Theory of Self-Organization of Cortical Maps

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Abstract: We have mathematically shown that cortical maps in the primary sensory cortices can be reproduced by using three hypotheses which have physiological basis and meaning. Here, our main focus is on ocular.dominance column formation in the primary visual cortex. Monte Carlo simulations on the segregation of ipsilateral and contralateral afferent terminals are carried out. Based on these, we show that almost all the physiological experimental results concerning the ocular dominance patterns of cats and monkeys reared under normal or various abnormal visual conditions can be explained from a viewpoint of the phase transition phenomena.ROUGH SKETCH OF OUR THEORYIn order to describe the use-dependent self-organization of neural connections {Singer,1987 and Frank,1987}, we have proposed a set of coupled equations involving the electrical activities and neural connection density {Tanaka, 1988}, by using the following physiologically based hypotheses: (1) Modifiable synapses grow or collapse due to the competition among themselves for some trophic factors, which are secreted retrogradely from the postsynaptic side to the presynaptic side. (2) Synapses also sprout or retract according to the concurrence of presynaptic spike activity and postsynaptic local membrane depolarization. (3) There already exist lateral connections within the layer, into which the modifiable nerve fibers are destined to project, before the synaptic modification begins. Considering this set of equations, we find that the time scale of electrical activities is much smaller than time course necessary for synapses to grow or retract. So we can apply the adiabatic approximation to the equations. Furthermore, we identify the input electrical activities, i.e., the firing frequency elicited from neurons in the projecting neuronal layer, with the stochastic process which is specialized by the spatial correlation function Ckp;k' p'. Here, k and k' represent the positions of the neurons in the projecting layer. II stands for different pathways such as ipsilateral or contralateral, on-center or off-center, colour specific or nonspecific and so on. From these approximations, we have a nonlinear