COMS30017
Computational Neuroscience

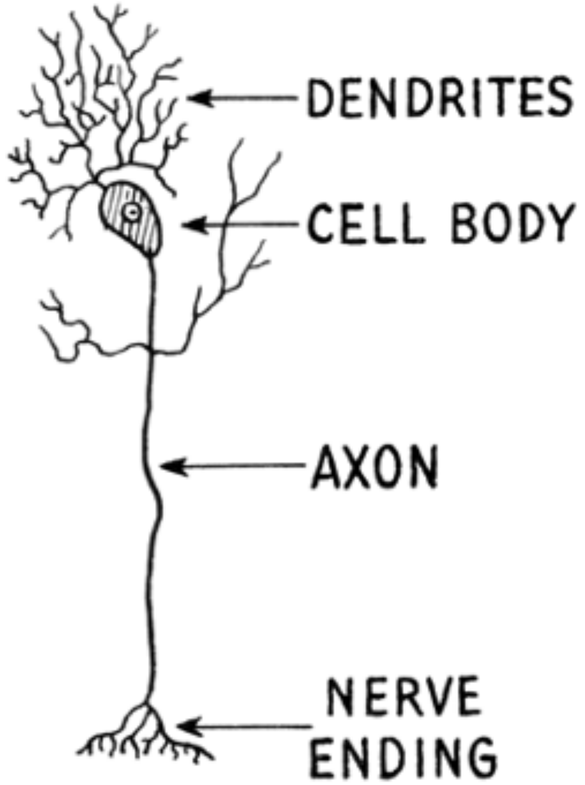
Single neuron anatomy

Intended learning outcomes

- Be able to name and describe the basic parts of a neuron: soma, axon, dendrite, synapse.

The basic parts of a neuron

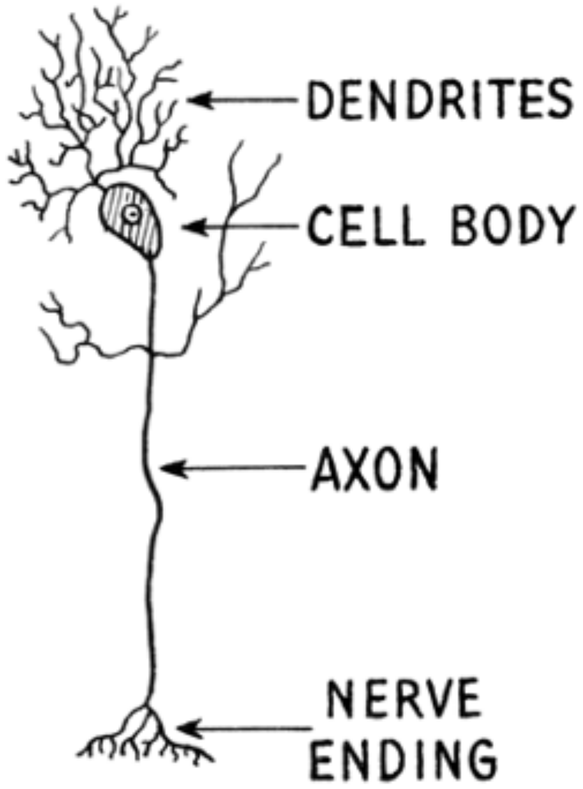
- Neurons are the main cellular component of the brain's circuitry.
- Neurons are cells. But unlike most cells in your body, they have highly specialised shapes, for two reasons:
  - They have to connect to other neurons. This implies having "wires".
  - They process information. Having multiple spatial compartments lets them do more complex computations.
- Neurons come in lots of different types, and therefore shapes. Even within a single type, no two individual neurons have identical shape.
- That said, most neurons have the same three basic parts:
  - **Soma / cell body**
  - **Axon**: the output wire.
  - **Dendrites**: the input wires.
- Connections between neurons are called **synapses**.



: http://commons.wikimedia.org/wiki/File:Dendrite_(PSF).png

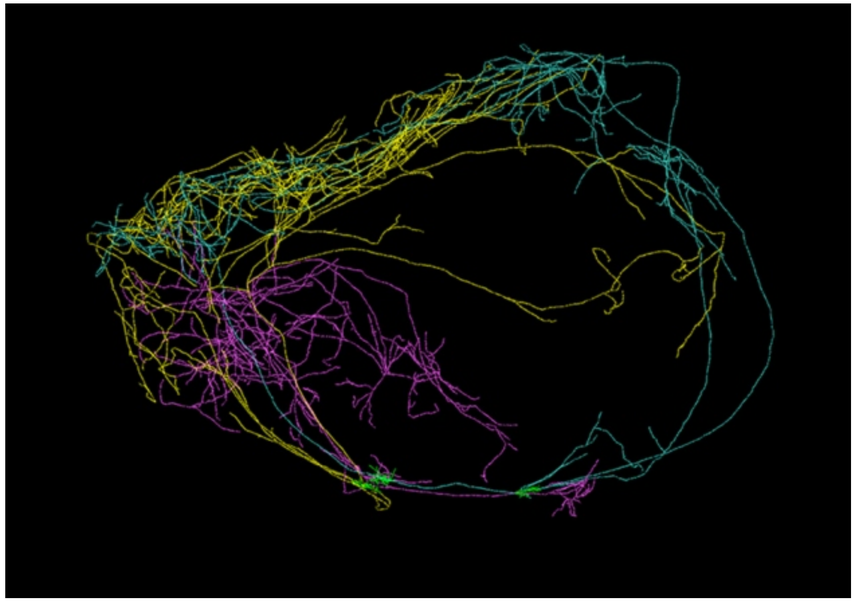
The soma / cell body

- Holds the nucleus (home of the DNA).
- All the mRNA and most of proteins, mitochondria etc get manufactured here and shipped out to the rest of the neuron.
- From a computational point of view it is where all the input signals get ‘summed up’.



Axon

- In most neurons there is a single axon carrying the output signal from the neuron.
- However multiple copies of this signal many get sent to many target neurons.
- Axon branches vary widely in length, some reach only locally within the same brain region, while others may project far away to other brain regions.
- Peripheral nerves are basically big long axons. The longest nerve in the human body (from toes to spinal cord) is around 1m in length.



A digital reconstruction of a neuron that encircles the mouse brain.

https://www.nature.com/news/a-giant-neuron-found-wrapped-around-entire-mouse-brain-1.21539

Dendrites

- Tree shaped with many branches, varying from ~5 to ~1000.
- Each neuron type has a distinct dendritic tree shape.
- From a computational point of view, the dendrites collect all the input signals and funnel them to the soma at the ‘root’ of the tree.
- Usually reaches only locally, within the same brain region.

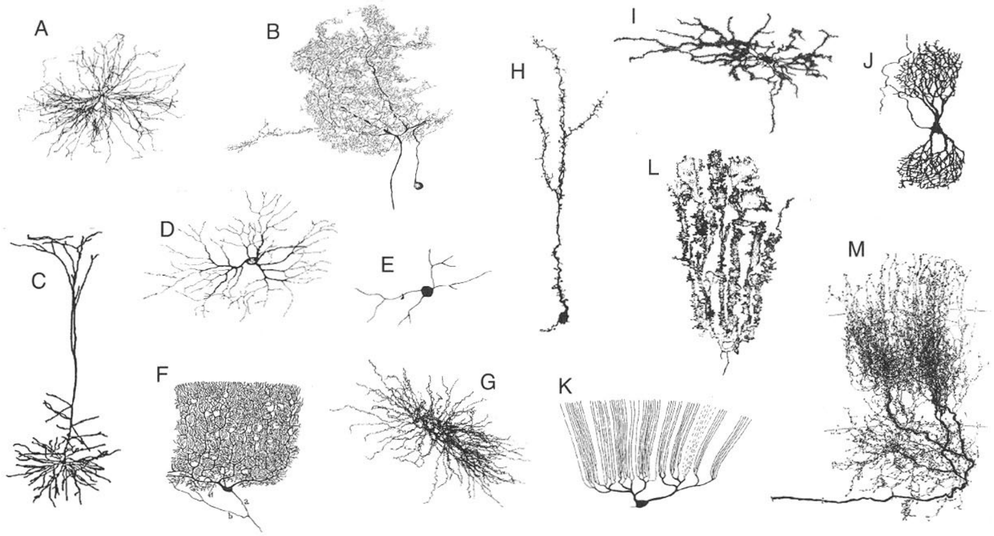
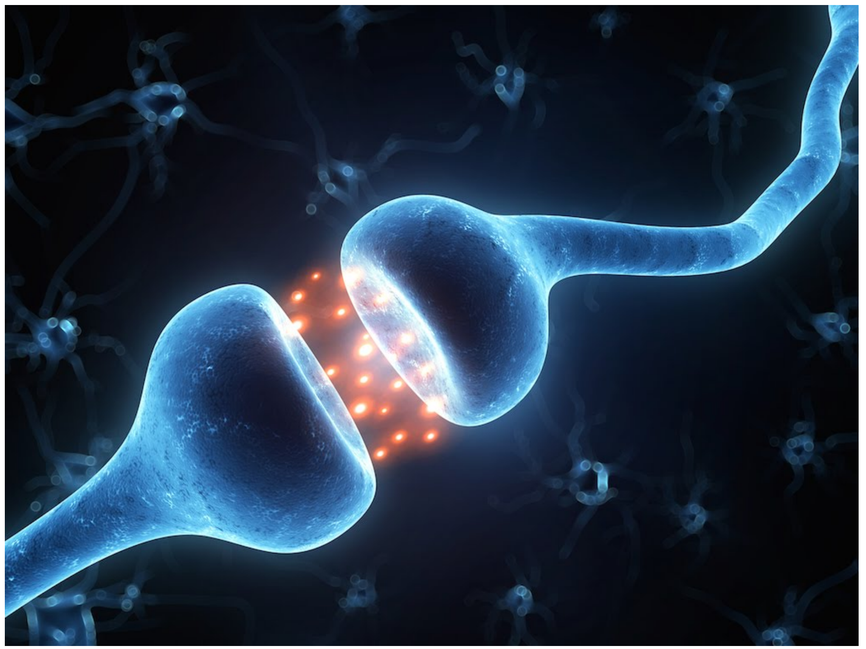


Fig. 3.1 Dendritic Trees of the World Great variety of dendritic trees (in addition to a glia cell and an axonal tree) observed in the nervous systems of animals. The cells are not drawn to scale. **(A)** α motoneuron in spinal cord of cat (2.6 mm). Reprinted by permission from Cullheim, Fleshman, and Burke (1987). **(B)** Spiking interneuron in mesothoracic ganglion of locust (0.54 mm). Unpublished data from G. Laurent, with permission. **(C)** Layer 5 neocortical pyramidal cell in rat (1.03 mm). Reprinted by permission from Amitai et al., (1993). **(D)** Retinal ganglion cell in postnatal cat (0.39 mm). Reprinted by permission from Maslim, Webster, and Stone (1986). **(E)** Amacrine cell in retina of larval tiger salamander (0.16 mm). Reprinted by permission from Yang and Yazulla (1986). **(F)** Cerebellar Purkinje cell in human. Reprinted by permission from Ramón y Cajal (1909). **(G)** Relay neuron in rat ventrobasal thalamus (0.35 mm). Reprinted by permission from Harris (1986). **(H)** Granule cell from olfactory bulb of mouse (0.26 mm). Reprinted by permission from Greer (1987). **(I)** Spiny projection neuron in rat striatum (0.37 mm). Reprinted by permission from Penny, Wilson, and Kitai (1988). **(J)** Nerve cell in the nucleus of Burdach in human fetus. Reprinted by permission from Ramón y Cajal (1909). **(K)** Purkinje cell in mormyrid fish (0.42 mm). Reprinted by permission from Meek and Nieuwenhuys (1991). **(L)** Golgi epithelial (glia) cell in cerebellum of normal-reeler mouse chimera (0.15 mm). Reprinted by permission from Terashima et al., (1986). **(M)** Axonal arborization of isthmotectal neurons in turtle (0.46 mm). Reprinted by permission from Sereno and Ulinski (1987). The lengths given are approximate and correspond to the maximal extent. Reprinted by permission from Mel (1994).

Koch, Biophyiscs of Computation (1999)

Synapses

- Synapses are the connections between neurons. They carry a signal from the axon of one neuron to the dendrite of another.
- They are small. Around ~1μm across.
- They vary in strength/weight and are important for learning and memory.
- The two most important types for us are:
  - glutamate synapses, which are excitatory (turn targets on)
  - GABA synapses, which are inhibitory (turn targets off)
- Synapses are nonlinear and can therefore do computation.
- Around ~10^{14} synapses in the adult human brain (compared with ~10^{11} neurons).



Test yourself questions

- Which part of the neuron carries the output signal?
- Which part of the neuron is involved in learning and memory?

Summary

- The basic parts of the neuron are the soma (cell body), axon, and dendrite.
- The connections between neurons are called synapses. For our purposes there are two types: excitatory and inhibitory.
- Neurons collect many input signals via dendrites, then send copies of one output signal via the axon to multiple neurons.