PERSPECTIVES

Back to basals: do basal dendrites link plateau potentials and Up states?

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One of the aims of cellular neuroscience is to understand how a neurone converts incoming information, in the form of active synapses, into appropriate action potential output. In neurones of the mammalian brain, the postsynaptic structure is usually a dendrite so a neurone's response to synaptic input is strongly influenced by the properties of its dendritic tree.

Much of what we know about the physiological properties of dendrites is derived from research on the apical dendrites of hippocampal and neocortical pyramidal neurones. Pyramidal cells are the main class of excitatory neurones in both hippocampus and neocortex and are therefore central to hippocampal and neocortical function, but this is not why these neurones are the subjects of choice for many dendritic physiologists. The reason is that the apical dendrites of pyramidal neurons are large, making it easier to obtain patch-clamp recordings from apical dendrites than from other, smaller-diameter dendrites. As a result we now understand apical in some depth. However, most synapses are not onto apical dendrites: more than 50% of a cortical pyramidal neurone's spines are on its basal dendrites (Larkman, 1991).

Fortunately basal dendrites have not completely escaped the attention of dendritic physiologists. Although the first whole-cell recordings from basal dendrites were reported only recently (Nevian *et al.* 2007), basal dendrites have been probed with optical imaging techniques (e.g. Schiller *et al.* 2000; Antic, 2003; Ariav *et al.* 2003; Milojkovic *et al.* 2005; Gordon *et al.* 2006). Like apical dendrites, basal dendrites contain voltage-gated conductances that support active propagation of action potentials and local dendritic spikes. Basal dendrites also possess unique features such as NMDA spikes (Schiller *et al.* 2000). These are local dendritic spikes, evoked by clustered synaptic activation, in which the dominant conductance is the NMDA receptor.

In this issue of *The Journal of Physiology*, Milojkovic *et al.* (2007) present results that expand the possible functions of NMDA receptors in basal dendrites. Milojkovic *et al.* (2007) used voltage- and calcium-imaging to investigate the mechanistic basis of plateau potentials that can be evoked by iontophoresis of glutamate onto the dendrites of layer 5 neocortical pyramidal neurons (Oakley *et al.* 2001; Milojkovic *et al.* 2005). Milojkovic *et al.* (2007) report that plateau potentials are followed by a small-amplitude, NMDA receptor-dependent 'foot' of depolarization that persists for hundreds of milliseconds and is accompanied by a sustained rise in dendritic calcium concentration near the site of stimulation. During this depolarized foot, the sensitivity of the dendrite (but not of neighbouring dendrites) to subsequent stimulation is reduced, suggesting that prolonged opening of NMDA receptors decreases the sensitivity of the dendrite to synaptic input following plateau depolarizations.

What physiological purpose might these plateau depolarizations fulfill? Milojkovic *et al.* (2005) note that the amplitudes and durations of plateau depolarizations are similar to those of Up states recorded *in vivo* and suggest that plateau depolarizations might contribute to depolarization during Up states. Up states are periodic depolarizations that are common in whole-cell recordings from many CNS neurons *in vivo*, including neocortical pyramidal neurons (Steriade *et al.* 1993). Up states result from elevations in synaptic activity in the local network (Wilson *et al.* 1996; Stern *et al.* 1997). There is no experimental evidence that basal dendrites play any special role during Up states, but compartmental modelling work has suggested that basal dendrites might be essential for the generation of Up states (Benucci *et al.* 2004). The similarity between plateau potentials and Up states is therefore intriguing.

There are, however, differences between Up states and the plateau potentials of Milojkovic *et al.* (2007). These plateau potentials are evoked by and persist long after a single, brief application of glutamate or brief synaptic stimulation, whereas an Up state probably persists only as long as synaptic activity is elevated (Wilson & Kawagucci, 1996; Benucci *et al.* 2004). In addition it is unclear whether plateau potentials occur *in vivo*. Little is known about the activity of basal dendrites in intact animals, but plateau depolarizations can be evoked by iontophoresis of glutamate onto apical dendrites (e.g. Oakley *et al.* 2001) and no rise in intracellular calcium concentration has been observed in apical dendrites during Up states *in vivo* (Waters & Helmchen 2004).

In summary, although we do not yet know under what conditions plateau potentials occur in neocortical neurons *in vivo*, studies like that of Milojkovic *et al.* (2007) provide insight into the properties of basal dendrites and are therefore leading us toward a better understanding of the physiology of the mammalian neocortex.

References

Ariav G *et al*. (2003). *J Neurosci* **23**, 7750–7758.
Benucci A *et al*. (2004). *Neural Comput* **16**, 2351–2378.
Gordon U *et al*. (2006). *J Neurosci* **26**, 12717–12726.
Larkman AU (1991). *J Comp Neurol* **306**, 332–343.
Milojkovic BA *et al*. (2005). *J Neurosci* **25**, 3940–3951.
Milojkovic BA *et al*. (2007). *J Physiol* **585**, 447–468.
Nevian T *et al*. (2007). *Nat Neurosci* **10**, 206–214.
Oakley JC *et al*. (2001). *J Neurophysiol* **86**, 514–527.
Schiller J *et al*. (2000). *Nature* **404**, 285–289.
Steriade M *et al*. (1993). *J Neurosci* **13**, 3252–3265.
Stern EA *et al*. (1997). *J Neurophysiol* **77**, 1697–1715.
Waters J & Helmchen F (2004). *J Neurosci* **24**, 11127–11136.
Wilson CJ & Kawagucci Y (1996). *J Neurosci* **16**, 2397–2410.

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