Lateral intracortical interactions and random inhomogeneities: A key to the spontaneous emergence of cortical maps in V1 without visual experience

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Recently, it has been shown that cortical maps of orientation and direction preference (OP and DS) appear early in development and independently of visual experience. Also, OP maps in kittens develop identically for both eyes for up to 3 weeks, even if the animals have been binocularly deprived. These experiments cannot be interpreted in terms of an activity-dependent self-organizing process, and it is unlikely that these response properties are predetermined genetically.

Using a simple model of coupled cortical columns, we show that this problem can be solved if intracortical interactions are strong. Acting excitatorily over short, and inhibitorily over medium ranges, these couplings together with typical afferent inputs (oriented gratings or bars) lead to localized activation clusters (blobs). If a small random jitter, e.g. in the neuronal density in a column, disturbs the symmetry of the system, the continuum of marginal stable states breaks down into subsets of stable attractors, and the blobs will locate at positions with strongest feedback and afferent input. Stimuli of different orientations consistently choose different subsets of blob positions: columns become orientation selective. Oscillations of the blobs around their positions, caused by moving stimuli forth and back, induce directional selectivity.

Due to the mexican-hat coupling, neighboring columns have similar response properties, leading to the emergence of cortical maps within milliseconds. Being smooth except for small discontinuities like pinwheels, our maps closely resemble real cortical maps. Our intracortical nature of OP naturally can explain why maps are identical for both eyes, appear with the first stimulus ever given, and do not require activity-dependent learning to emerge.