Pyramidal neuron

Pyramidal neurons (pyramidal cells) are a type of neuron found in areas of the brain including the cerebral cortex, the hippocampus, and the amygdala. Pyramidal neurons are the primary excitation units of the mammalian prefrontal cortex and the corticospinal tract. Pyramidal neurons were first discovered and studied by Santiago Ramón y Cajal.

Since then, studies on pyramidal neurons have focused on topics ranging from neuroplasticity to cognition.

The basic excitatory neurons of the cerebral cortex, the pyramidal cells, are the most important signal integrators for the local circuit. They have quite characteristic morphological and electrophysiological properties that are known to be largely constant with age in the young and adult cortex. However, the brain undergoes several dynamic changes throughout life, such as in early development phases and cognitive decline in the aging brain.

Goriounova et al., finded that high IQ scores and large temporal cortical thickness associate with larger, more complex dendrites of human pyramidal neurons. They showed in silico that larger dendritic trees enable pyramidal neurons to track activity of synaptic inputs with higher temporal precision, due to fast action potential kinetics. Indeed, they finded that human pyramidal neurons of individuals with higher IQ scores sustain fast action potential kinetics during repeated firing. These findings provide the first evidence that human intelligence is associated with neuronal complexity, action potential kinetics and efficient information transfer from inputs to output within cortical neurons [1)].

Hippocampal network activity is generated by a complex interplay between excitatory pyramidal cells and inhibitory interneurons. Although much is known about the molecular properties of excitatory synapses on pyramidal cells, comparatively little is known about excitatory synapses on interneurons [2)].

Descriptive and Comparative Experimental Studies

Barzó et al. set out to search for intrinsic cellular changes in supragranular pyramidal cells across a broad age range: from birth to 85 years of age, and they found differences in several biophysical properties between defined age groups. During the first year of life, subthreshold and suprathreshold electrophysiological properties changed in a way that shows that pyramidal cells become less excitable with maturation, but also become temporarily more precise. According to the findings, the morphological features of the three-dimensional reconstructions from different life stages showed consistent morphological properties, and systematic dendritic spine analysis of an infantile and an old pyramidal cell showed clear, significant differences in the distribution of spine shapes. Overall, the changes that occur during development and aging may have lasting effects on the properties of pyramidal cells in the cerebral cortex. Understanding these changes is important to unravel the complex mechanisms underlying brain development, cognition, and age-related neurodegenerative diseases [3)]

1)

Goriounova NA, Heyer DB, Wilbers R, Verhoog MB, Giugliano M, Verbist C, Obermayer J, Kerkhofs A, Smeding H, Verberne M, Idema S, Baayen JC, Pieneman AW, de Kock CP, Klein M, Mansvelder HD. Large and fast human pyramidal neurons associate with intelligence. Elife. 2018 Dec 18;7. pii: e41714. doi: 10.7554/eLife.41714. [Epub ahead of print] PubMed PMID: 30561325.

2)

Polepalli JS, Wu H, Goswami D, Halpern CH, Südhof TC, Malenka RC. Modulation of excitation on parvalbumin interneurons by neuroligin-3 regulates the hippocampal network. Nat Neurosci. 2017 Feb;20(2):219-229. doi: 10.1038/nn.4471. PubMed PMID: 28067903; PubMed Central PMCID: PMC5272845.

3)

Barzó P, Szöts I, Tóth M, Csajbók ÉA, Molnár G, Tamás G. Electrophysiology and morphology of human cortical supragranular pyramidal cells in a wide age range. Elife. 2025 Mar 28;13:RP100390. doi: 10.7554/eLife.100390. PMID: 40152903.