## **Quick guides**

## **Pyramidal neurons**

John M. Bekkers

What is a pyramidal neuron? A common class of neuron found in the cerebral cortex of virtually every mammal, as well as in birds, fish and reptiles. Pyramidal neurons are also common in subcortical structures such as the hippocampus and the amygdala. They are named for their shape: typically they have a soma (cell body) that is shaped like a teardrop or rounded pyramid. They also tend to have a conical spray of longer dendrites that emerge from the pointy end of the soma (apical dendrites) and a cluster of shorter dendrites that emerge from the rounded end (basal dendrites) (Figure 1).

Why are they important? There are two dominant families of neurons in the cortex, excitatory neurons, which release the neurotransmitter glutamate, and inhibitory neurons, which release  $\gamma$ -amino-butyric acid (GABA). Pyramidal neurons are the most populous members of the excitatory family in the brain areas they inhabit. They comprise about two-thirds of all neurons in the mammalian cerebral cortex, which places them center-stage for many important cognitive processes.

What do pyramidal neurons do? Like many other types of neuron, their main job is to transform synaptic inputs into a patterned output of action potentials. What makes them special is their numerical dominance, as well as the fact that they are 'projection neurons'—they often send their axons for long distances, sometimes out of the brain altogether. For example, pyramidal neurons in layer 5 of the motor cortex send their axons down the spinal cord to drive muscles. Pyramidal neurons might thus be thought of as the 'movers and shakers' of the brain.

Are all pyramidal neurons the same? They have a strong family resemblance, with their upright posture of apical and basal dendrites; but they vary in their appearance across different species and cortical regions. Some may even merge with other

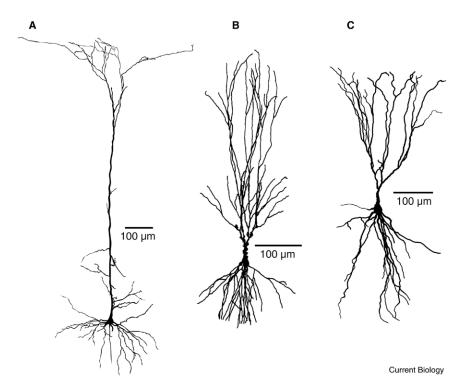


Figure 1. Dendritic morphologies of typical pyramidal neurons in different brain regions. (A) Layer 5 pyramidal neuron in the rat somatosensory cortex (courtesy of Maarten Kole). (B) Pyramidal neuron in area CA3 of the rat hippocampus (reproduced with permission from Gonzales *et al.* (2001).) (C) Layer 2 pyramidal neuron in the primary olfactory cortex of the mouse (unpublished work of Norimitsu Suzuki and myself).

types of excitatory neurons, like spiny stellate cells. Molecular approaches are revealing genetic diversity amongst pyramidal neurons, confirming the existence of distinct subtypes.

## Do different-shaped pyramidal neurons also function differently?

There is a lot of evidence for functional specialization by subtypes of pyramidal neurons. Pyramidal neurons have long been a favorite of neurophysiologists because they are big, bountiful and beautiful. Hence, there is probably more known about the inner workings of these neurons than any other class of neuron in the brain. For example, layer 5 pyramidal neurons are thought to benefit from their large size, partitioning off parts of themselves into semi-autonomous processing units. On the other hand, the smaller pyramidal neurons in the hippocampus behave more like a committee, allowing all of their synapses an equal 'vote' in deciding whether or not to fire an action potential.

What happens when pyramidal neurons go wrong? As might be expected from their ubiquity and long

axonal projections, faulty pyramidal cells are an important cause of brain disorders. Epilepsy, due to excessive neuronal excitation, is particularly common in brain regions containing many interconnected pyramidal neurons, such as the hippocampus. Some neurodegenerative disorders, including Alzheimer's disease, disproportionately kill pyramidal neurons, leading to characteristic cognitive changes. Thus, pyramidal neurons are the building blocks for high-level functions like memory and consciousness. When they misbehave, the consequences can be profound.

## Where can I find out more?

Gonzales, R.B., DeLeon Galvan, C.J., Rangel, Y. M., and Claiborne, B.J. (2001). Distribution of thorny excrescences on CA3 pyramidal neurons in the rat hippocampus. J. Comp. Neurol. 430, 357–368.

Nelson, S.B., Hempel, C., and Sugino, K. (2006).
Probing the transcriptome of neuronal cell types. Curr. Opin. Neurobiol. 16, 571–576.
Spruston, N. (2008). Pyramidal neurons: dendritic structure and synaptic integration. Nat. Rev.

John Curtin School of Medical Research, The Australian National University, Canberra, Australia.

E-mail: John.Bekkers@anu.edu.au

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