAT)

Structural

Many x-rays are taken at different angles in the horizontal plane and then put together

tumors, blood clots, MS

Magnetic Resonance Imaging

Structural

Uses magnetic fields and radio waves to provide more detailed and 3-D images.

Not limited to the horizontal plane

More expensive & scary

Positron-Emission Tomography

Functional – activity

Injected radioactive tracer is taken up by active cells

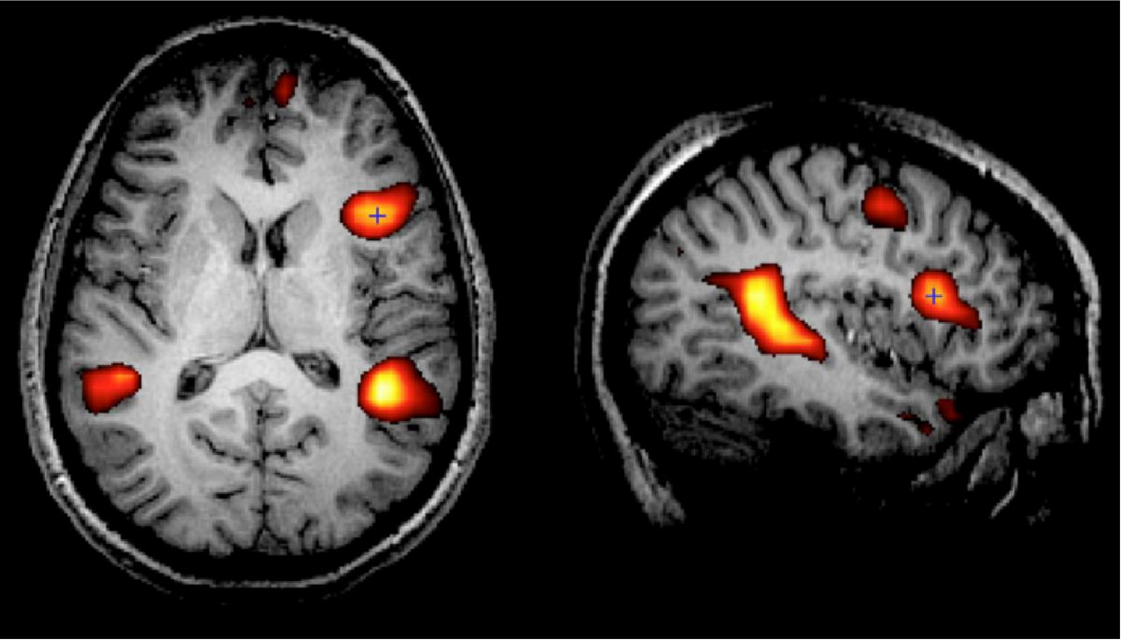
Regional cerebral blood flow, glucose metabolism, oxygen consumption

Help diagnosis Alzheimer's and schizophrenia

Single Proton Emission Computed Tomography

Functional – activity

Similar to PET but with lower resolution



Functional MRI: Function & structure

provides info on brain activity (blood oxygenation) with much better temporal and spatial resolution

Diffusion Tensor Imaging: Structure

Measures the diffusion of water within the tissues of the brain

Allows you to see white matter (neuronal tracts) within the brain

Electroencephalography EEG: Function

Electrical activity across the surface of the brain

Great temporal resolution but poor spatial resolution

Which one to use depends on what you are looking for, age (CT uses radiation), pregnancy status (radiation and dyes), kidney function (dyes), steel implants (MRIs), claustrophobia, allergies to some dyes, necessity for sedation in some cases.

Electrophysiology: EEG