Development of the Cerebral Cortex: IX. Cortical Development and Experience: I

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Childhood is the time for learning. Many cognitive and motor skills are gained quickly during childhood and are not mastered as easily if the learning process begins later. Developmental neurobiologists are keenly interested in this "window" of opportunity. The early development of the brain—the birth and differentiation of neurons, their migration to proper brain regions, the growth of their axons to roughly appropriate targets, and the generation of synapses between interacting neurons—relies primarily on intrinsic factors within the CNS and is largely independent of environmental events. However, environmental factors such as drugs, alcohol, and viral illnesses are able to disrupt normal brain development during critical periods

Environmental factors become critically important during later stages of brain maturation. In humans and other mammals, the number of synapses increases dramatically after birth. The specificity of neuronal connections is then refined during early postnatal life. Experimental data have shown conclusively that neuronal activity is critical for the elaboration of synaptic territories, as well as for making proper synaptic connections. Thus, once the initial circuitry of the CNS is guided by intrinsic factors into roughly correct patterns, after birth environmentally derived activity takes over to refine connections between neurons.

In the 1960s and 1970s, Torsten Wiesel and David Hubel eries of experiments on this topic,

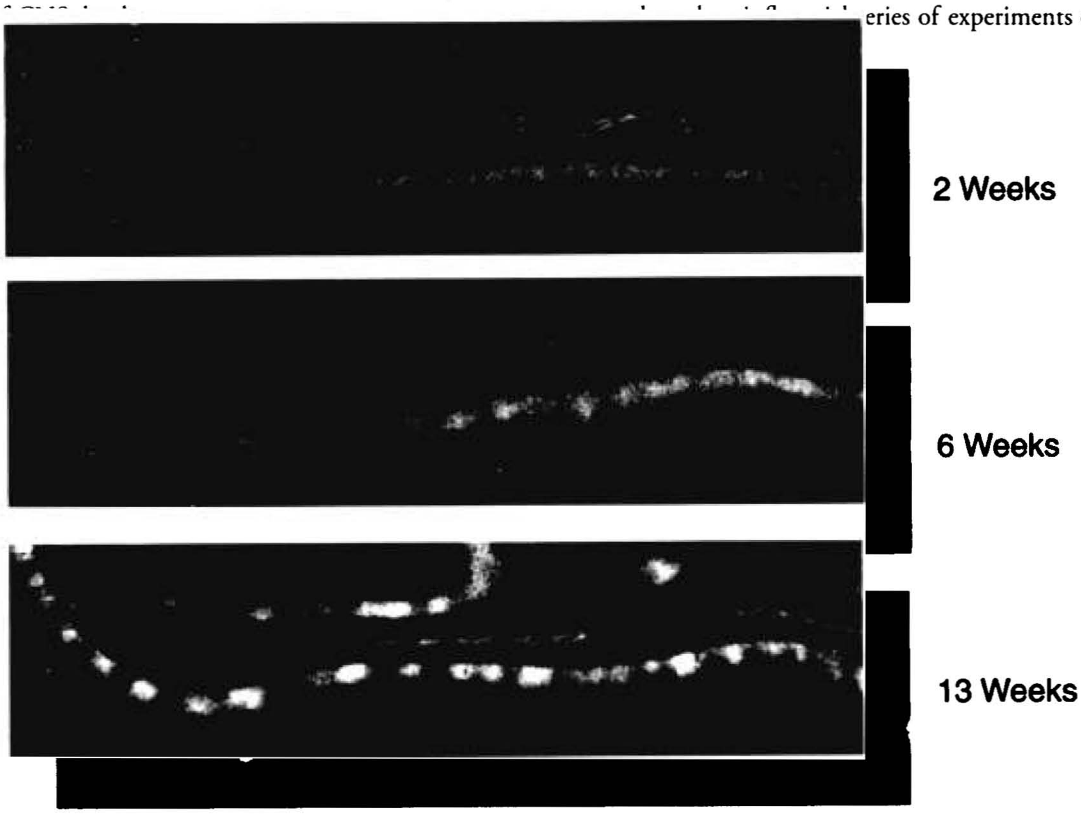

Fig. 1 The development of ocular dominance columns in the cat. At 2 weeks, there is a continuous band of synaptic connections in layer IV that represent the input to the visual cortex from geniculocortical afferents. At 6 weeks, fluctuations in the intensity are already apparent. By 13 weeks, the pattern of cortical striping is similar to that seen in the adult. The segregation of synaptic inputs within the cortical layer depends on synaptic activity from postnatal visual experiences. Adapted from Ocular dominance columns and their development in layer IV of the cat's visual cortex: a quantitative study, LeVay S, Stryker MP, Shatz CJ, *Journal of Comparative Neurology,* 179:223–244, 1978; copyright © 1978, Wiley-Liss, Inc. Reprinted by permission of Wiley-Liss, Inc., a subsidiary of John Wiley & Sons, Inc.

for which they received the Nobel Prize in 1981. Their work demonstrated that the organization of the adult visual cortex relies heavily on early visual experiences. The primary visual cortex receives input from the two eyes via a relay in the thalamic visual area (the dorsal lateral geniculate nucleus). Like all cortices, the primary visual cortex is a layered structure, with visual input forming synapses on neurons in layer 4.

In the adult, the input from the right and left eyes is separated into alternating bands within layer 4, which Hubel and Wiesel called ocular dominance columns. Interestingly, early in development, the right- and left-eye inputs in layer 4 are not segregated, but overlap extensively. The development of ocular dominance columns in the cat over the first 3 months of life is shown in Figure 1.

Hubel and Wiesel demonstrated that the normal segregation of inputs that is present later in life requires visual activity during a circumscribed window of time in the postnatal period. For example, if an animal is raised with visual input only from the right eye, the right-eye inputs to the visual cortex will occupy most of the territory in layer 4. The left-eye inputs will occupy very little territory. Importantly, this ability to reorganize the pattern of inputs is temporally limited. Restricting vision to only one eye in adult animals has little effect on the organization of inputs to the primary visual cortex. Moreover, a return to normal, binocular visual experience in the adult cannot repair the abnormal organization of inputs to the visual cortex resulting from early visual deprivation. The period during which abnormal visual activity can lead to a disruption of the normal pattern of alternating right- and left-eye columns is called the "critical period."

Dramatic deficits are seen in the visual cortex of humans and experimental animals if they do not experience normal vision during early critical periods. A clinical example of this occurs in children born with a congenital cataract. If the cataract is not diagnosed and removed during the first years of life, the child will remain permanently blind in that eye. Even if the cataract is removed in adulthood, normal vision will never be established. This is in marked contrast to cataracts that develop in adults. Even after many years, normal vision returns once the cataract is removed.

Although the visual cortex is the best-studied example of how early experiences have a critical effect on sculpting the cortex, it is reasonable to speculate that similar mechanisms and temporal restrictions influence the development of other regions of the brain. Recent work on the acquisition of language has underscored how profoundly early neuronal activity can influence the organization of the brain. Functional magnetic resonance imaging scans have been used to determine the spatial relationship of language centers in individuals who have learned native as well as second languages. If a child learns a second language early in life, both the native and second language are represented in the same cortical region. In contrast, when a second language is acquired in adulthood, a new language center that is clearly separated from the native language center is established in the cortex. Although these findings do not yet explain why young children are able to learn a new language more easily than older individuals, they do support the findings that early experiences affect the way the brain develops.

WEB SITES OF INTEREST

http://nobel.sdsc.edu/laureates/medicine-1981-2-autobio.html
http://nobel.sdsc.edu/laureates/medicine-1981-3-autobio.html
http://christie.prognet.com/contentp/npr/nf6f09.html
http://www.epub.org.br/cm/n01/arquitet/camadas_i.htm

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