Lecture 2: Neuron: Properties and Cellular Anatomy

Levels of analysis of a neuron

Where is the cell body of the neuron located?

Where is the dendritic field (inputs) of the neuron?

Where does the neuron send its axon (outputs)?

What functional system is the neuron part of?

What types of drugs can access the neuron?

What input does the neuron get, and what receptors are present postsynaptically?

What transmitters does the neuron release presynaptically?

What are the intracellular signaling and transcriptional networks that modulate long-term function of the neuron?

Properties of Neurons

1. have inputs and outputs (dendrites and axons)
2. make connections (synapses) with:
   - sensory receptor cells
   - muscle or gland cells
   - each other
3. have long fibers (axons) for long-distance connections
4. use rapid electrical and slower chemical transmission

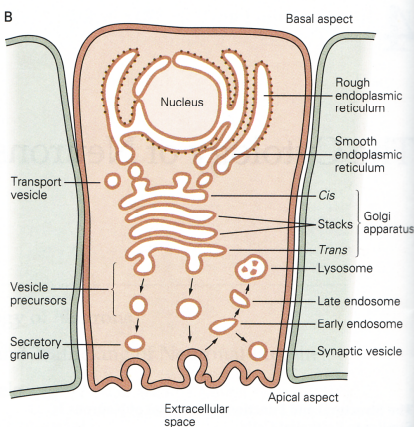
Specific properties:

1. central neurons (brain and spinal cord neurons) do not divide, cannot be replaced (with some exceptions...)
2. 90% of all genes are expressed only in neurons.

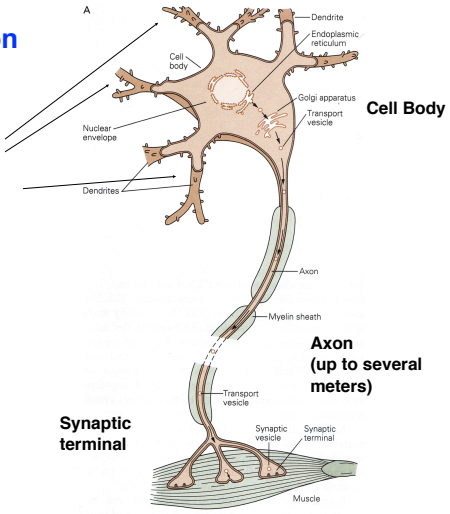
Physical properties

1. **Polarity** -- the cell is not symmetrical
2. **Compartimentalized** -- segregation of cellular components to different areas
3. **Excitable** -- maintains a membrane potential, electrochemically integrates incoming signals, and responds non-linearly with action potentials.
4. **Connectable** -- forms unidirectional connections with other neurons and target tissues

Polarity: epithelial cell



Polarity: neuron



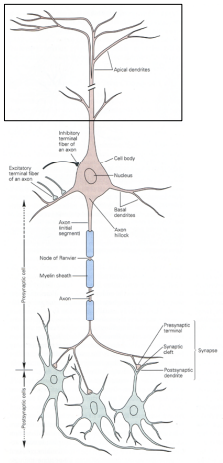
Cell Body

Dendrites (up to several mm)

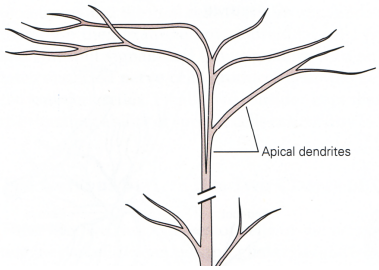
Axon (up to several meters)

Synaptic terminal

Neuron: Dendrites



input site of neuron: dendrites have postsynaptic densities with receptors, intracellular signaling, and ribosomes



apical - high up in dendritic arbor
basal - closer to soma

Kandel Figure 2-2

Reconstruction of Dendrite and Spines from Serial Electron Micrographs

Majority of excitatory synapes in CNS are located on spines.

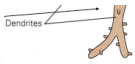
Especially profuse and plastic in brain regions with high plasticity of function (e.g. hormone-sensitive, drug-sensitive, learning and memory sites).

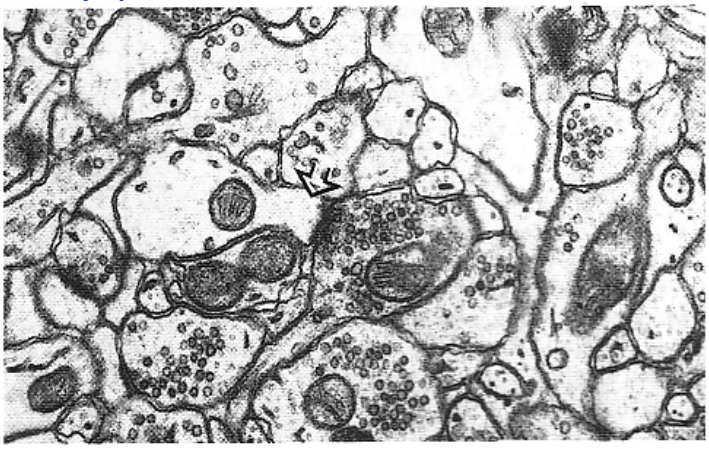
3 types of spines:

stubby
thin
mushroom

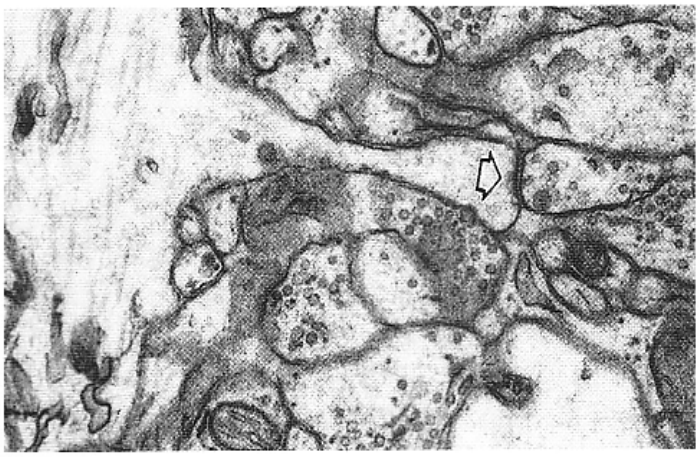
(morphology thought to reflect maturity or stability of spine)

Stubby Spine

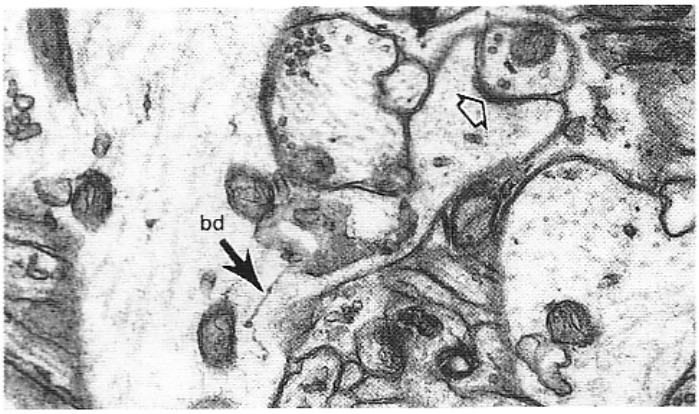




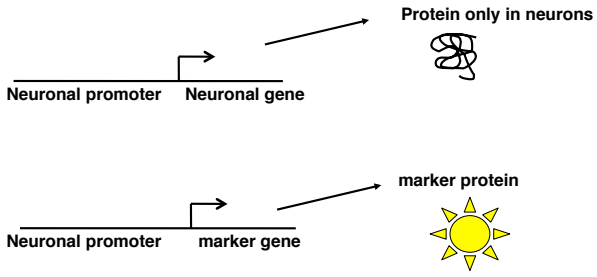
Thin Spine



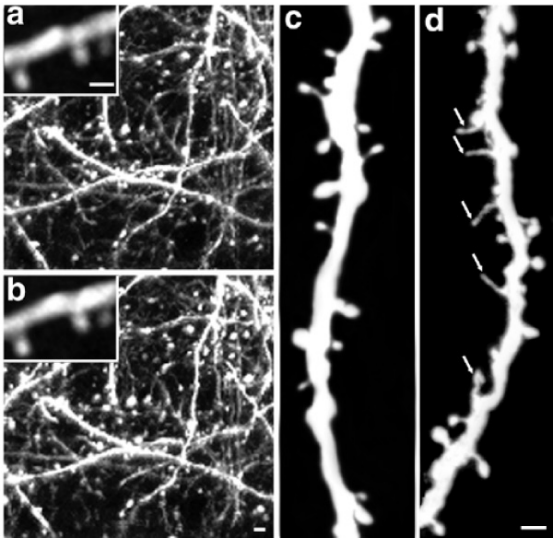
Mushroom Spine

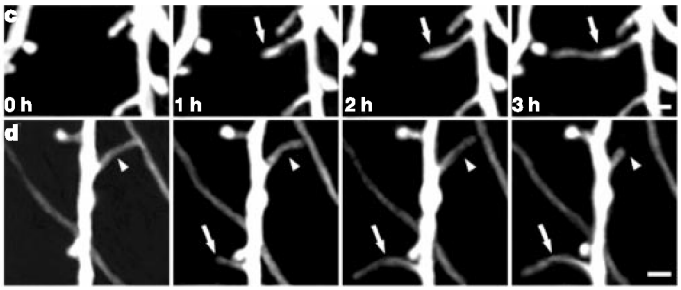


Transgenic Labeling of Neuronal Protein

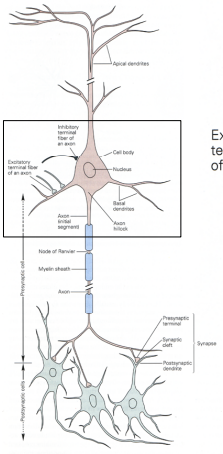


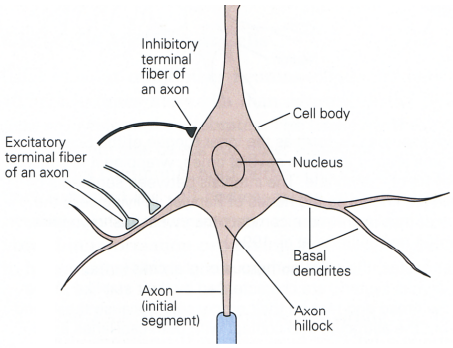
e.g. Neuron-specific enolase promoter driving yellow fluorescent protein





Neuron: Soma

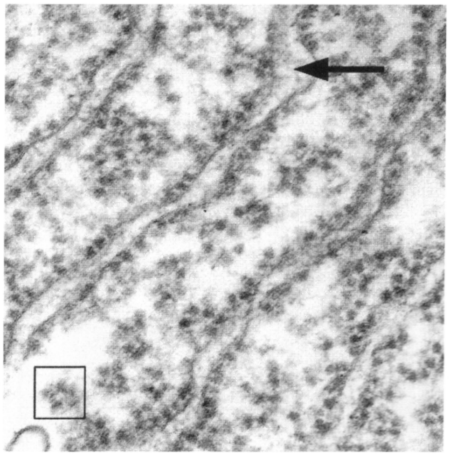




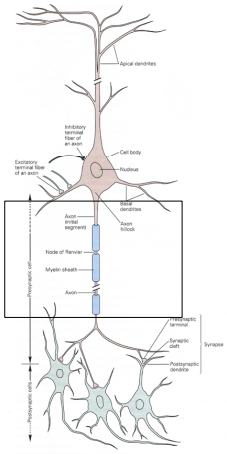
soma has typical cellular machinery: nucleus, ribosomes, ER, Golgi, etc.

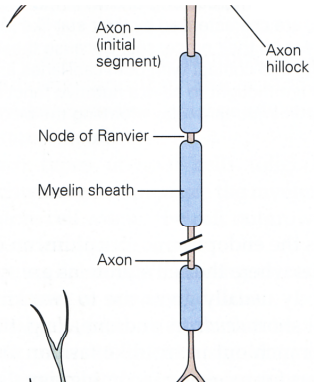
Nissl Material:

ribosome complexes in cell body of neuron



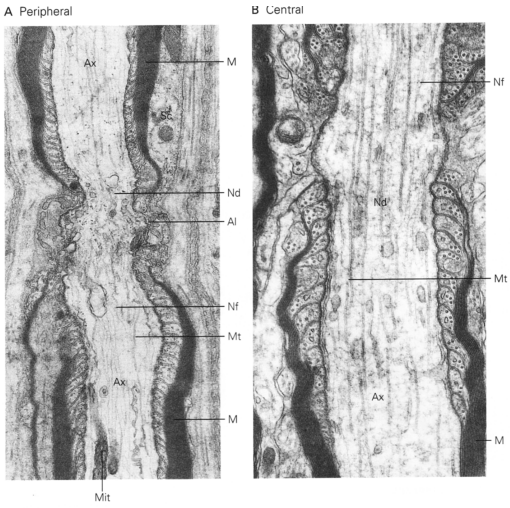
Neuron: Axon



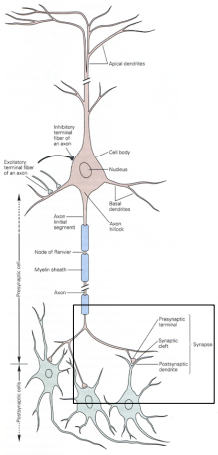


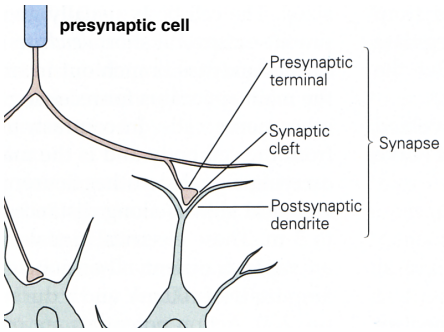
Axon:
Microtubules & Neurofilaments

for rapid transport of organelles and synaptic vesicles to end of axon

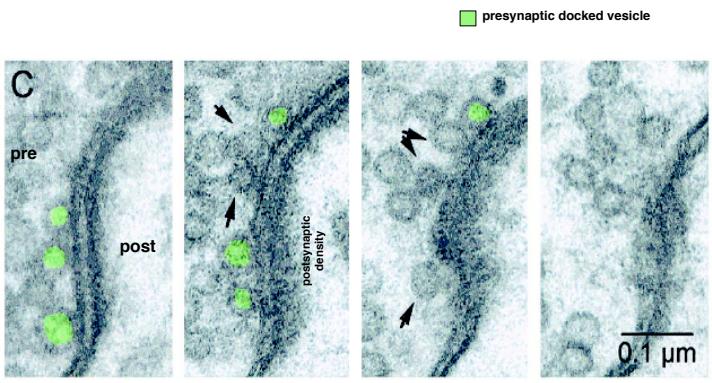


Neuron: Synapse



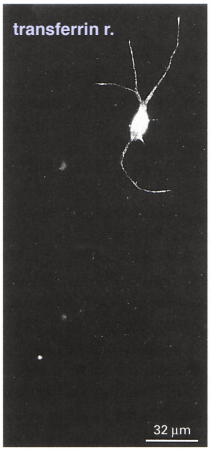


postsynaptic cells

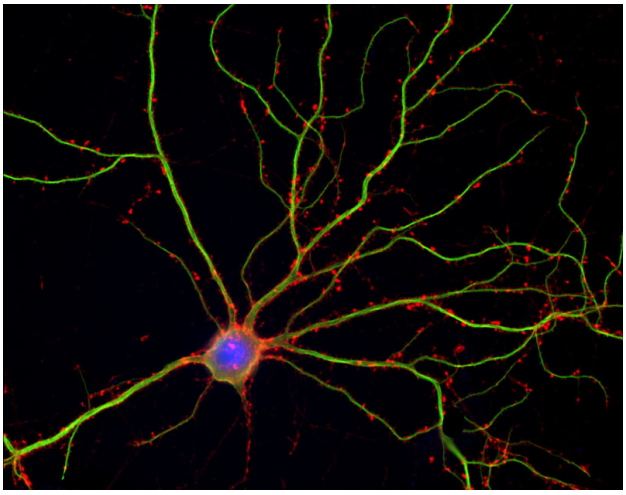


Axon-Dendrite Contacts *Xu-Friedman et al, 2001*

dendrite or axon marked by different proteins



neurons grow dendrites and axons even in culture



DNA in blue, MAP2 (dendrites) in green, actin (spines) = red

Where to find Cell Bodies, Dendrites, and Axons...

1. **Cells:**
   - ganglia in periphery
   - gray matter of CNS
   - nuclei = dense clusters of neurons
2. **Axons:**
   - long peripheral nerve bundles
   - white matter = fiber tracts of CNS
   - fibers of passage perforating nuclei
3. **Dendrites:**
   - in computationally-intensive regions of the brain, e.g.
     hippocampus & pyramidal cell dendritic fields
     cortex of cerebellum & purkinje cell dendrites

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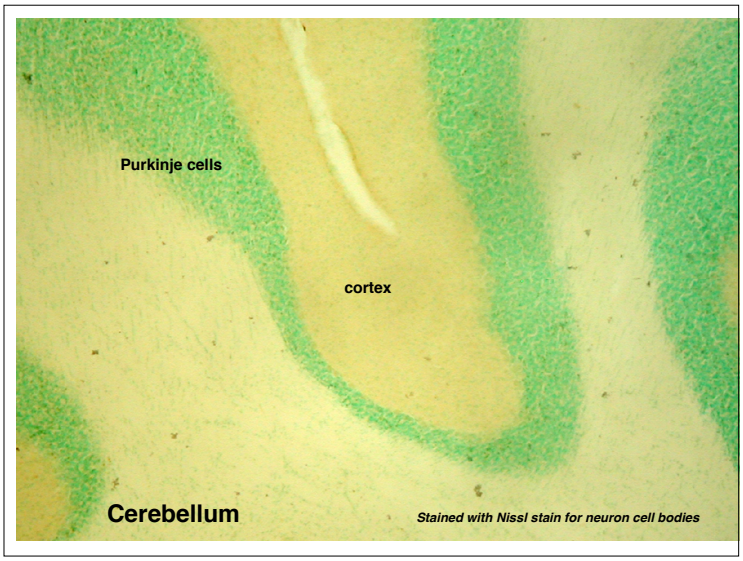
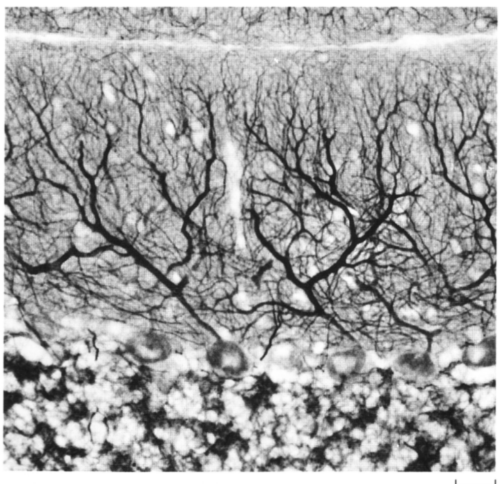
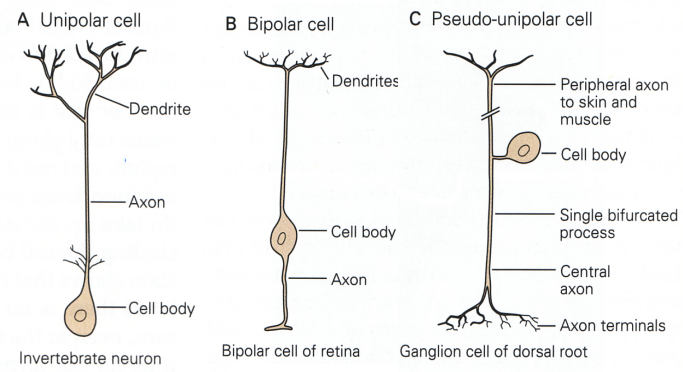
Note: interneurons are small, with dendrites, cell body, and axons all within a small patch of gray matter or within a nucleus



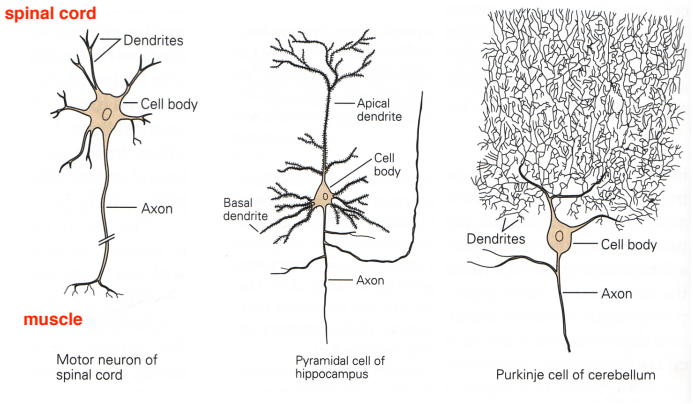


Golgi stain fills a subpopulation of cells entirely

Neurons come in varying morphology



Neurons come in varying morphology: multipolar cells



Branching of Dendrites and Axons increases connectivity:

CNS is very interconnected:

Total number of neurons in cerebral cortex = 10 billion

Total number of synapses in cerebral cortex = 60 trillion (yes, trillion)

(G.M. Sheperd 1998)

Achieved by large increase in surface area:

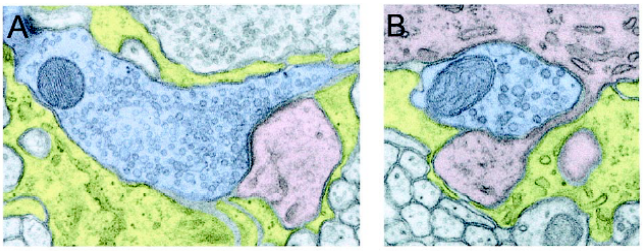
Surface area of 10 μm wide spherical cell = 300 μm^2

Surface area of a typical neuron = 250,000 μm^2

Surface area of all 100 billion neurons in brain = 25,000 m^2

(the size of four soccer fields -- M. Bear et al 2001)

Axon - Climbing fiber
Dendrite - Purkinje Cell
Glial cell - Astrocyte



Axon-Dendrite Contacts *Xu-Friedman et al, 2001*

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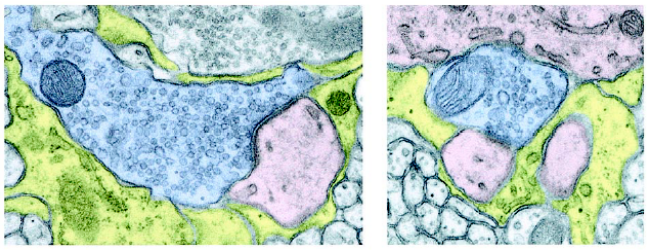

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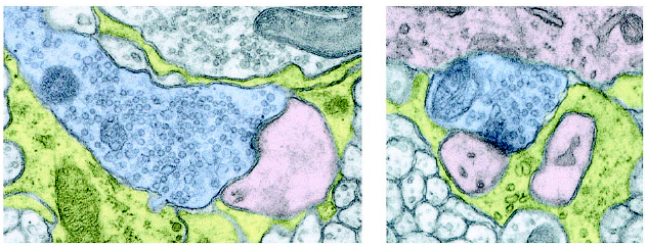

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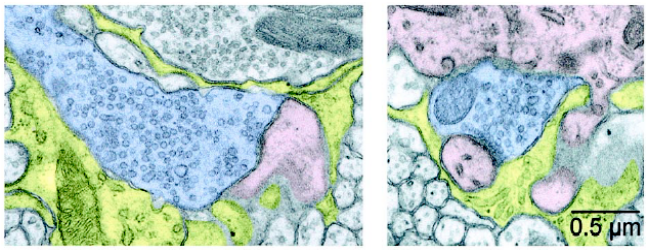

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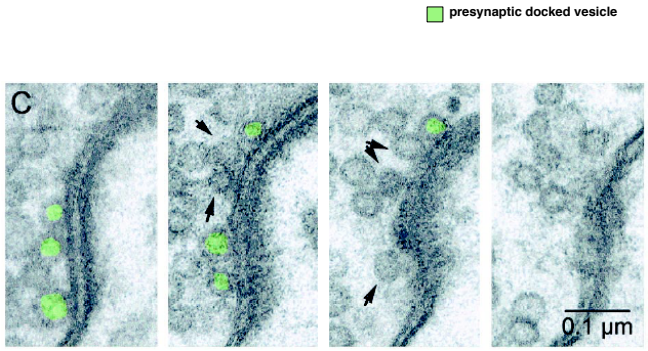
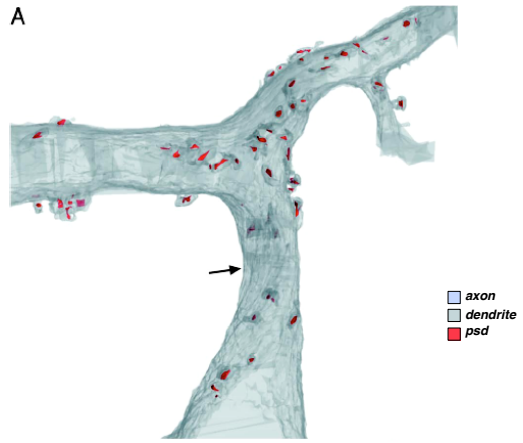


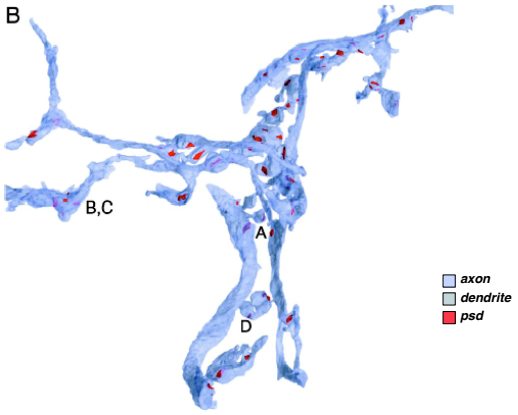
Axon-Dendrite Contacts *Xu-Friedman et al, 2001*

Purkinje Dendrite

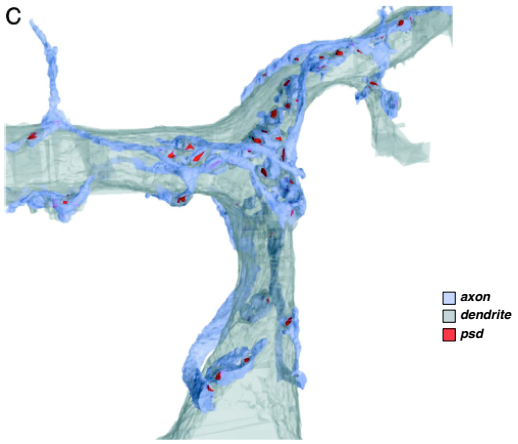


Axon-Dendrite Contacts *Xu-Friedman et al, 2001*

Climbing Fiber Axon



Axon-Dendrite Contacts *Xu-Friedman et al, 2001*



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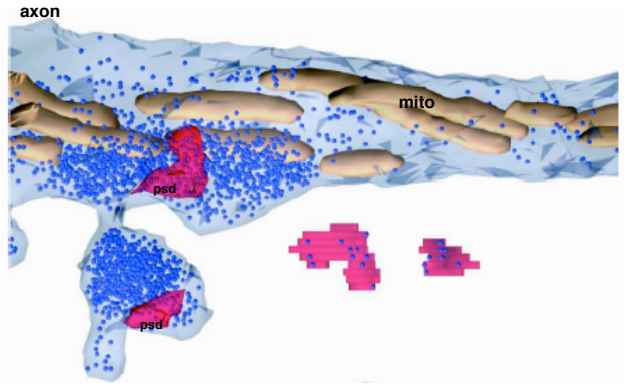
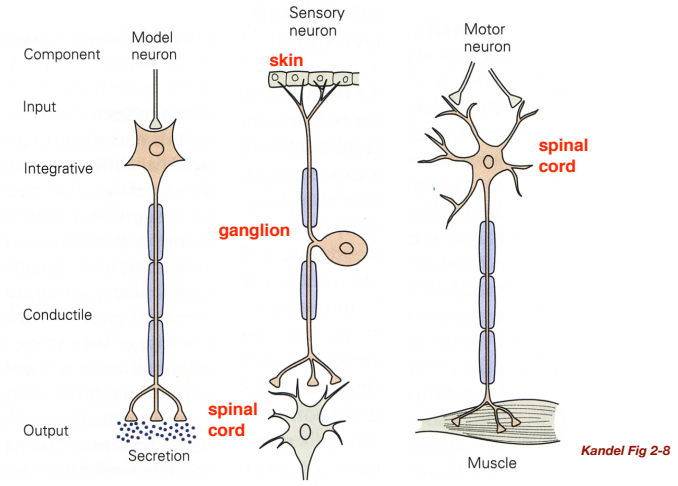


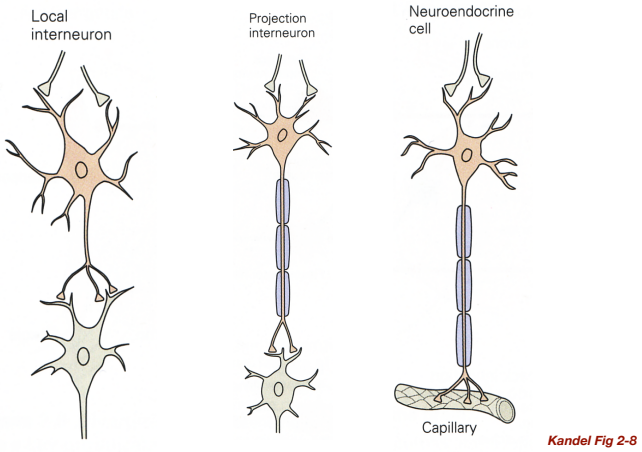
Axon-Dendrite Contacts *Xu-Friedman et al, 2001*

Important types of neurons



Kandel Fig 2-8

Important types of neurons

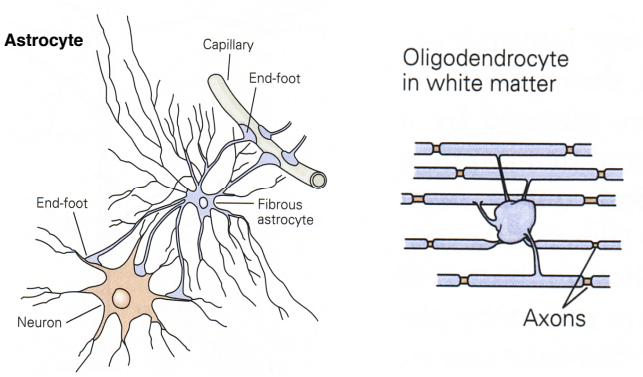


Kandel Fig 2-8

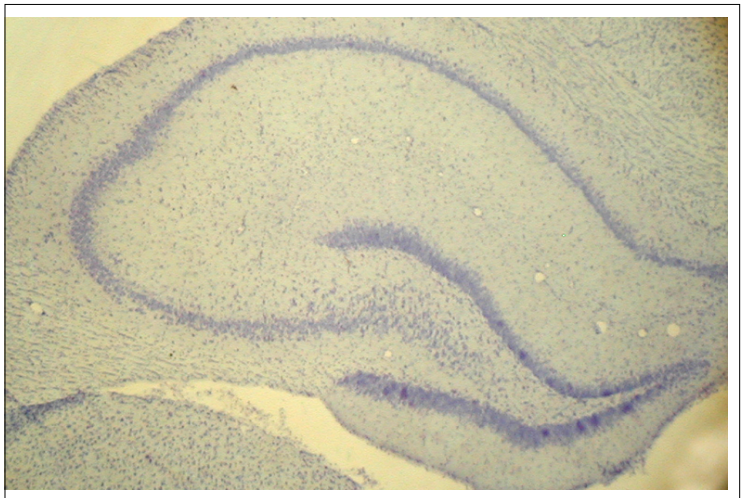
Glial Cells

1. **Support and organize neurons as structural elements**
2. **Oligodendrocytes (in brain) and Schwann cells (in periphery) produce myelin to insulate axons**
3. **Scavengers and immune cells**
4. **Radial glia guide migrating neurons**
5. **Form an impenetrable lining of the brain's capillaries = blood-brain-barrier**
6. **House-keeping and nourishment by uptaking chemicals released by neurons, providing energy (lactate), precursor chemicals and growth factors to keep neurons functioning.**

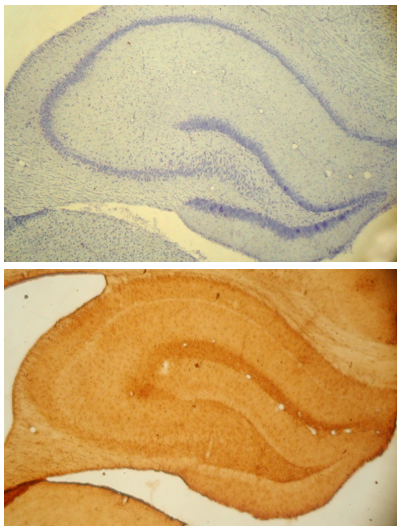
Glial Cells

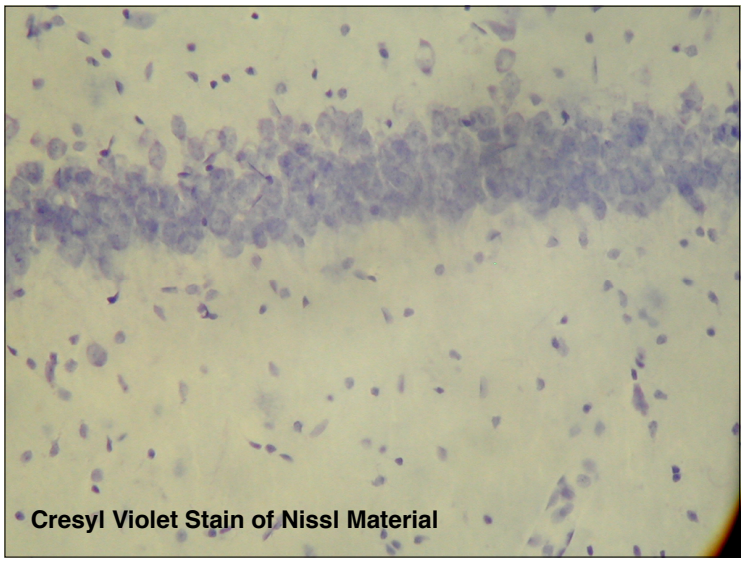


GFAP staining of hippocampus (glial cells)

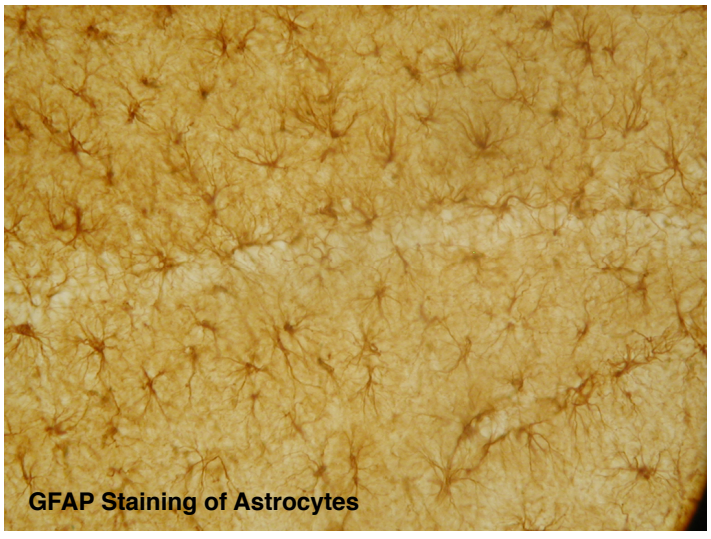


Cresyl Violet staining of hippocampus (neurons)





Cresyl Violet Stain of Nissl Material



GFAP Staining of Astrocytes

Schwann Cell in periphery

(myelinating long sensory or motor neurons)