CELLULAR NEUROSCIENCE

CNS and PNS composed of cells:

All cells are basically a solution of saltwater and proteins (cytoplasm) in a little bag made of fat and proteins (membrane)

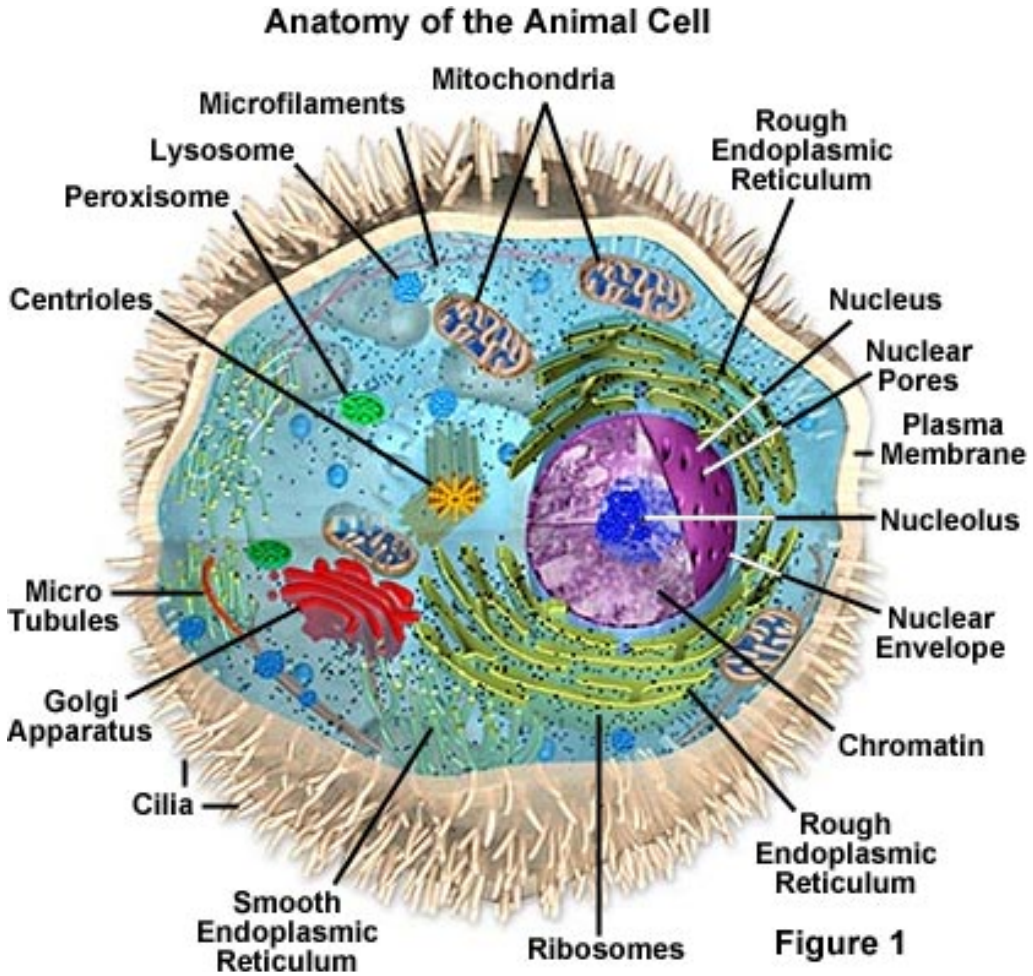
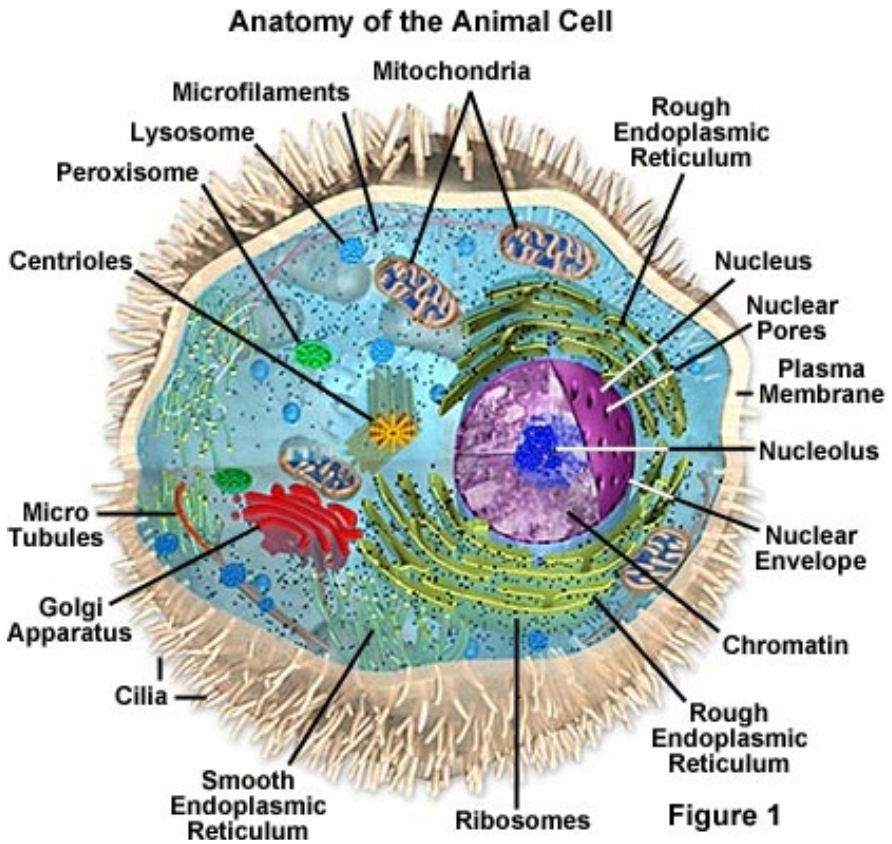


Figure 1

CELLULAR NEUROSCIENCE

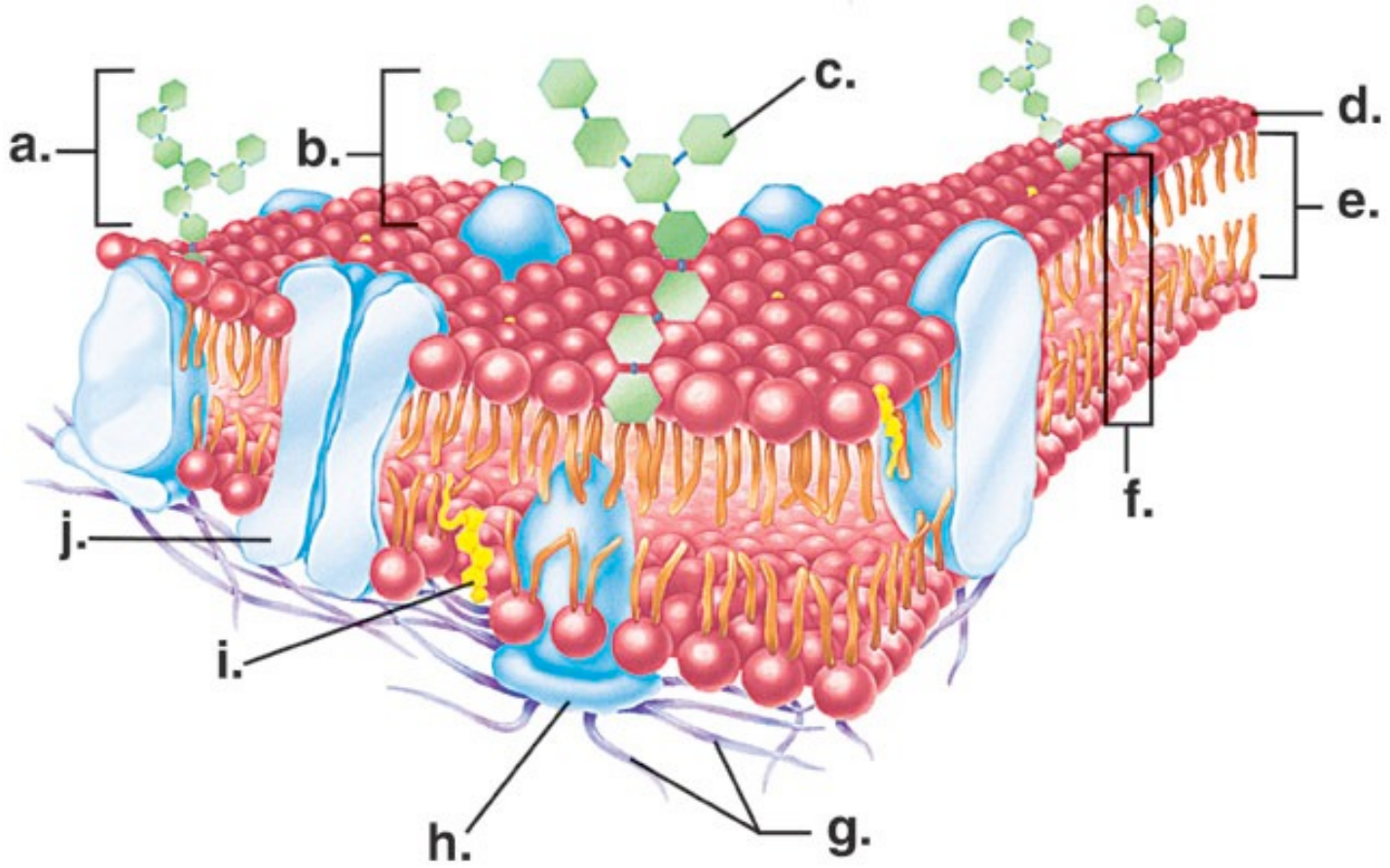
- proteins (folded chains of amino acids) are the building blocks of cells (receptors, transport structures, cytoskeleton, microtubules, etc)
- enzymes - proteins that control (catalyze) chemical reactions



CELLULAR NEUROSCIENCE

All surrounded by the cell membrane:

• a “bag” made of a “lipid bi-layer” - 2 layers of fat embedded with various proteins



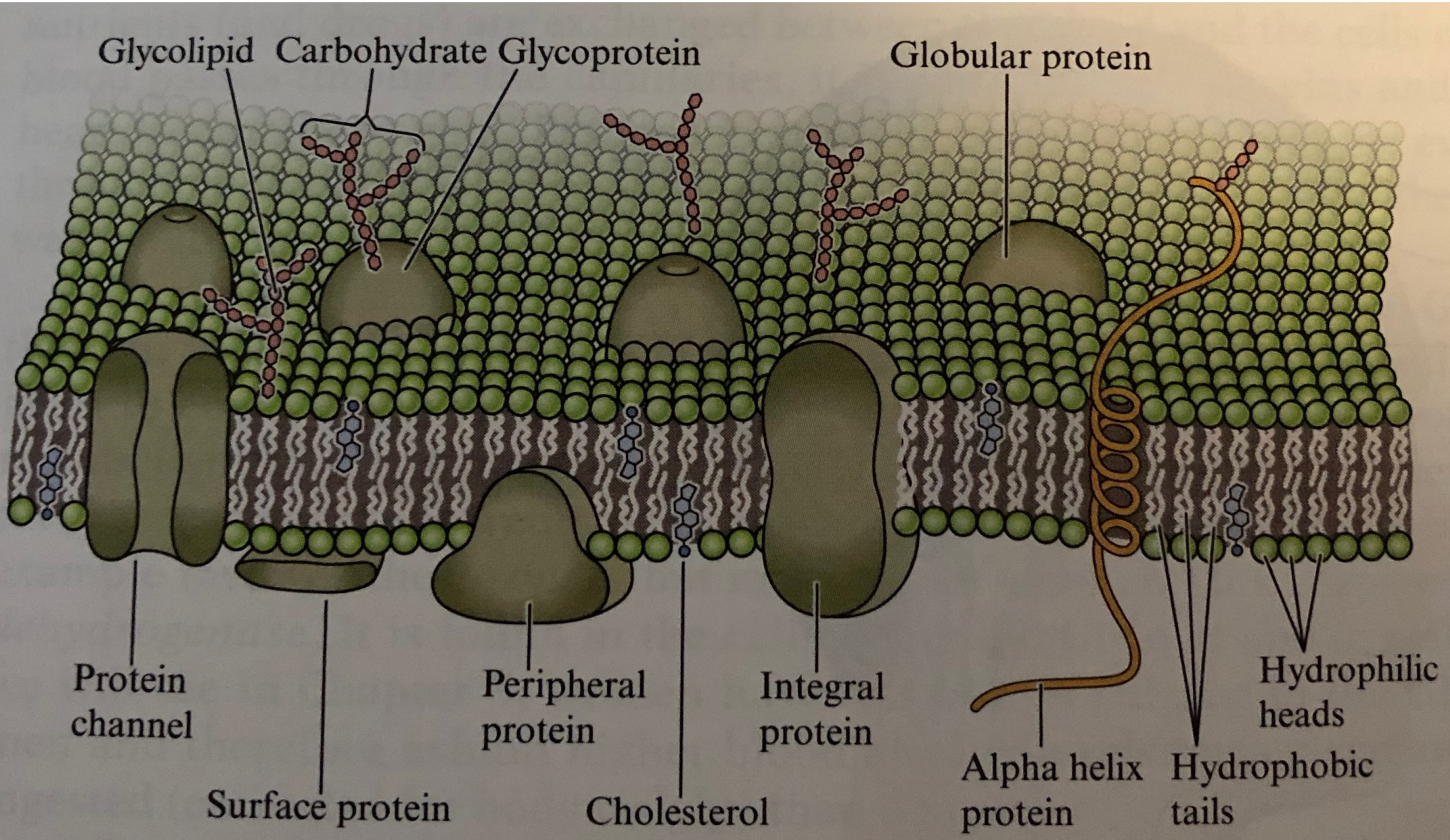


FIGURE 1.7 Diagrammatic representation of a cell membrane, a phospholipid bilayer in which cholesterol and protein molecules are embedded. Both globular and helical kinds of protein traverse the bilayer. Cholesterol molecules tend to keep the tails of the phospholipids relatively fixed and orderly in the regions closest to the hydrophilic phospholipid heads; the parts of the tails closer to the core of the membrane move about freely.

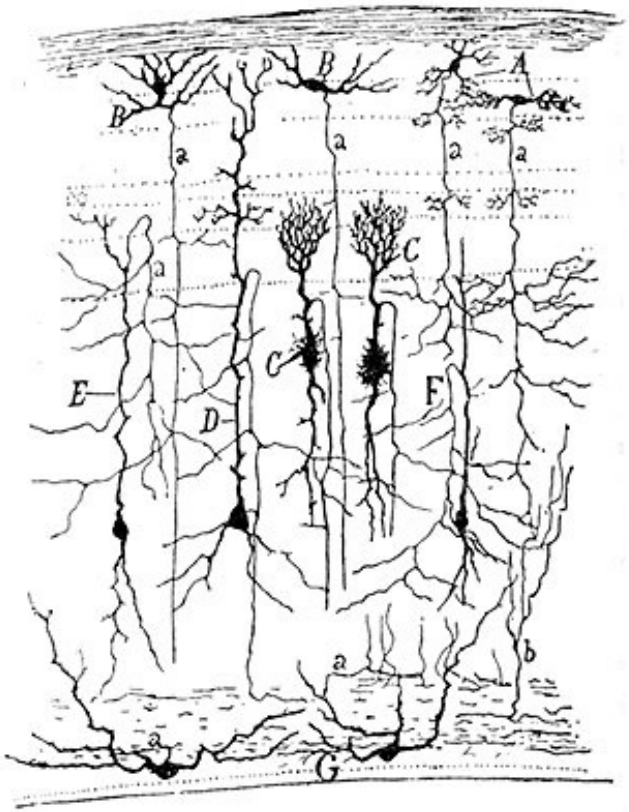
CELLULAR NEUROSCIENCE

- neuron - nerve cell
  - soma / dendrites / axon
- glia - “support” cells (like astrocytes)
  - Latin for “glue”

  - “neurovascular unit”
    - neuron
    - astrocytes
    - endothelial cells (vasculature such as capillaries)
    - pericytes / smooth muscle cells (surround capillaries)

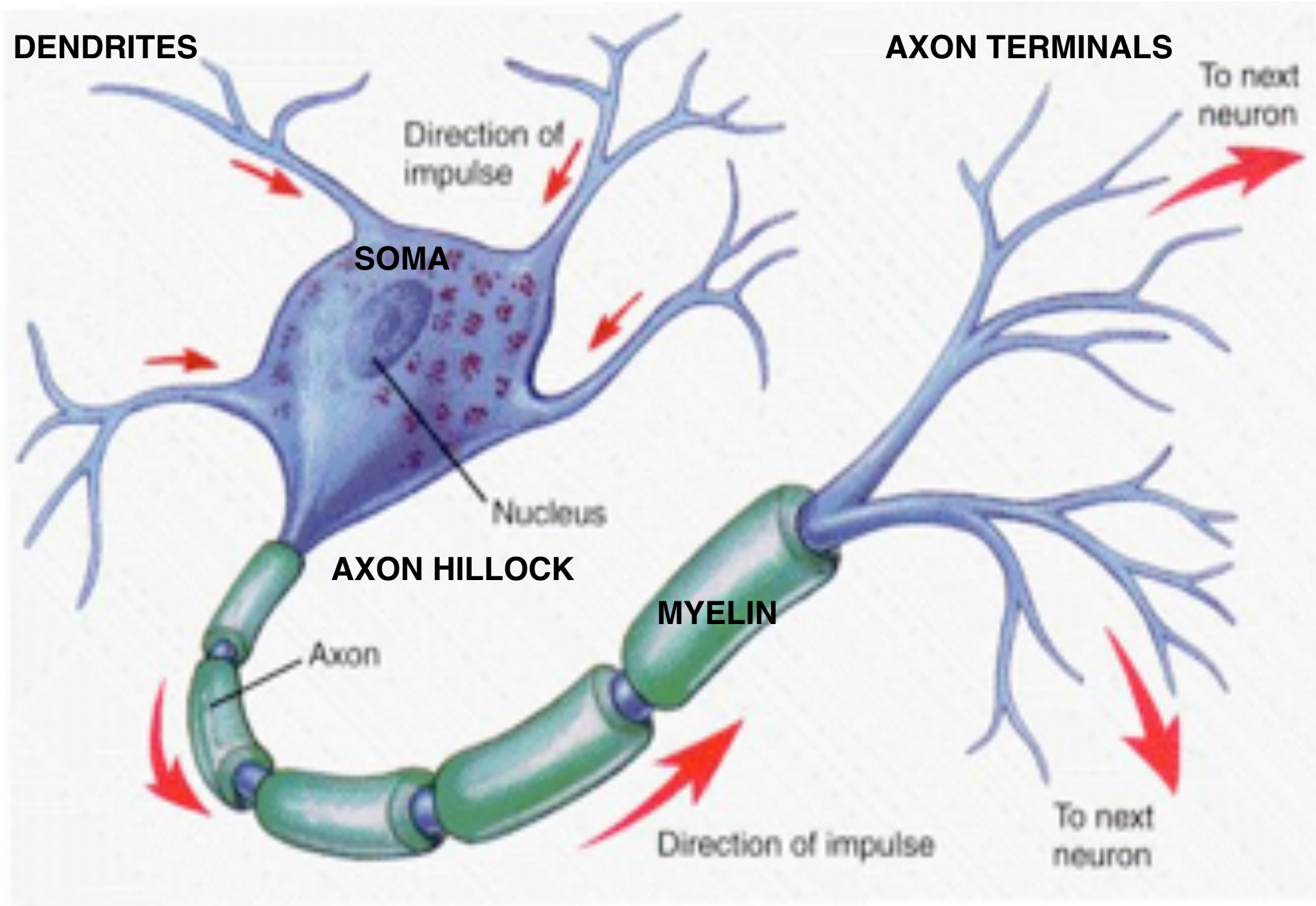
CELLULAR NEUROSCIENCE

- Until late 1800s, it was thought that the brain was a mass of connected glands
- *Neuron doctrine* of Cajal & Golgi (1906 Nobel Prize) with a stain that Golgi invented Cajal discovered that *neurons* are discreet elements (not connected)
  - Gaps between neurons are called *synapses*

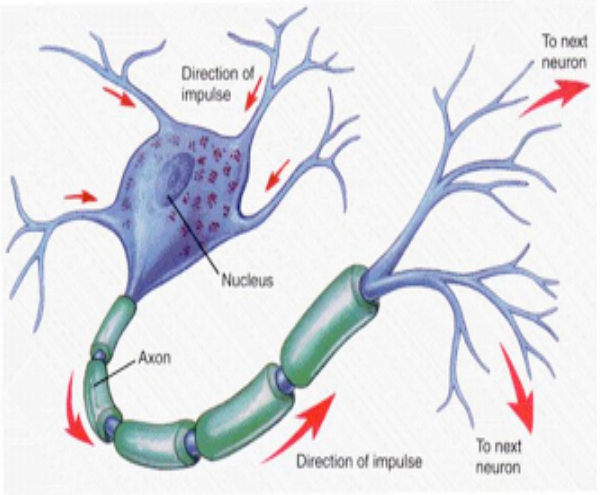


Histology - using stains to study microscopic structure of tissue (Floyd Bloom - "The gains in the brain are mainly in the stain.")

NEUROPHYSIOLOGY

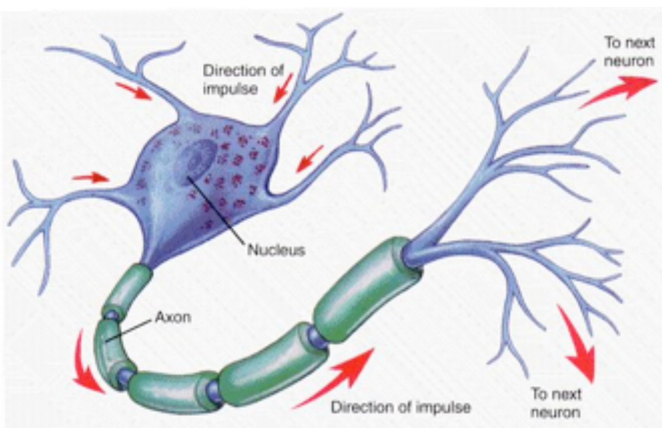


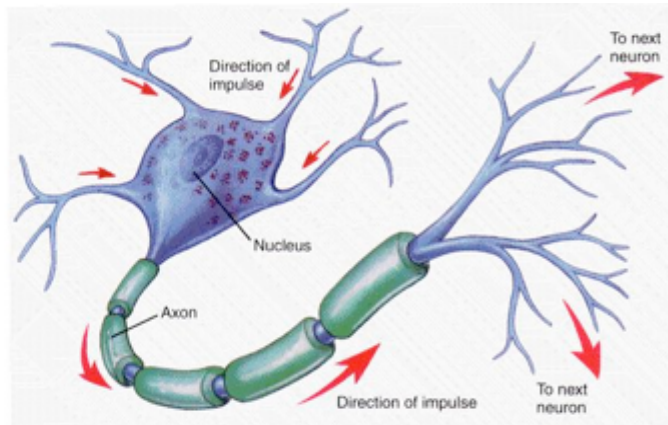
CELLULAR NEUROSCIENCE

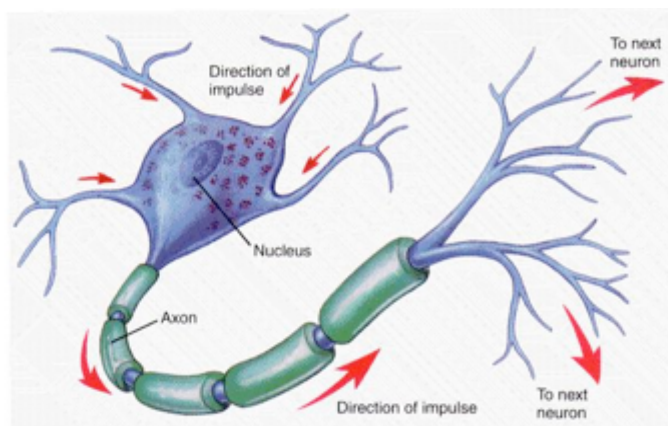


- Neuron - 3 main parts:
  - 1) soma - cell body
    - cell nucleus
    - mitochondria (provide energy)
    - production of neurotransmitters (NTs) and receptors
  - "Processes"
    - 2) dendrites - inputs
      - (passively) transmits an electrical signal ("PSP") from receptors to soma
    - 3) axon - outputs
      - (actively) transmits an electrical signal ("AP") from soma to axon terminal (which contains neurotransmitters)

PRESYNAPTIC

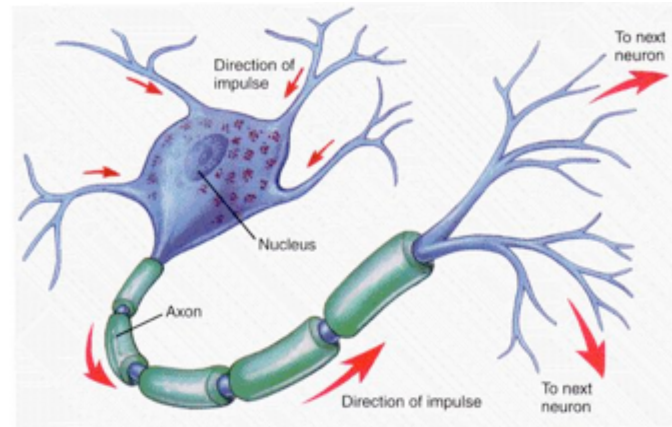


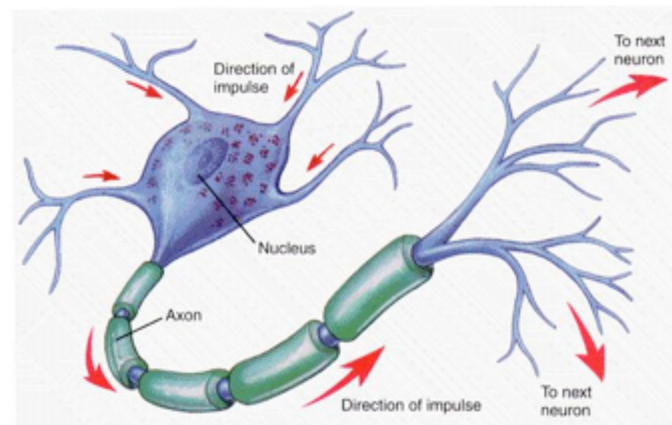


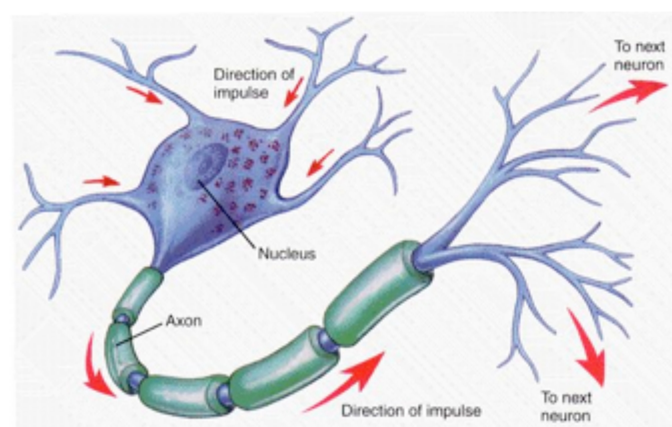


POSTSYNAPTIC AND PRESYNAPTIC

POSTSYNAPTIC

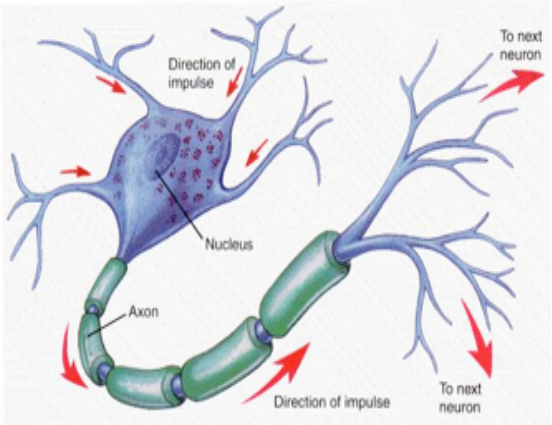






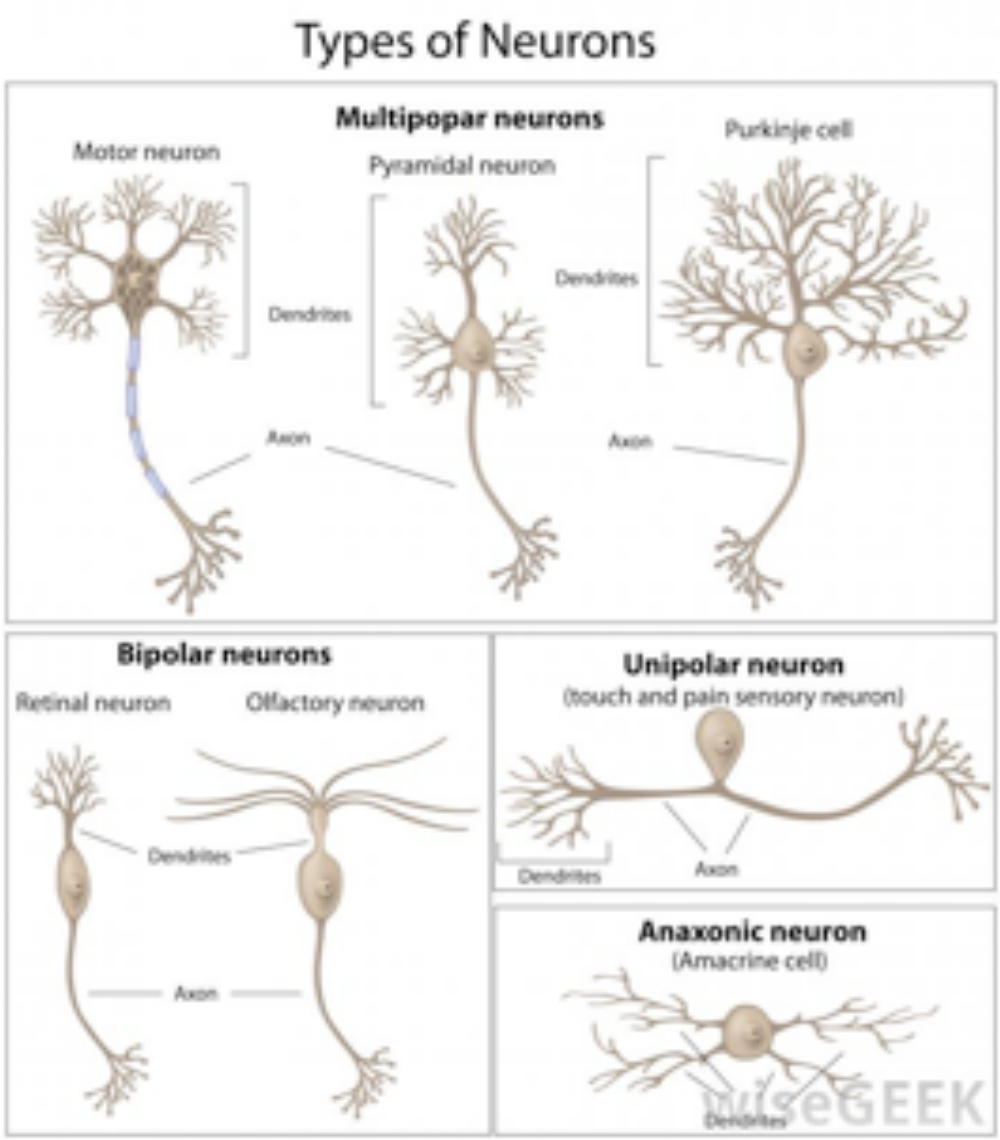
CELLULAR NEUROSCIENCE

- neurons integrate and transmit information
  - signaling / impulse / action potential / spike
  - approximately 100 billion neurons in the brain
    - ~1/2 the volume of the CNS
  - about 10,000 different types based on morphology (shape) / physiology / function



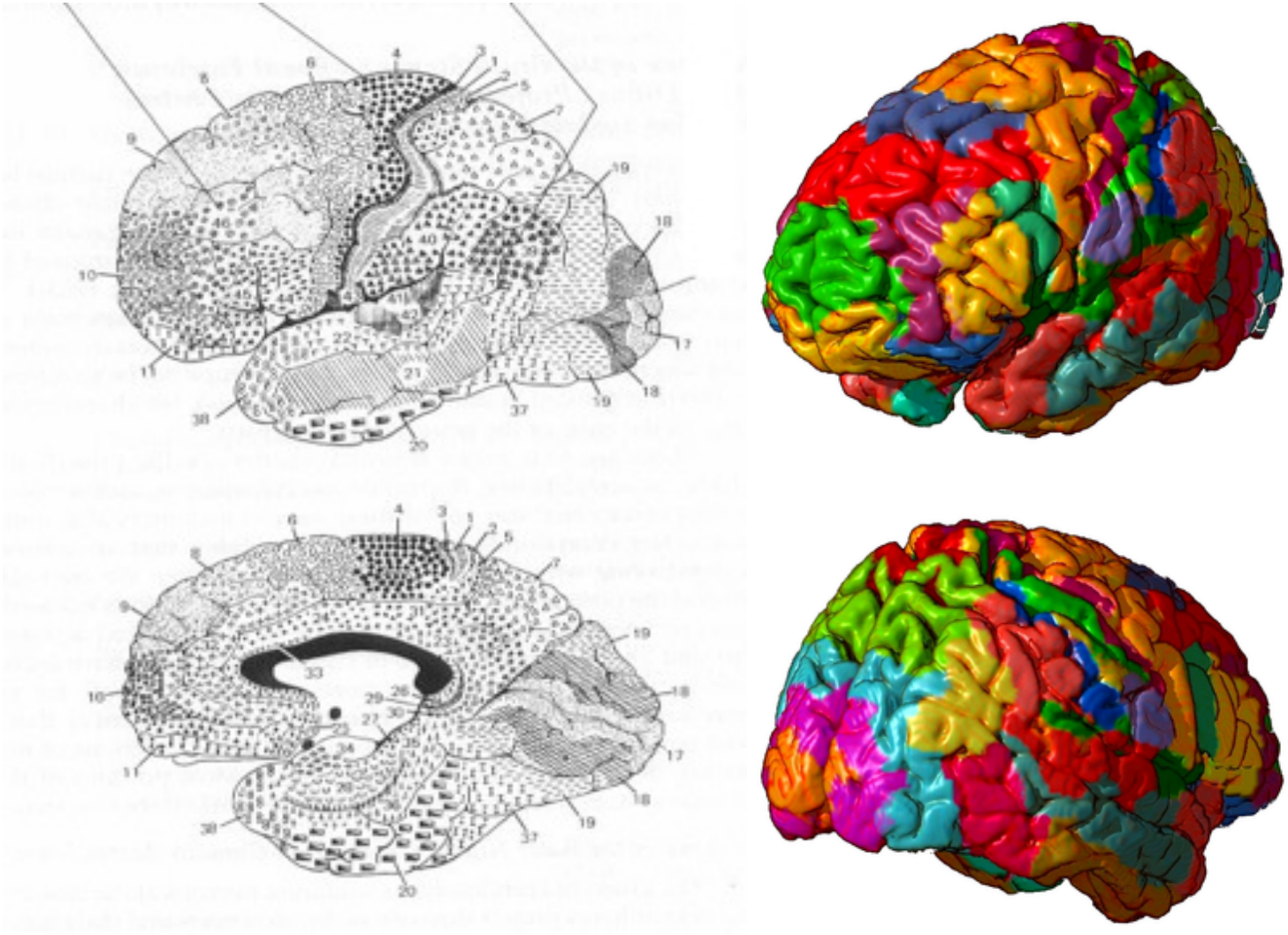
CELLULAR NEUROSCIENCE

- 3 main categories by *Shape (morphology)*:
  - unipolar - somatosensory
  - bipolar - vision, auditory
  - multipolar - most common



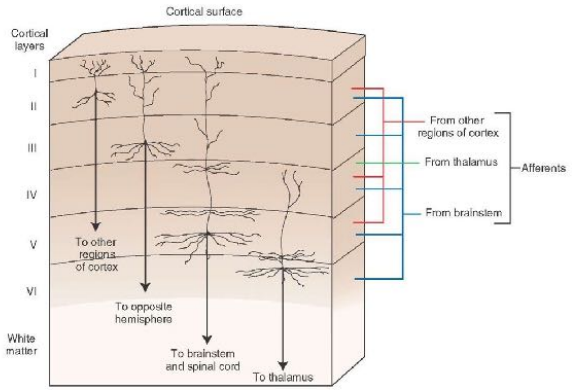
CELLULAR NEUROSCIENCE

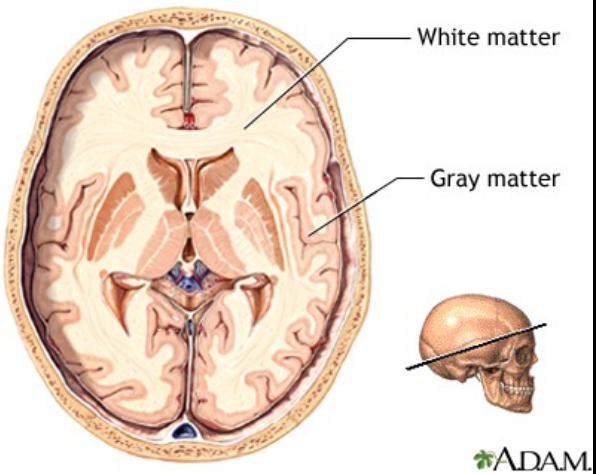
Brodmann (1909) - categorized areas based on cell morphologies (52 different areas grouped into 11 “histological” areas)

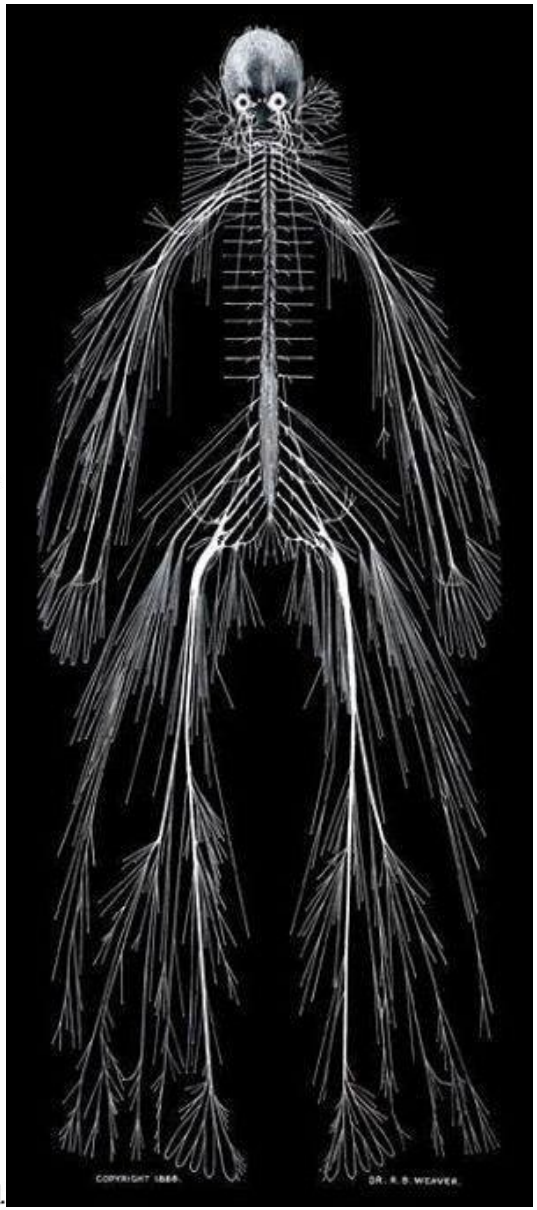


CELLULAR NEUROSCIENCE

- 3 categories of neurons *by function*:
  - sensory neurons
    - *bring info in*
  - motor neurons
    - *send info out*
  - interneurons
    - *connections*
      - local (small unmyelinated axons)
      - relay (larger myelinated axons)





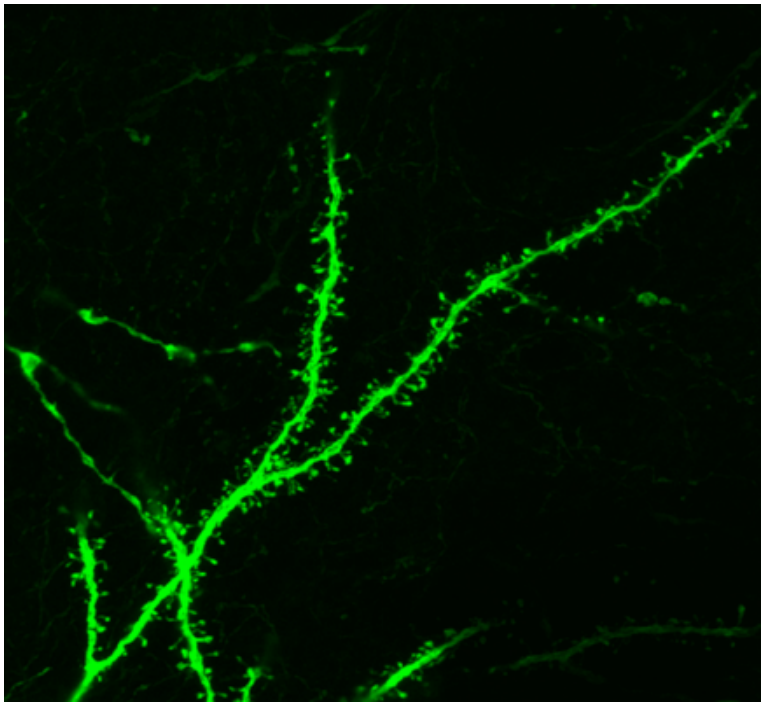


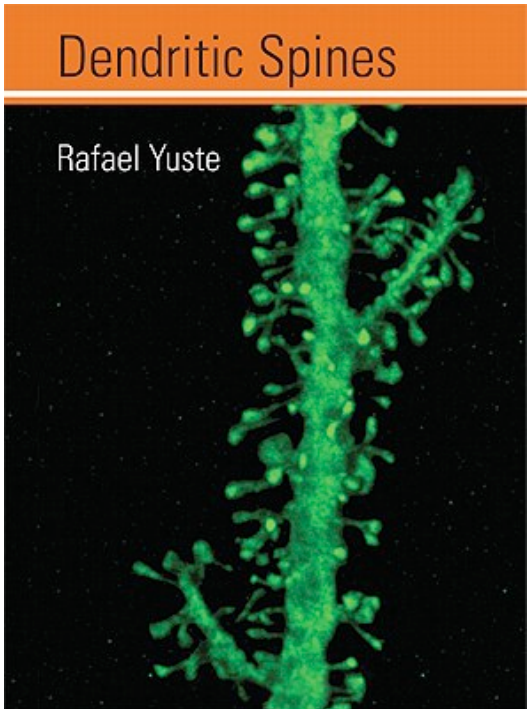
CELLULAR NEUROSCIENCE

Membrane on a neuron's "input zones" (dendrites and soma) contains receptors for specific "neurotransmitters" (NTs)

generate an electrical signal that travels (passively) toward the axon ("PSP") - can be "excitatory" (EPSP) or inhibitory (IPSP)

- dendrites ("tree") - 95% of a neuron's inputs
  - dendritic "spines" typically contain "excitatory" receptors
  - all sensory neurons have specialized dendrites
- soma - some receptors, typically "inhibitory"

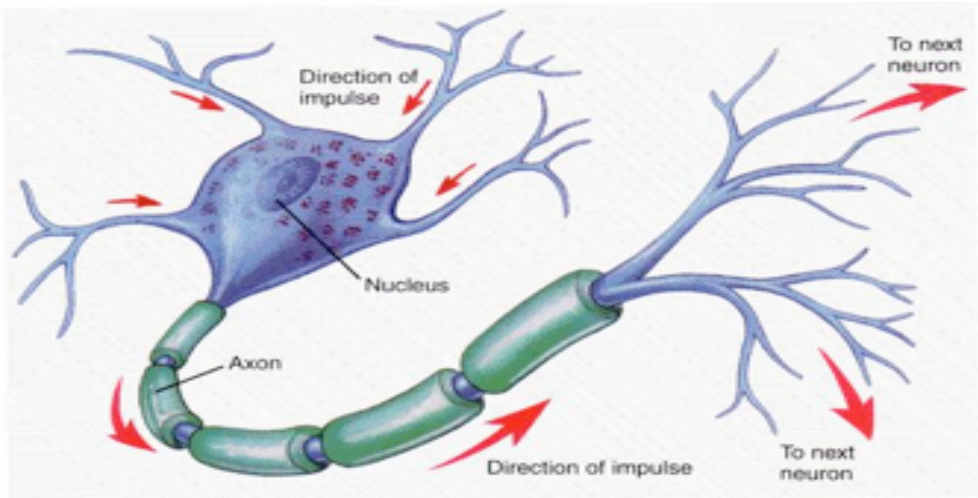


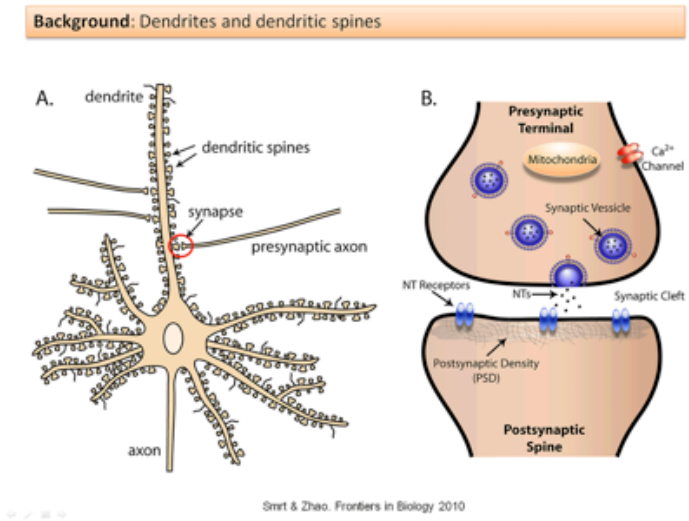


CELLULAR NEUROSCIENCE

The axon is the neuron's "output zone"

- *axon hillock / initial segment* - where axon meets soma
  - electrical signal ("AP"; "information") usually starts here
- *axon fiber* - (actively) conducts AP away from soma toward terminals
  - *myelin* - coating on axon that speeds impulse (up to 6x)
    - *nodes of Ranvier* - gaps in myelin exposing bare axon
- *axon collaterals* - branches (1 main axon from soma, but it can split)
  - *terminal ("transmission zone")*
    - *synaptic vesicles - packets of neurotransmitters*
      - *balls of fat filled with NT molecules ("ligand" / "first messenger")*
        - *released into the synapse via exocytosis when calcium enters the axon terminal*

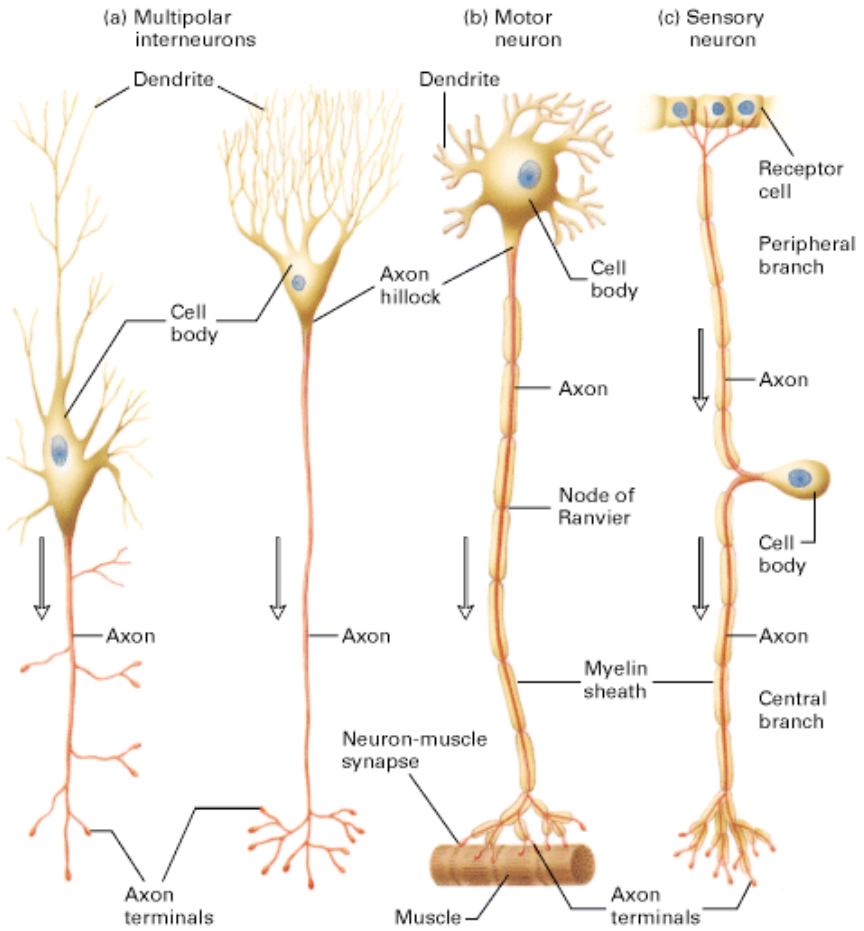




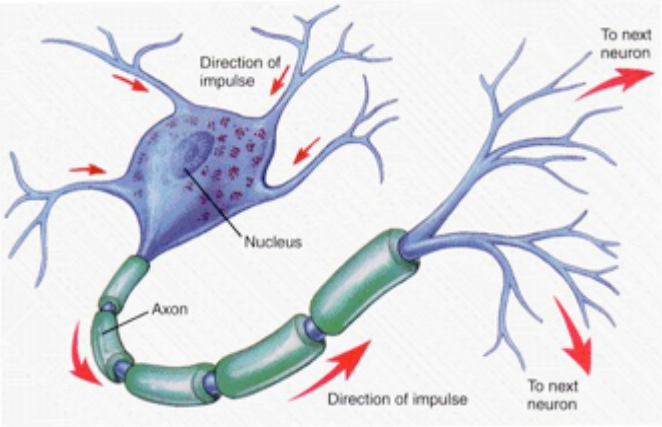
CELLULAR NEUROSCIENCE

normal flow of info in a “generic” neuron:

dendrites > soma > axon > terminal



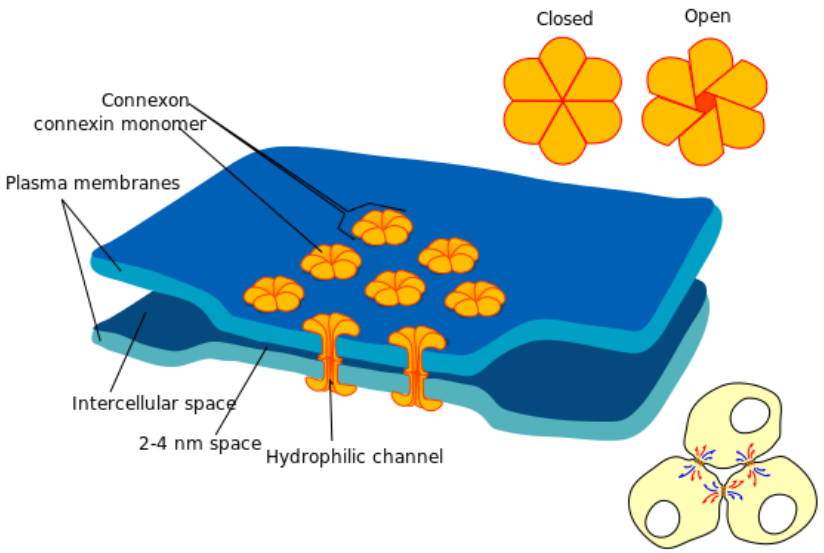
CELLULAR NEUROSCIENCE

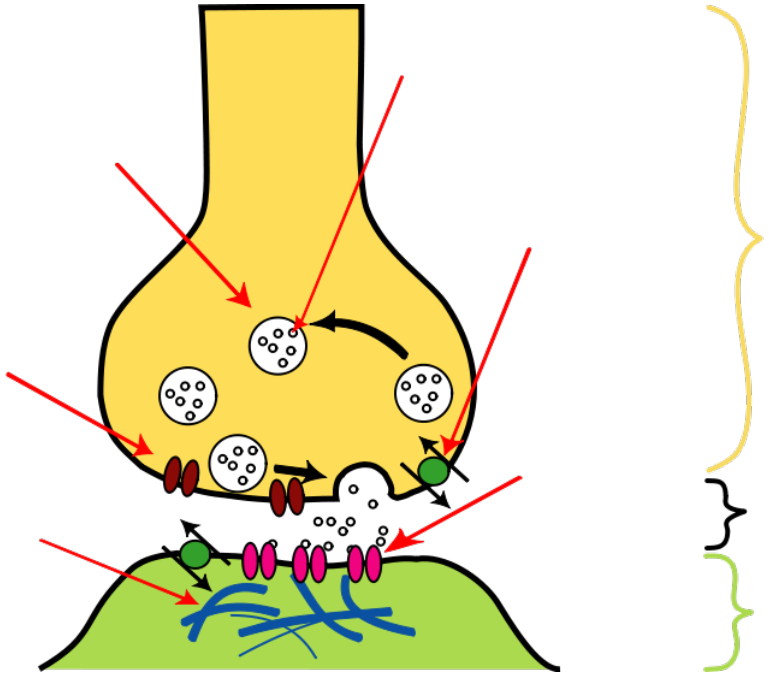


- Neurotransmitters are released (generally) from axon terminals onto the dendrites of other neurons at *synapses*
  - gaps between neuronal "processes" (remember the "neuron doctrine")
- an <u>electrical signal</u> ("action potential") is generated at the axon hillock of the "*pre-synaptic*" neuron
  - AP is actively transmitted to the axon terminal >
    - axon terminal releases NT <u>(chemical signal)</u> into synaptic cleft >
      - NT binds with receptors on the dendrites of the "*post-synaptic*" neuron (usually 1000s), creating a passive <u>electrical</u> signal that will either help to <u>induce</u> or <u>suppress</u> an action potential in <u>those</u> neurons
- each of the ~100 billion neuron makes ~5000 synapses – the possible combinations are almost infinitely complex

CELLULAR NEUROSCIENCE

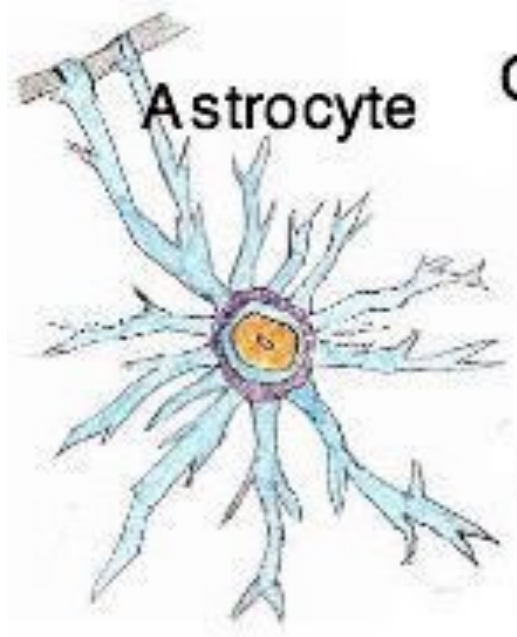
- Neurons can “communicate” via 2 types of synapses
  - *electrical (gap junctions)* - specialized membrane channels that connect pre- and post-synaptic neurons
  - *chemical* - presynaptic release of neurotransmitters (NTs) causes postsynaptic current flow by activating receptors that open ion channels

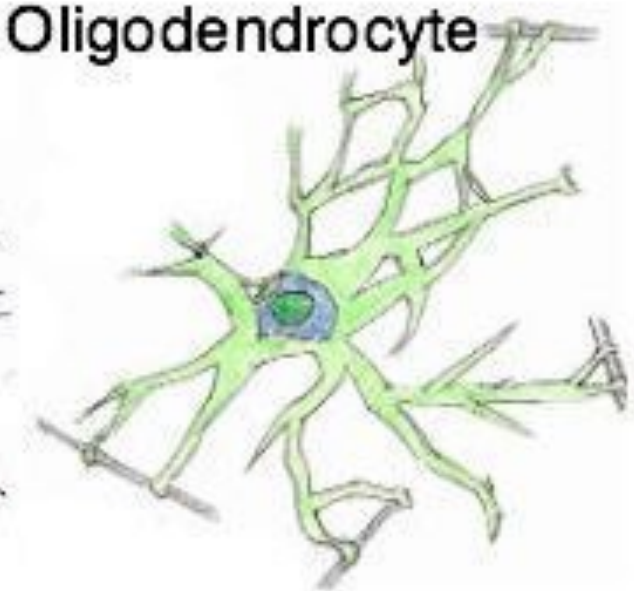


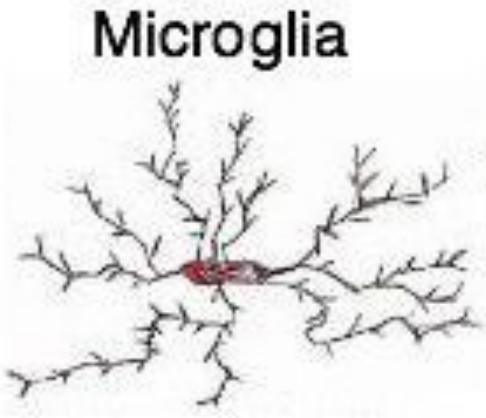


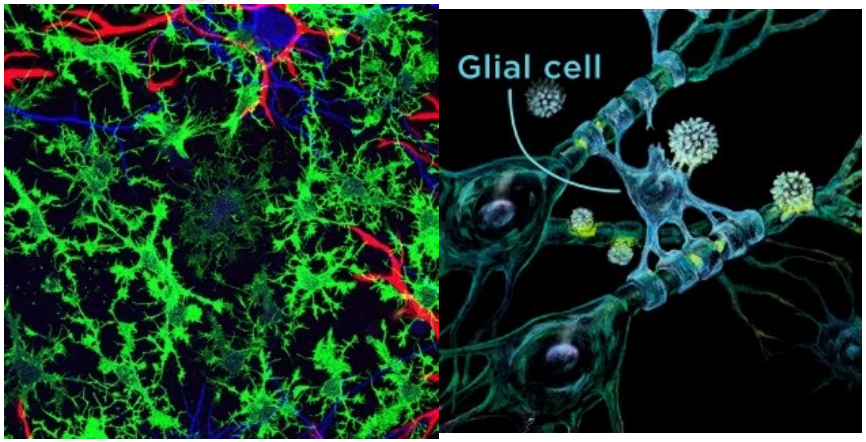
CELLULAR NEUROSCIENCE

Glial cells - ~1/2 nervous system volume
10-50x more than neurons (maybe)
support the functions of neurons









CELLULAR NEUROSCIENCE

astrocytes - support, nourishment, debris removal (phagocytosis)

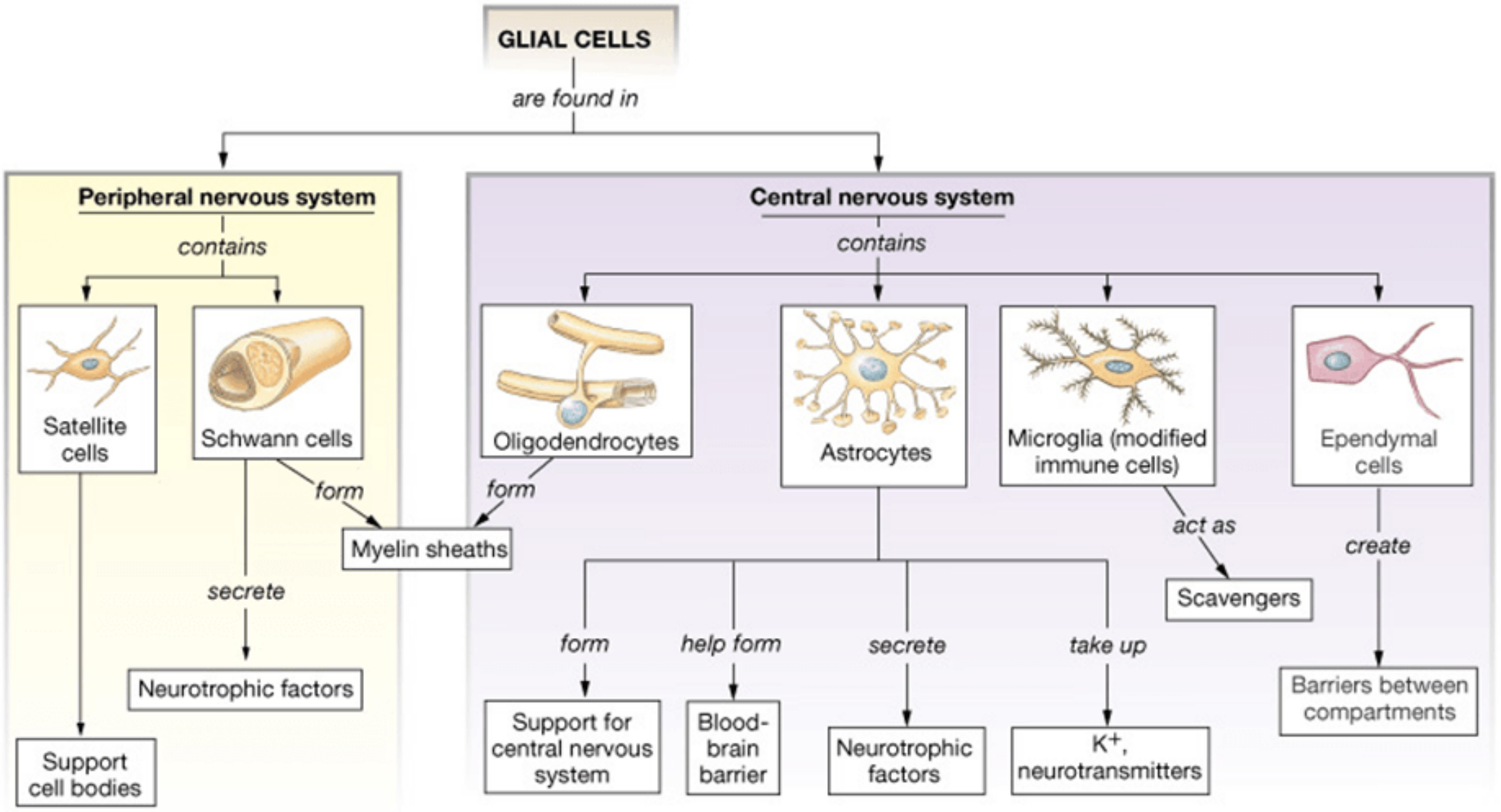
microglia - phagocytosis / immune / inflammatory response

Myelin:

- *oligodendrocytes* - axonal insulation (myelin sheath around long axons)
    - gaps between oligodendrocytes are the nodes of Ranvier

- *Schwann cells* - myelin sheath around long axons in the PNS
    - provide conduit for regrowth of damaged axons

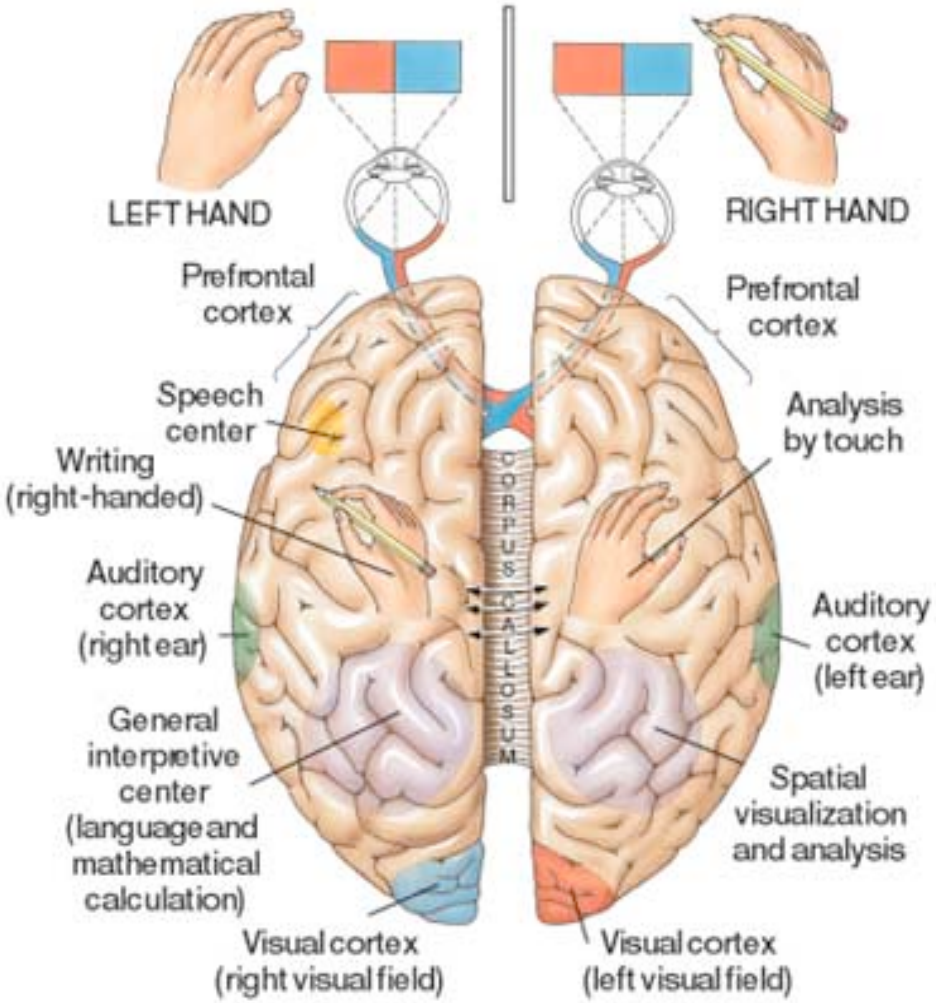
CELLULAR NEUROSCIENCE

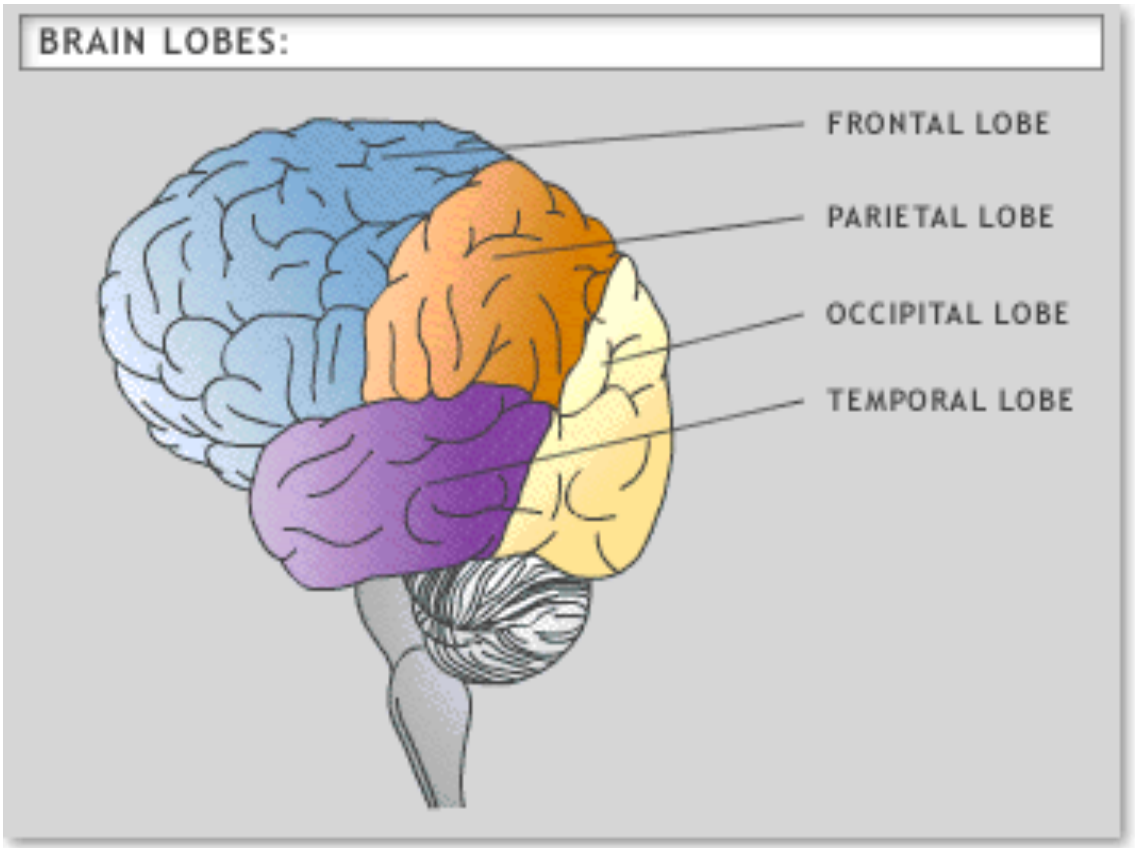


CONNECTING IT ALL TOGETHER

• 2 hemispheres connected via *corpus callosum and* several other smaller fiber pathways ("white matter pathways" / axons of long projection neurons)

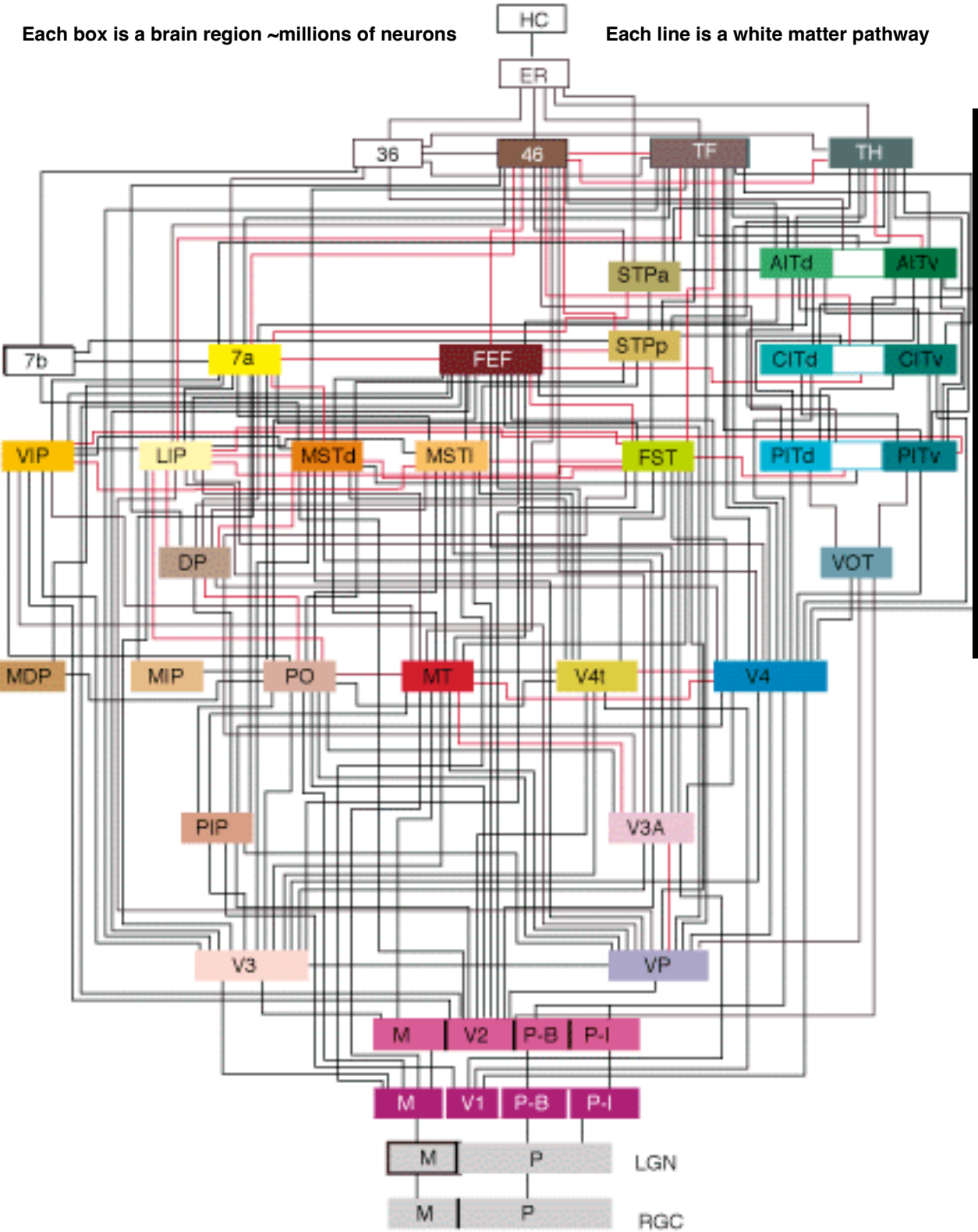
• most of brain's sensorimotor processing is "crossed"

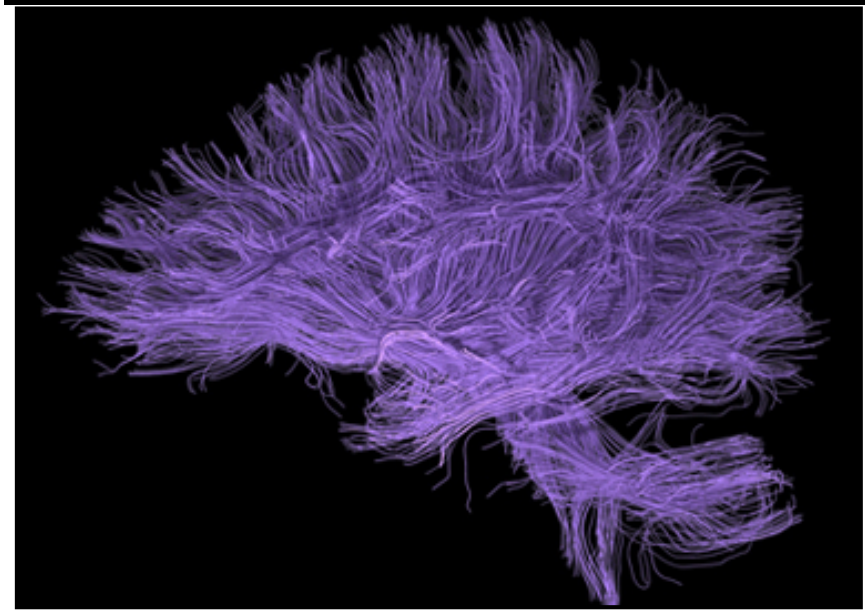




Each box is a brain region ~millions of neurons

Each line is a white matter pathway





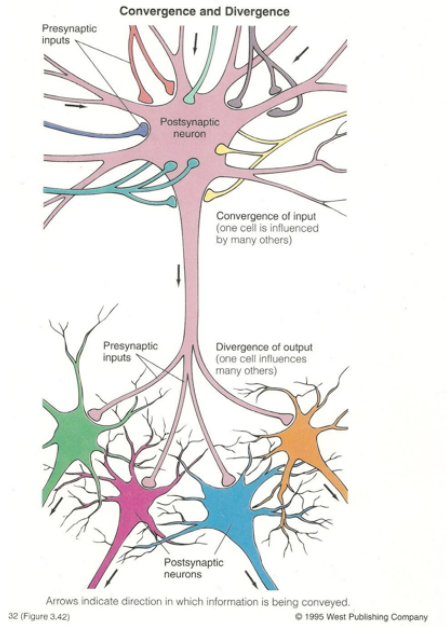
CONNECTING IT ALL TOGETHER

- Connectionism Mechanisms:
  - parallel processing - multiple pathways for similar information
    - damage to one path will not necessarily break down whole network (redundancy)
  - distributed processing - several separate groups of neurons required for a specific function

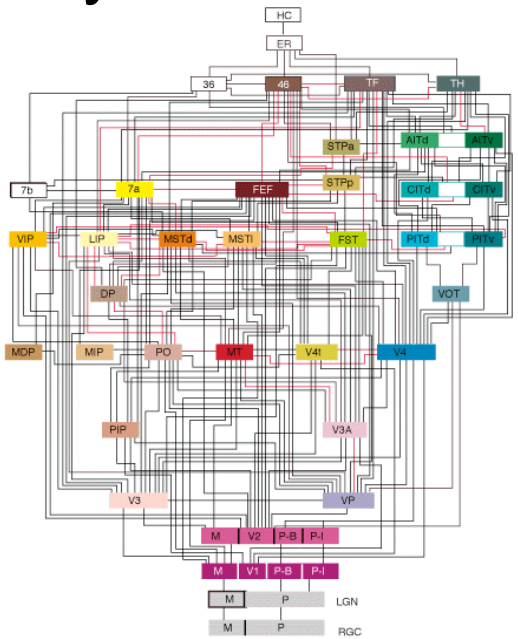
CONNECTING IT ALL TOGETHER

- Connectionism Mechanisms:
  - convergence - many neurons (or many areas) can converge on 1 neuron (or 1 area)
  - divergence - 1 neuron (or 1 area) can connect with thousands of neurons (or areas)
- an individual neuron (or area) is usually both convergent and divergent

cellular level

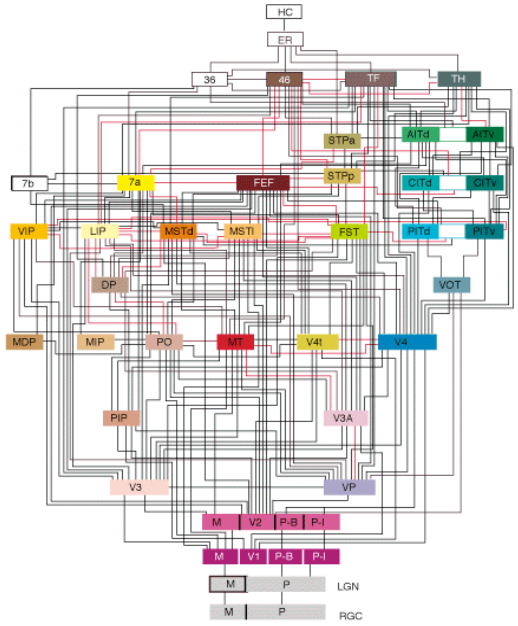


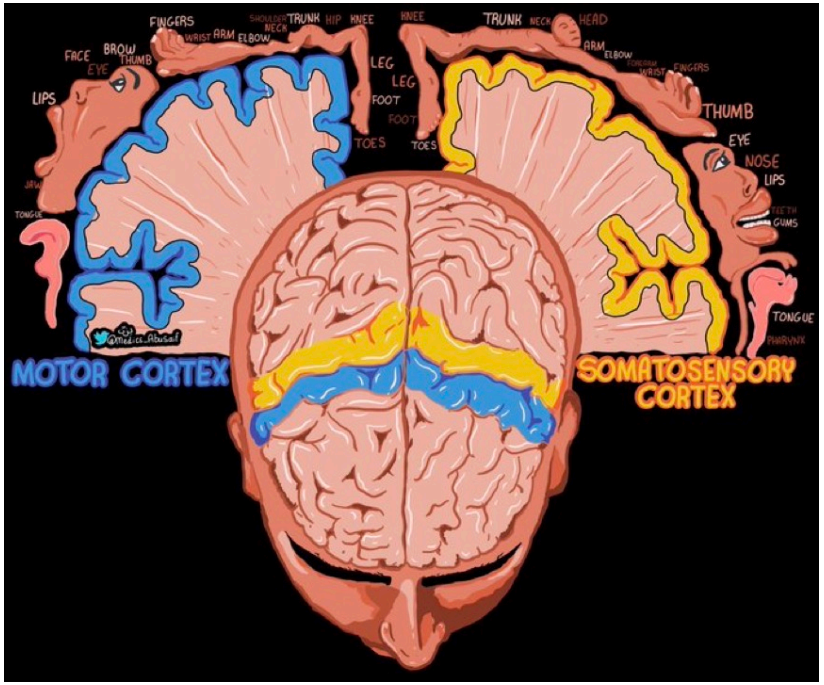
system level



CONNECTING IT ALL TOGETHER

- Connectionism Mechanisms:
  - Somatosensory cortex (*homunculus*) processes somatosensory info simply because it's physically "wired up" to sensory neurons in the PNS ("receptors")
    - Touching your thumb will end up activating a specific group somatosensory cortex columns via "afferent pathways"
  - neuroplasticity - growth and change capacity / dynamic
    - pathway circuitry and boundaries of functional neuronal areas are constantly changing





“Neuroscience model”
stimulus - ORGANISM - response
(works on both cellular and systems levels)

1) receptor receives external input >
2) afferent brings information into system >
3) integrator processes the information >
4) efferent sends processed information out >
5) effector produces action

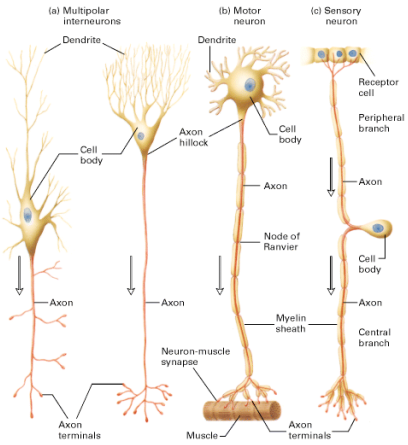
input > integrate > output

“Neuroscience model”
stimulus - ORGANISM - response
Cellular level

follows organization of a “generalized neuron”

Stimulus = neurotransmitter, Response = release neurotransmitter

1. receptors - receptor proteins on dendrite bind with neurotransmitter producing electrical signal
2. afferent - dendrite carries signal toward axon hillock
3. integrator - axon hillock sums up signals to determine whether to generate another electrical signal (action potential)
4. efferent - axon carries AP away from the cell body / axon hillock
5. effector - axon terminal releases neurotransmitter



“Neuroscience model”
stimulus - ORGANISM - response
System level

Stimulus = light, Response = appropriate eye movements

1. receptors - photoreceptors t*ransduce* light into neural signals
2. afferent - optic nerve carries signal toward CNS
3. integrator - thalamus, occipital cortex, etc. - process information into a *perception*
4. efferent - oculomotor nerve carries signal away from CNS to the
5. effector - muscles of head / eyes move toward light