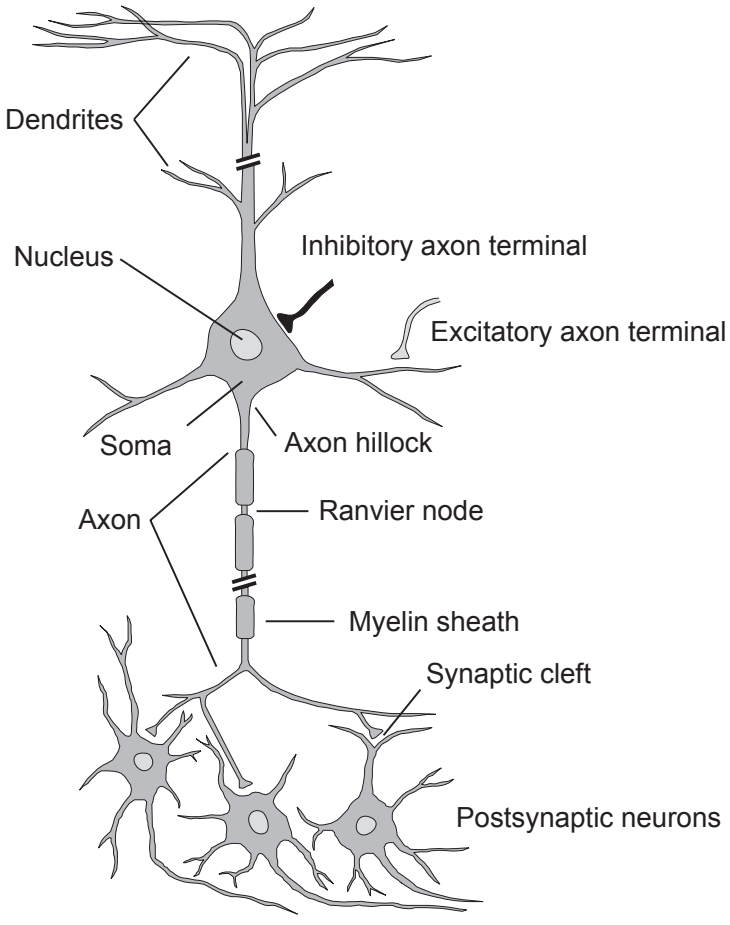
Neuroinformatics 2016

March 3, 2016

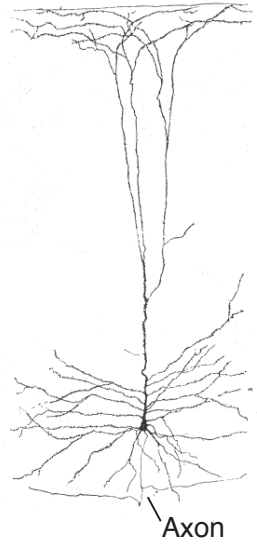
Neuron, synapse and neuron models

Biological background

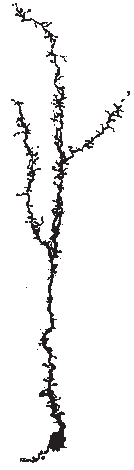
A. Schematic neuron



B. Pyramidal cell



C. Granule cell



D. Spiny cell

E. Purkinje cell

Glial cells

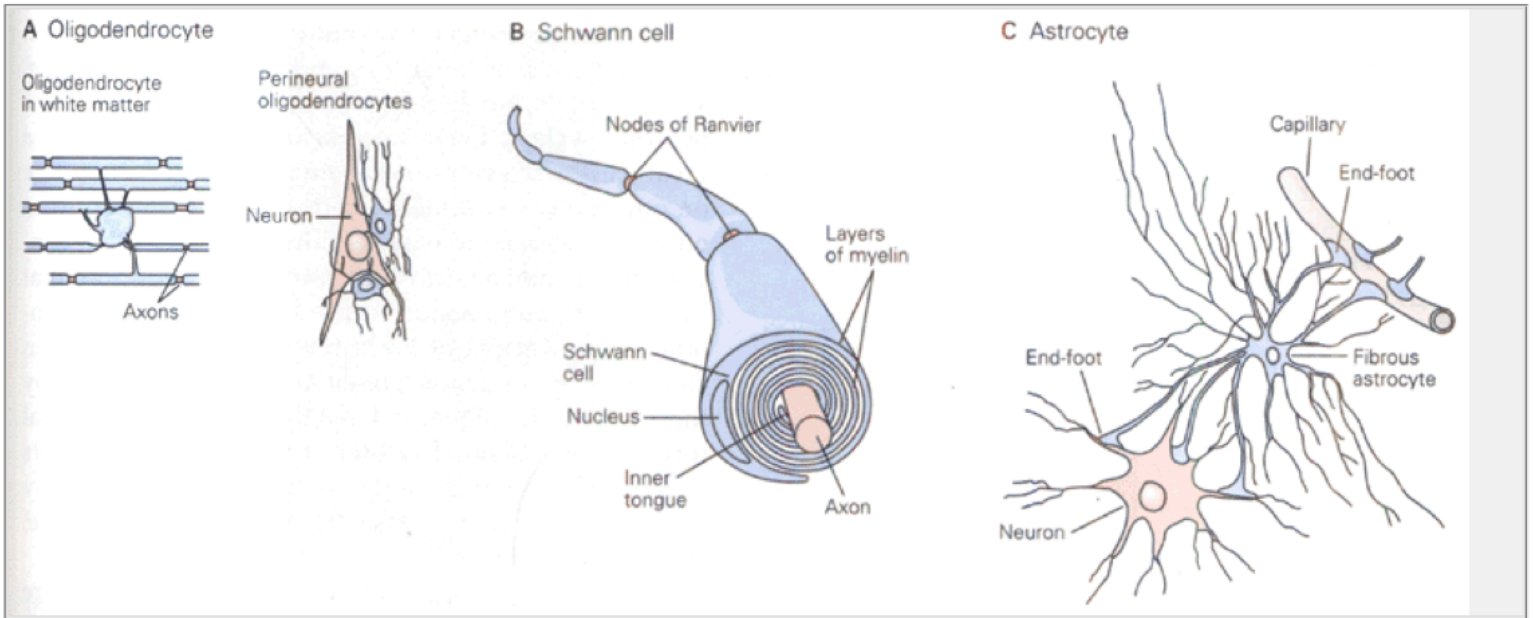
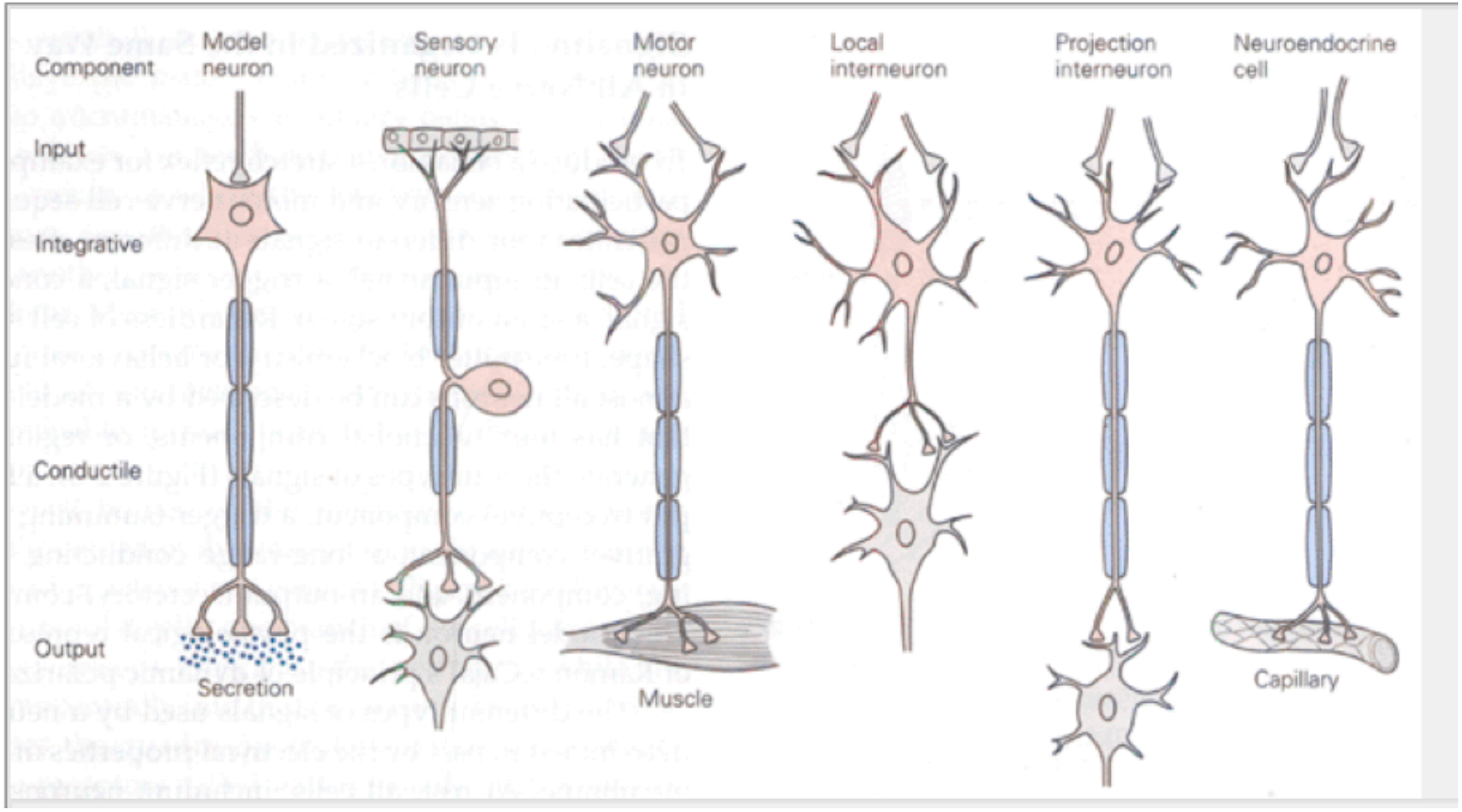
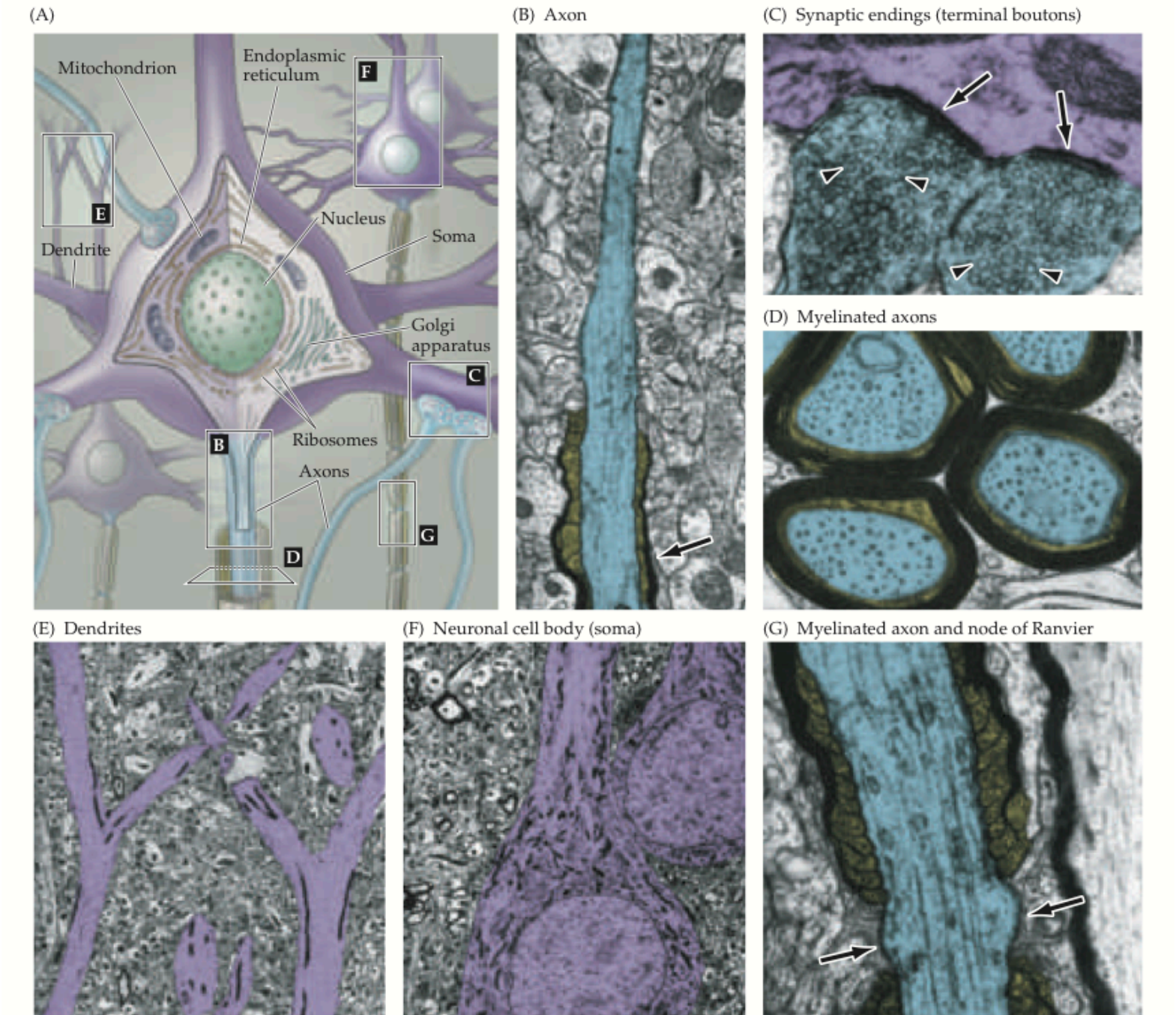


Figure 2-1 The principal types of glial cells in the central nervous system are astrocytes and oligodendrocytes and in the peripheral nervous system, Schwann cells.

Four components of neurons

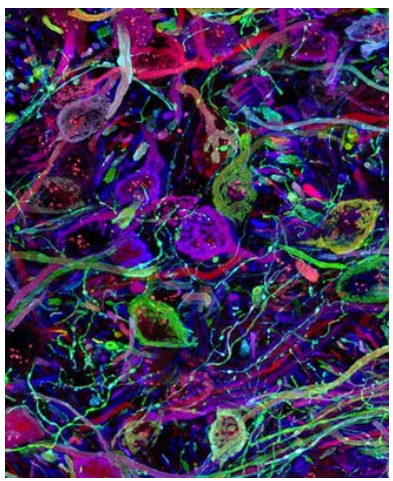
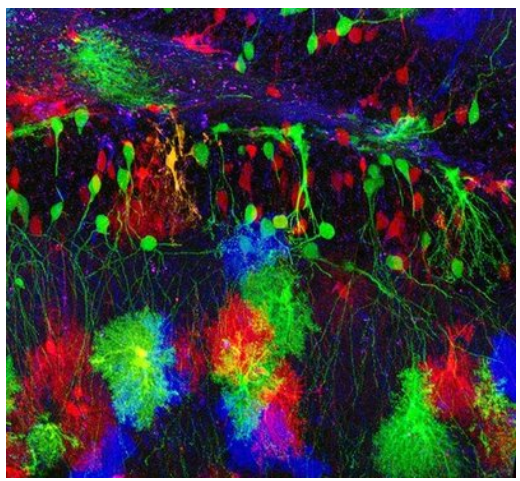
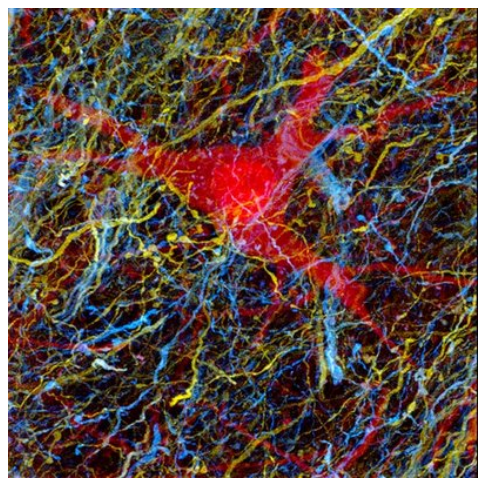


Microscopical features of neurons

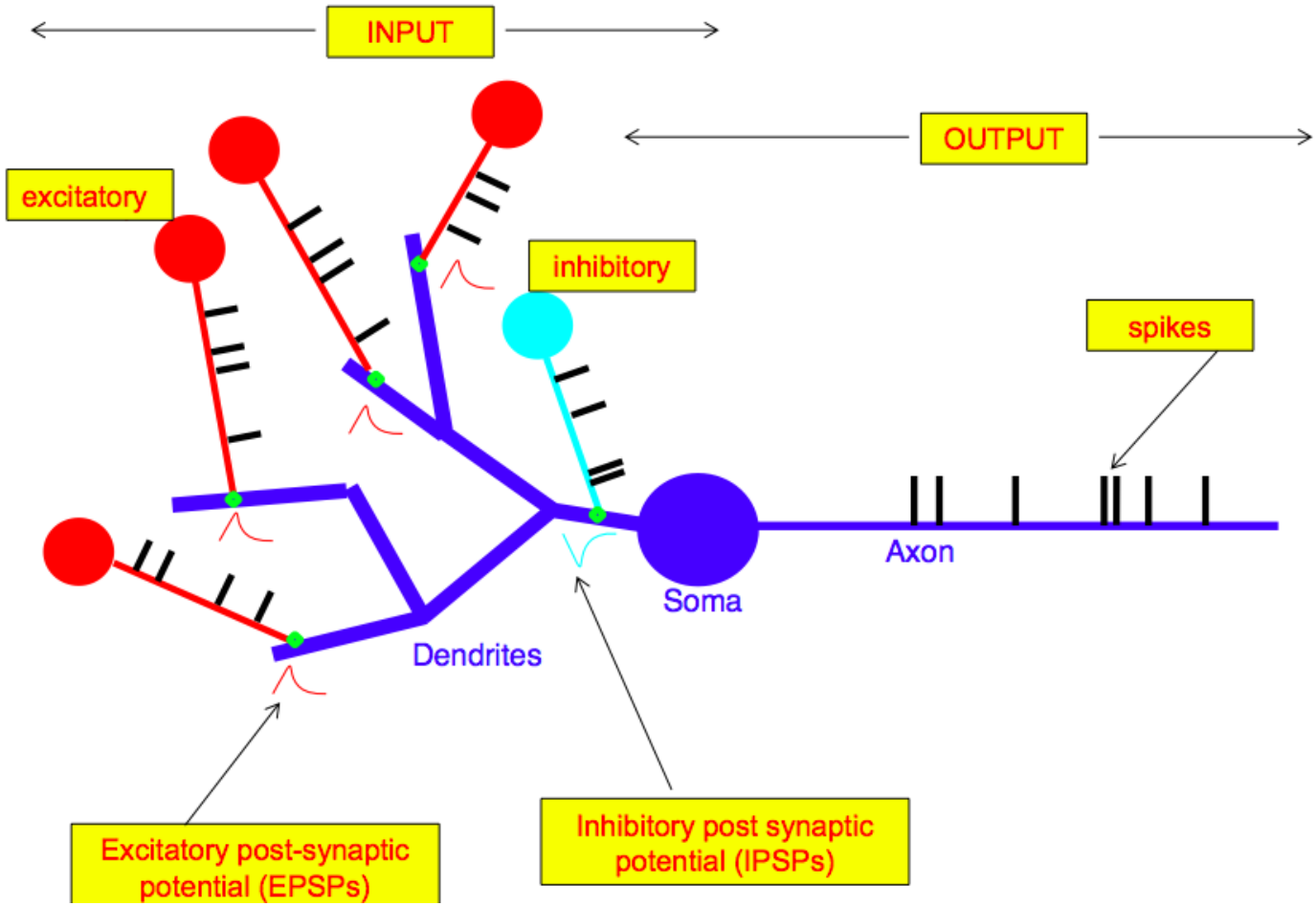


Brainbows

- Auditory portion of a mouse brainstem. A special gene (extracted from coral and jellyfish) was inserted into the mouse in order to map intricate connection. As the mouse thinks, fluorescent proteins spread out along neural pathways
- This view of the hippocampus shows the smaller glial cells (small ovals) in the proximity of neurons (larger with more filaments).
- A single neuron (red) in the brainstem
- `http://www.wired.com/science/discoveries/multimedia/2007/10/gallery_fluorescentneurons`

Neuron as input-output device



Neuron types

Classification by anatomical features ("the face" of dendrites and axons)

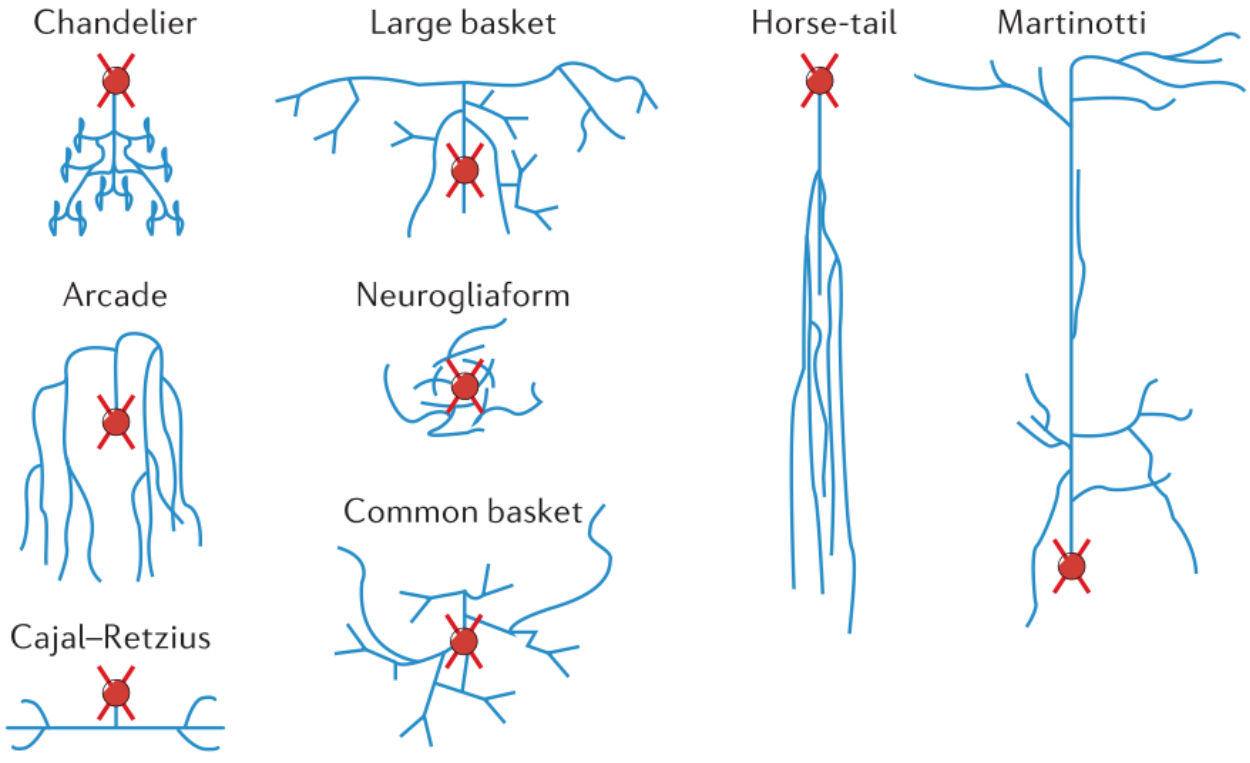
Classification – functional (e.g., Excitatory (principal) vs. Inhibitory (inter) neurons)

Classification using electrical/spiking activity pattern

Classification using chemical characteristics

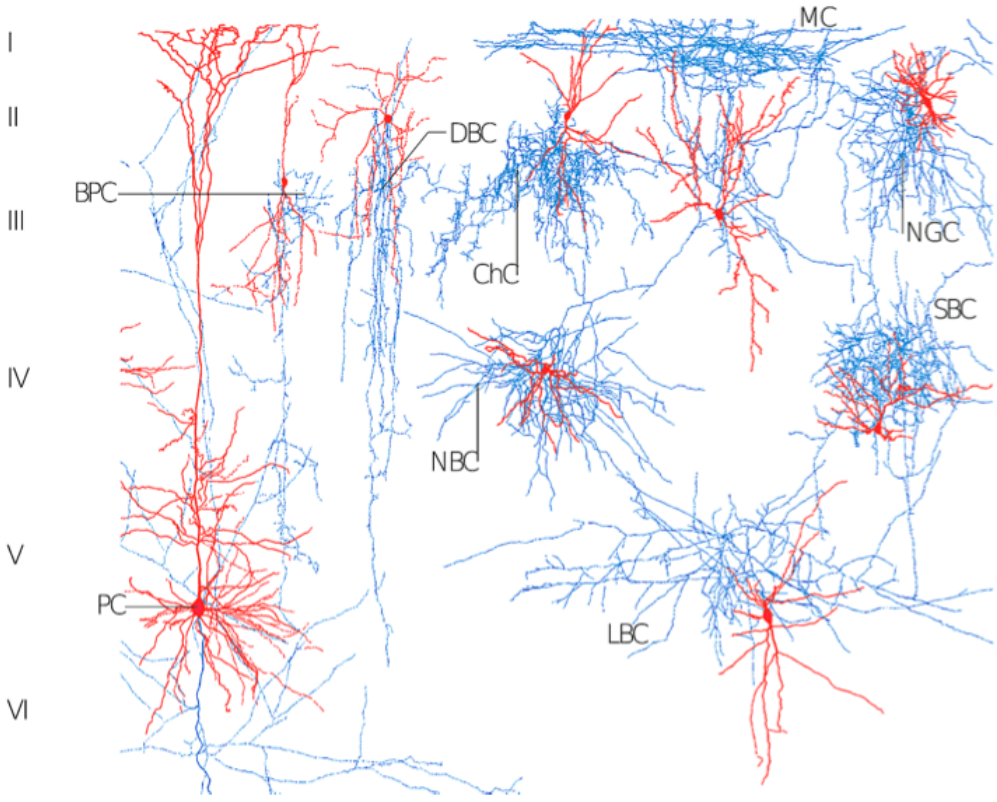
Classification using gene expression

Morphometric-based classification of (inhibitory) interneurons



DeFelipe et al., Nature Review neuroscience, 2013

Microcircuit of the Neocortex

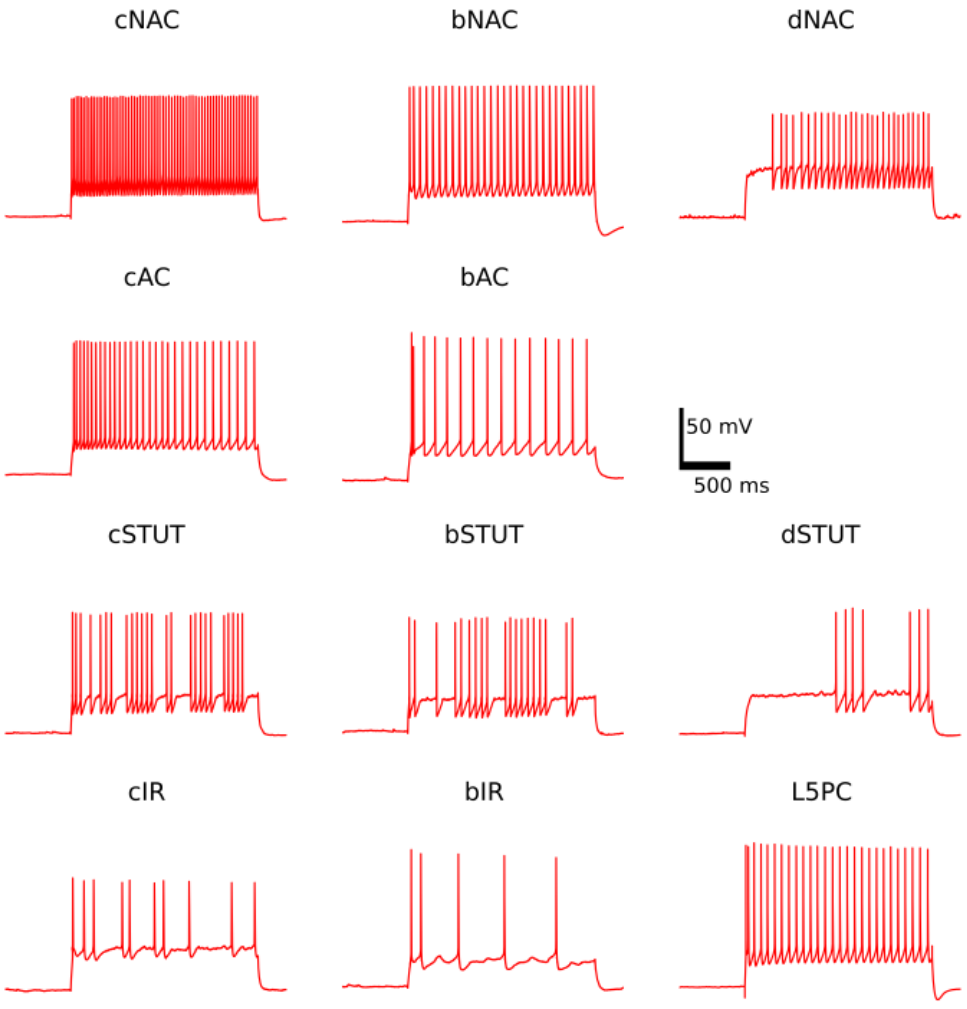


Principal neurons (excitatory) - axon projects to other brain regions

Interneurons (inhibitory) – local axonal projection

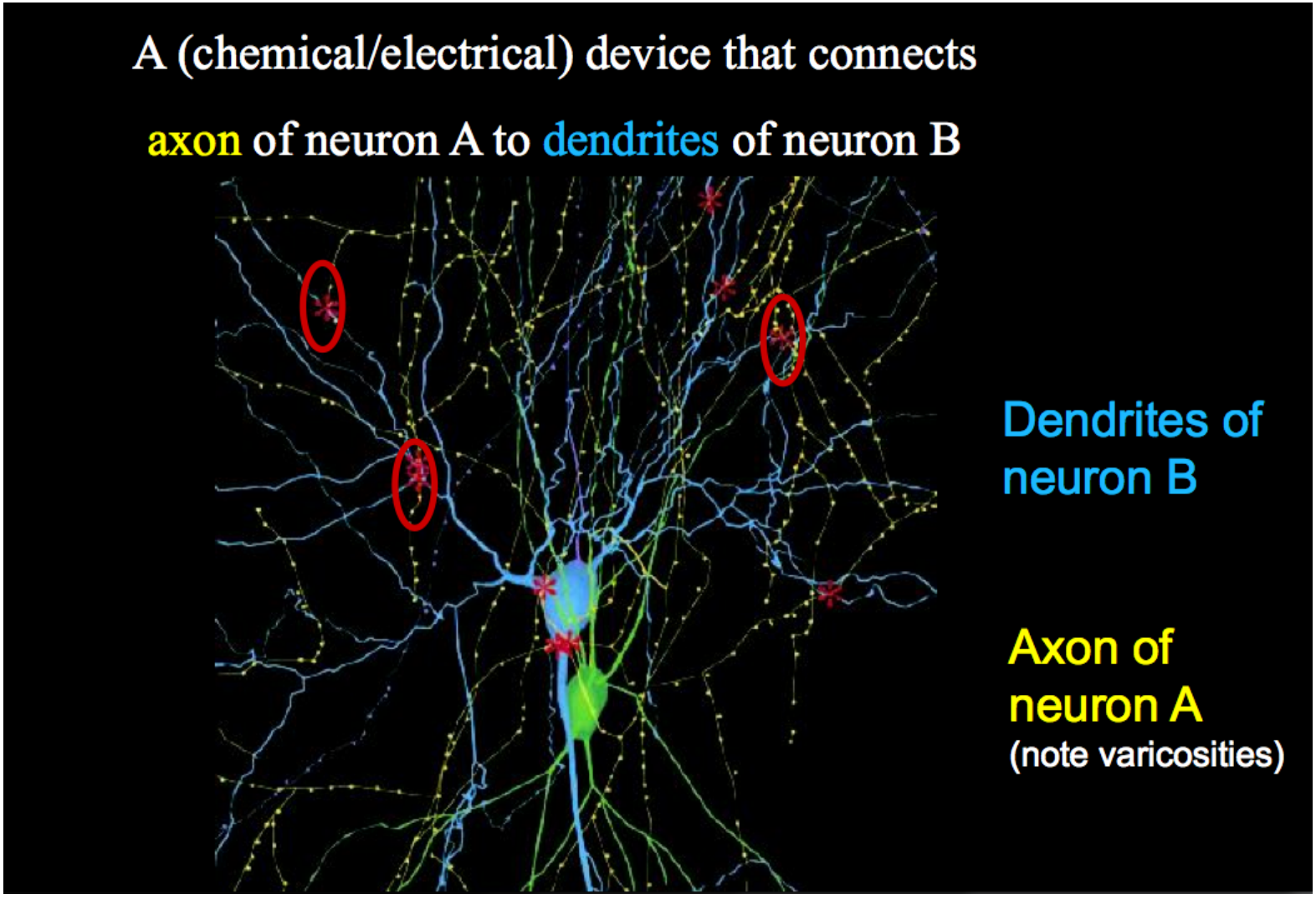
Z. J. Huang, G. Di Cristo & F. Ango
Nature Reviews Neuroscience 8, 673-686 (September 2007)

Electrically based neuron classification

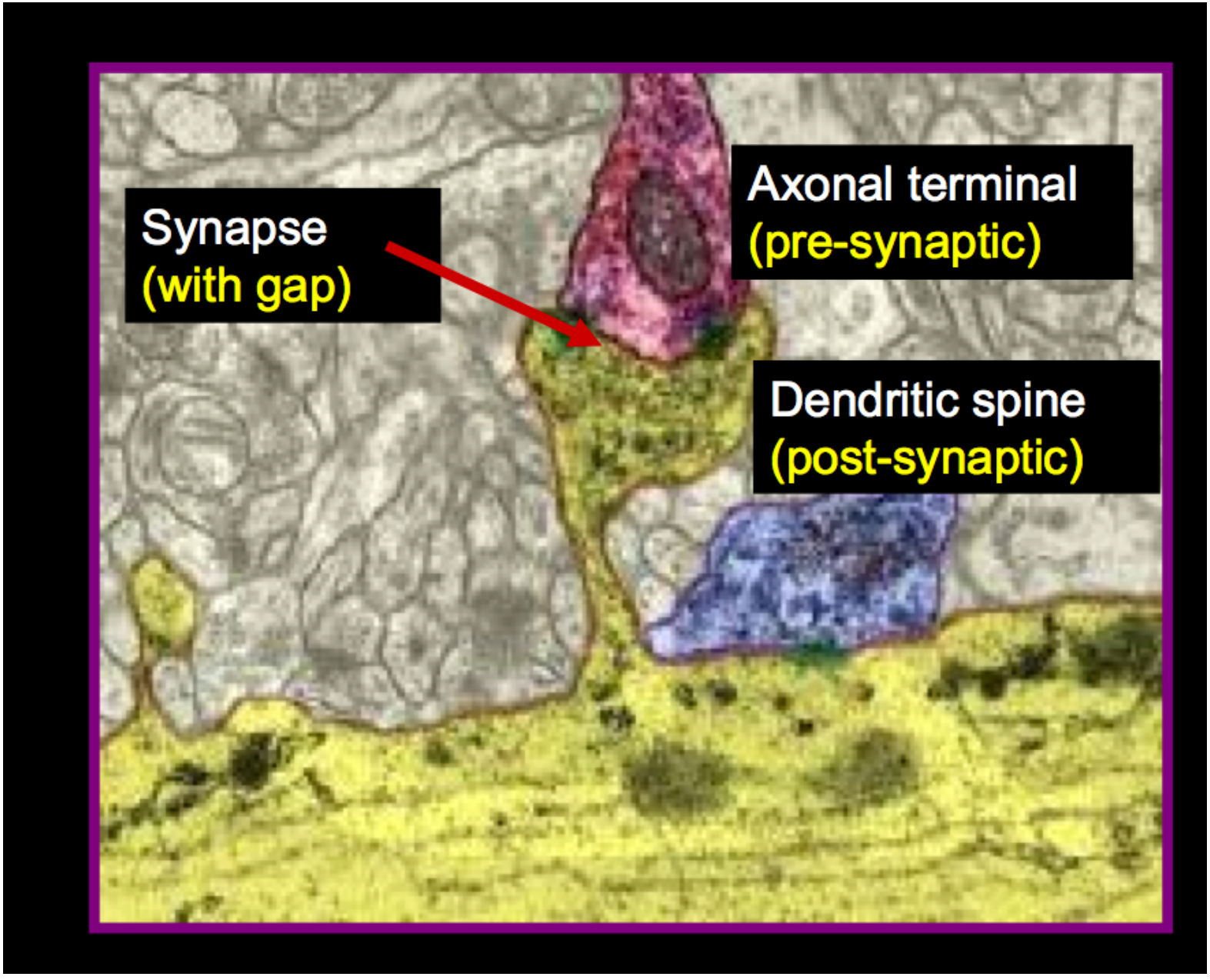


Courtesy of the Blue Brain data-base

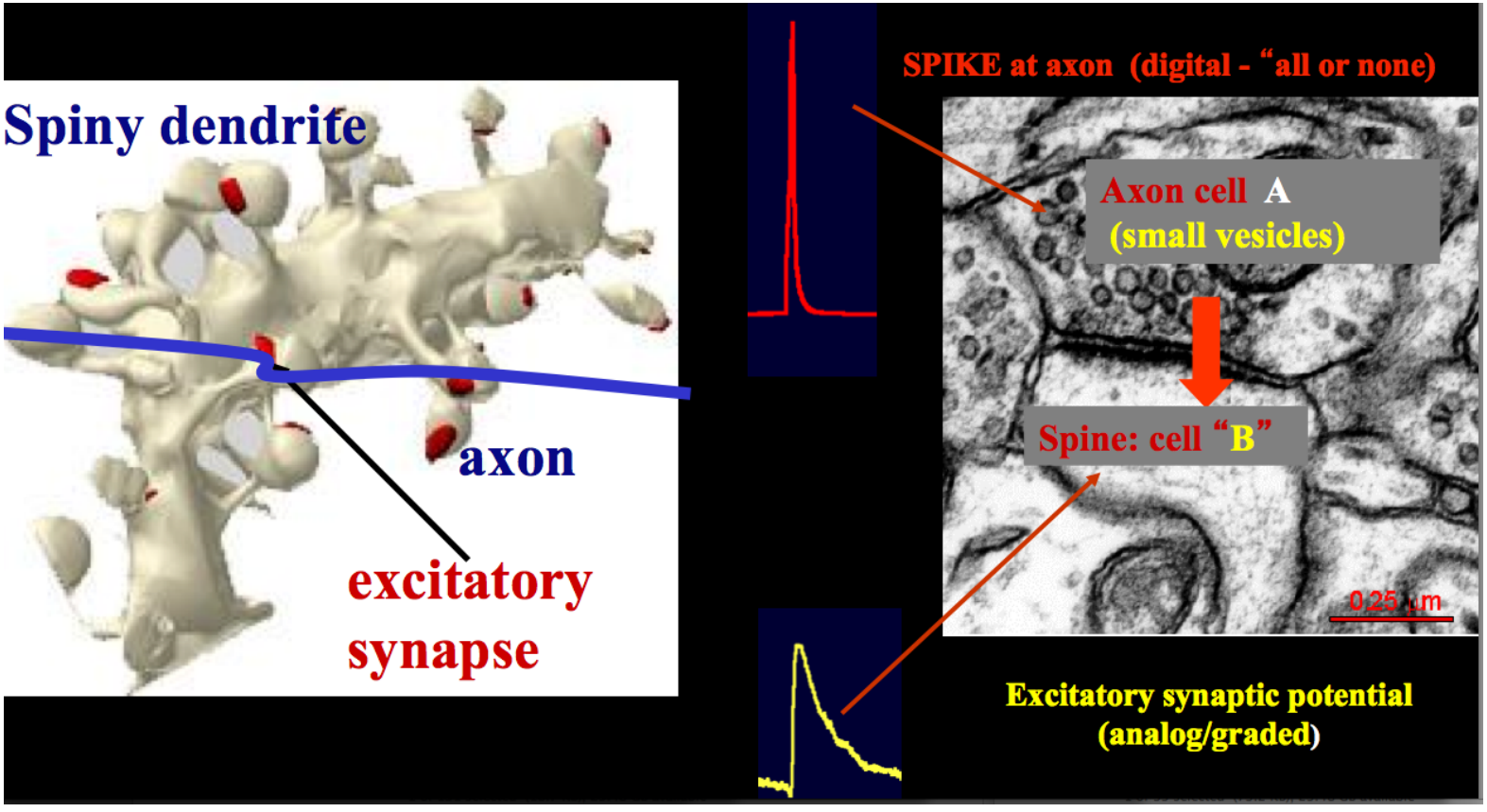
Synapse


A (chemical/electrical) device that connects
axon of neuron A to dendrites of neuron B
Dendrites of neuron B
Axon of neuron A
(note varicosities)

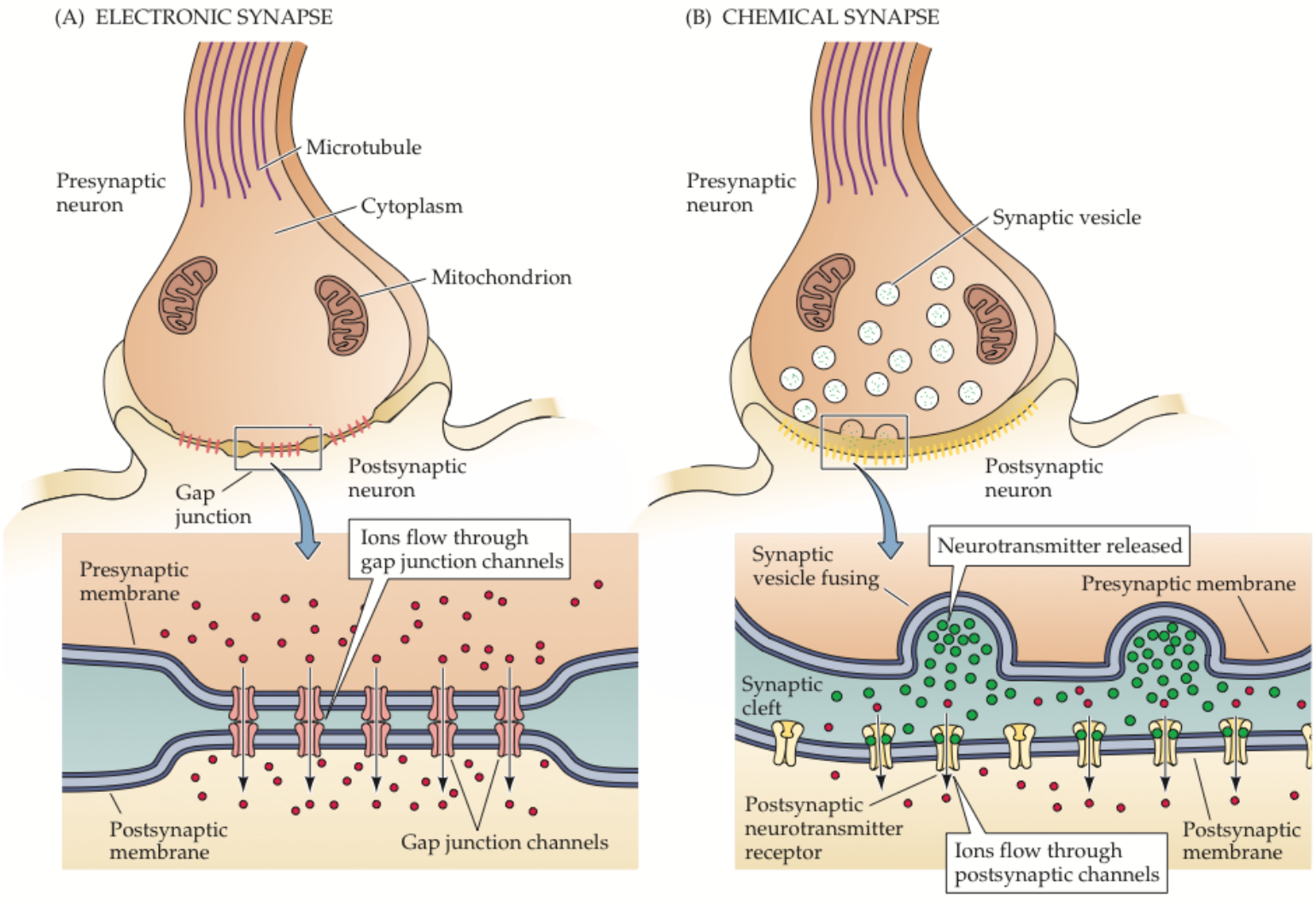
Chemical Synapse



Digital Analog Device



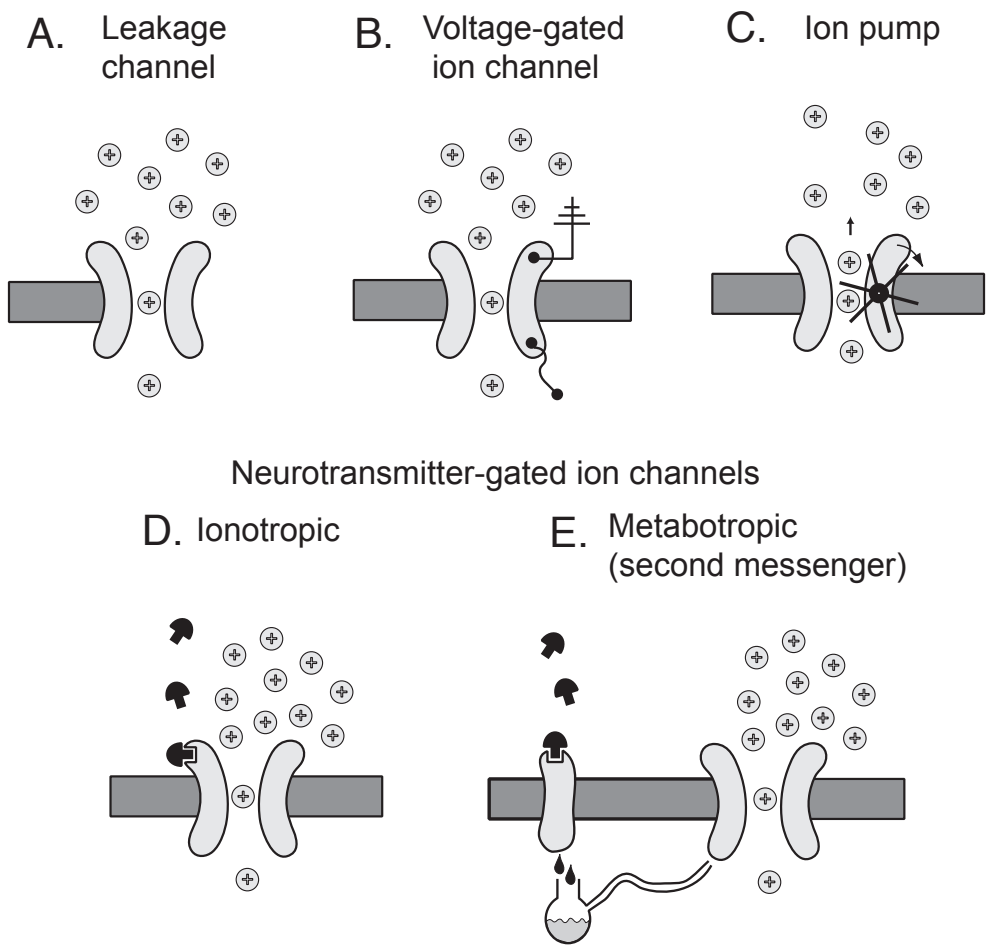
Electrical and Chemical Synapse



gap 3.5 nm, delay .2 ms, no gain

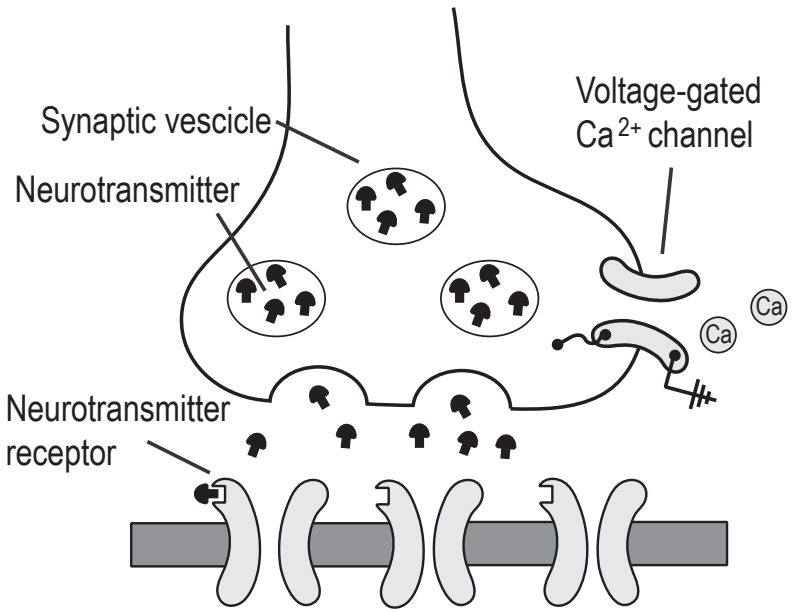
gap 40 nm, delay 2ms, gain

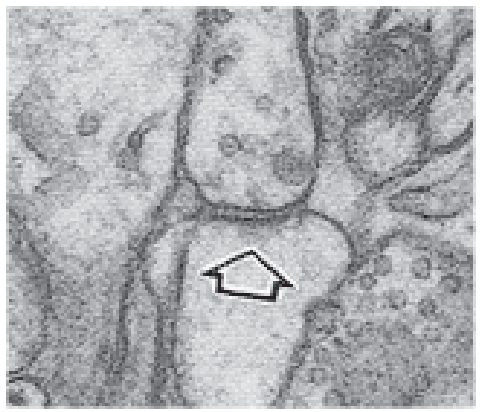
Ion channels



Synapse

- pre-synaptic neuron
- synaptic cleft - 40nm,
- synaptic vescicles
- release of vescicles controlled by voltage-gated Ca++ channels
- post-synaptic membrane with neurotransmitter receptors





Excitatory vs inhibitory synapses

Excitatory

- increase potential of post-synaptic neuron
- found at dendrites
- neurotransimitters:
  - Glu (glutamate - most common),
  - ACh (acetylcholine - neuromuscular junction)
  - DA (dopamine - motor behavior, motivation, arousal)

Inhibitory

- decrease potential of post-synaptic neuron
- found at body of post-syn. neuron
- neurotransimitters:
  - GABA (Gamma-aminobutyric acid)

excitatory and inhibitory potentials

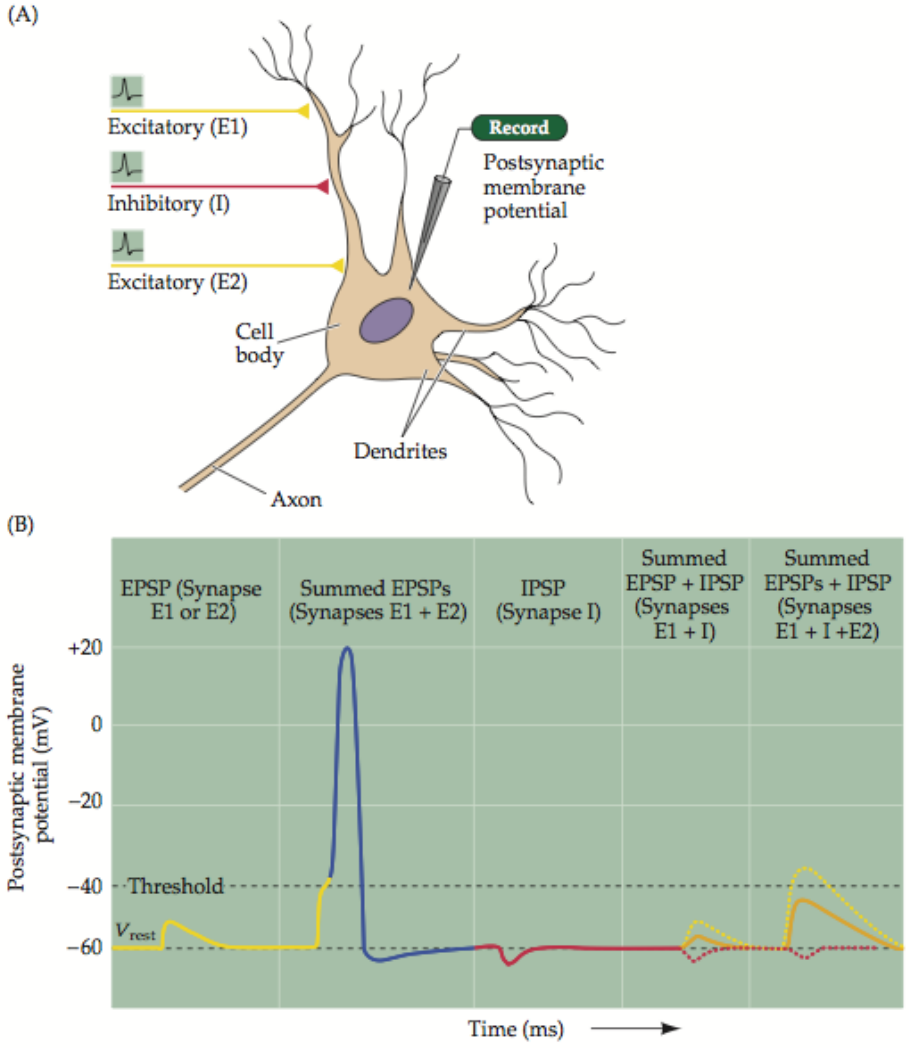


Figure 5.20 Summation of postsynaptic potentials. (A) A microelectrode records the postsynaptic potentials produced by the activity of two excitatory synapses (E1 and E2) and an inhibitory synapse (I). (B) Electrical responses to synaptic activation. Stimulating either excitatory synapse (E1 or E2) produces a subthreshold EPSP, whereas stimulating both synapses at the same time (E1 + E2) produces a suprathreshold EPSP that evokes a postsynaptic action potential (shown in blue). Activation of the inhibitory synapse alone (I) results in a hyperpolarizing IPSP. Summing this IPSP (dashed red line) with the EPSP (dashed yellow line) produced by one excitatory synapse (E1 + I) reduces the amplitude of the EPSP (orange line), while summing it with the suprathreshold EPSP produced by activating synapses E1 and E2 keeps the postsynaptic neuron below threshold, so that no action potential is evoked.

Further Readings

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