

On the origin of the cortical architecture

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In tangential penetrations across primary visual cortex, one often observes systematic changes in the receptive field properties of neurons (such as their preferences for orientation and ocular dominance), while vertical electrode penetrations encounter cells sharing similar response properties. The full two-dimensional structure of these ‘functional maps’ has been best visualized using intrinsic optical imaging. Despite years of research onto the columnar architecture of the cortex there are many important questions that remain unanswered, including the actual origin of the maps, their shapes and mutual relationships and, above all, their functional significance in normal visual processing.

Theoretical approaches to cortical map formation based on self-organization and symmetry-breaking normally assume initially random, or disordered, maps. However, we now know that salient features of the adult cortical organization, including the subregion segregation of simple cells, orientation, and ocular dominance maps, and cytochrome oxidase blobs, manifest themselves at the earliest stages of cortical development, *before* the onset of the critical period. Thus, to fully understand cortical map formation we need to answer the following two separate questions. *Initial map establishment*: What are the factors that determine the structure of maps at the earliest stages of development? *Map maintenance and plasticity*: To what extent do activity-dependent developmental processes maintain, modify, or refine, this initial state? The relative contributions of these two stages of development can be properly assessed only after clear descriptions of both processes are obtained.

Here I address the first of these two questions. How exactly are the initial cortical maps established? Two main hypotheses have been considered so far: (a) Correlation-based mechanisms relying on the pattern of spontaneous activity in the retina and the LGN, and (b) molecular guidance directing the developing thalamocortical projections into forming the desired maps. This study elaborates on an alternative hypothesis: the blueprint for the formation of simple-cells receptive fields in layer 4, the feature maps in the cortex, and many of their inter-relationships, may reside in the layout of the retinal ganglion cell mosaics along with a simple statistical connectivity scheme between the thalamus and the cortex.

I show that this simple ‘statistical connectivity’ model accounts for a large number of experimental findings, including the relationship between retinotopy, orientation maps, spatial frequency maps and cytochrome oxidase patches. The theory’s simplicity, explanatory and predictive power makes it a serious candidate for the origin of the cortical architecture.

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