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Dense gap-junction connections support dynamic Turing structures in the cortex

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The recent report by Fukuda *et al* [1] provides convincing evidence for dense gap-junction connectivity between inhibitory neurons in the cat visual cortex, each neuron making 60 +/- 12 gap-junction dendritic connections with neurons in both the same and adjoining orientation columns. These resistive connections provide a source of diffusive current to the receiving neuron, supplementing the chemical-synaptic currents generated by incoming action-potential spike activity. Fukuda *et al* describe how the gap junctions form a dense and homogeneous electrical coupling of interneurons, and propose that this diffusion-coupled network provides the substrate for synchronization of neuronal populations.

To date, large-scale population-based mathematical models of the cortex have ignored diffusive communication between neurons. Here we augment a well-established mean-field cortical model [2] by incorporating gap-junction-mediated diffusion currents, and we investigate the implications of strong diffusive coupling. The significant result is the model prediction that the 2D cortex can spontaneously generate centimetre-scale Turing structures

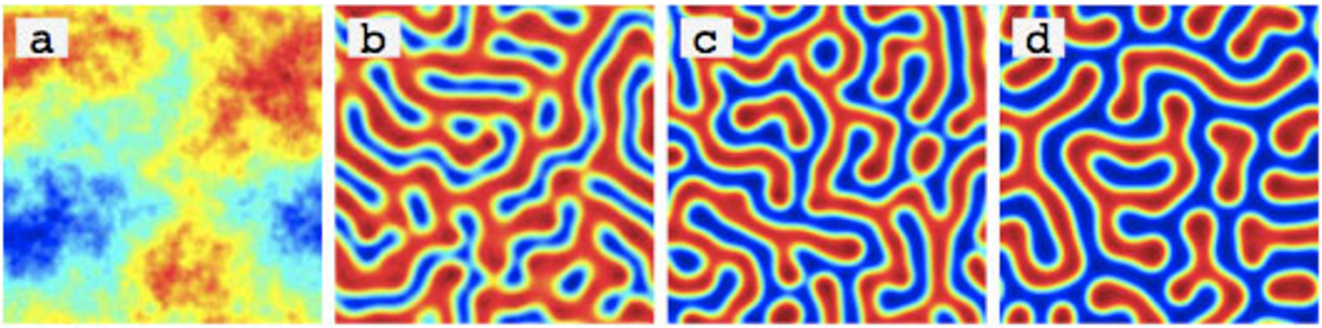

Figure 1
Diffusion-induced Turing patterns in a square cortex of side 25 cm. Panel a shows the case of zero diffusion: the cortex organizes into a diffuse, cloud-like pattern, but fails to generate a Turing structure. Panels b-d show increasing inhibitory diffusion. These cases evolve into stable serpentine Turing patterns containing alternating regions of low-(blue) and high-firing (red) cells.

(spatial patterns), in which regions of high-firing activity are intermixed with regions of low-firing activity (see Fig. 1). Since coupling strength decreases with increases in firing rate, these patterns are expected to exchange contrast on a slow time-scale, with low-firing patches increasing their activity at the expense of high-firing patches. These theoretical predictions are consistent with the slowly fluctuating large-scale brain-activity images detected from the BOLD (blood oxygen-level-dependent) signal [3].

References

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