Traveling waves in cerebellar cortex mediated by asymmetric synaptic connections between Purkinje cells

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Understanding how anatomical connectivity and neuronal biophysics interact to govern patterns of activity in the brain is essential if we are to understand neural computation. Purkinje cells exhibit spontaneous pacemaker activity and form the sole output of the cerebellar cortex. Although Purkinje cell axon collaterals were first postulated by Cajal to synapse onto other Purkinje cells, the function of this connection in the cerebellar cortex is unknown. We have used multiple patch-clamp recordings targeted with two-photon microscopy to characterize functional monosynaptic connections between GFP-expressing Purkinje cells in the mouse cerebellar cortex. Purkinje cell axon collaterals project asymmetrically in the sagittal plane, directed away from the lobule apex, and form synapses on other Purkinje cell somata. Based on our anatomical and physiological characterization of this recurrent connection, we construct a network model that robustly generates waves of activity traveling along chains of connected Purkinje cells. We provide direct experimental evidence for traveling waves of activity in Purkinje cells in sagittal slices from juvenile mice. Since similar waves of activity are essential for proper circuit formation in several brain regions, we suggest that these waves may play an important role in wiring the cerebellar cortex and in governing the timing of activity in the mature circuit.

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