Diversity of pyramidal neurons across neocortical areas in the primate: Biophysics, morphology, and postnatal development

Ichiro Fujita
Osaka University Graduate School of Frontier Biosciences, Osaka 56-8531, Japan

The primate cerebral cortex consists of dozens of distinct areas. It is often assumed that neurons of the same type in the same layer are similar in morphology and physiology across cortical areas. In fact, structure, biophysical membrane properties, and developmental profiles of cortical neurons vary among them.

Dendritic trees and axonal arbors of pyramidal neurons become increasingly more complex through series of functionally related cortical areas. Terminal patches of horizontal axons in layers II and III in the inferotemporal cortex (TE) are larger in size and more complex in shape and distribution pattern than those in the primary visual cortex (V1) [1), 2)] . Basal dendritic trees of layer III pyramidal neurons become progressively larger, more branched and more spinous with anterior progression through the ventral visual pathway (V1, V2, V4, TEO, TE) [3)] . Examination with high-voltage electron-microscope reveals greater diversity in the morphology of dendritic spines in TE than in V1.

Basal dendritic trees of pyramidal cells in ventral cortical areas have different growth and atrophy profiles during normal development [4), 5)]. In all cortical areas, spine density along the dendrites increases from birth to 3.5 months of age, beyond which pruning exceeds any further spine growth resulting in a net decrease in the number of spines found within the dendrites. The extent of this pruning differs among cortical areas. Cells in V1, V2 and V4 prune more spines than they grow, whereas cells in TEO and TE do not. In the adult, V1, V2 and V4 have fewer spines than they are born with, whereas cells in adult TEO and TE have more spines they are born with.

Neurons in V1 and TE exhibit marked differences in a number of membrane properties. The differences are found in time constant (V1<TE), input resistance (V1>TE), depolarizing sag potential (V1>TE), the maximum rate of firing induced by depolarizing current injection (V1>TE), and the width of individual action potentials (V1 <TE). The differences point to greater sensitivity of V1 neurons to a temporal change in synaptic inputs as compared to TE neurons. These properties mature over a prolonged period after birth. V1 matures earlier than TE.

These specializations in pyramidal cell structure and physiology are likely to influence cortical functions at the systems, cellular and subcellular levels.

References

1) Fujita, I., Fujita, T. (1996) J. Comp. Neurol., 368:467-486
2) Tanigawa, H., Wang, Q., Fujita, I. (2005) Cerebral Cortex 15: 1887-1899.
3) Elston GN, Rosa MGP (1998) Cereb Cortex 8: 278-294.
4) Elston, G.N., Oga, T., Fujita, I. (2009) J. Neurosci. 29: 3271-3275.
5) Elston, G.N., Oga, T., Okamoto, T., Fujita, I. (2009) Cerebral Cortex doi. :10.1093/cercor/bhp203