"Do we learn to see?"
The role of Nature and Nurture in Brain Development

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My background is a bit unusual in the sense that I grew up in a mental hospital in Sweden and as a young boy learned to interact with individuals with behavioral problems. This experience was probably what led me to medical school and to foster my interest in neuroscience. After medical school and some clinical experience in child psychiatry the need for more knowledge of brain functions became painfully obvious and from that time on my focus has been on systems neuroscience and brain development.

I had the incredible luck in 1955 to be invited as a postdoctoral student to the laboratory of Stephen Kuffler then at Johns Hopkins Medical School. He had just published the classical work on the receptive field of cat retinal ganglion cells and became my mentor and role model. The second strike of luck was that shortly after I arrived David Hubel joined the laboratory. The two of us set off on a 20-year exciting journey from the retina through the lateral geniculate body to the primary visual cortex analyzing the structure and function of this part of the visual system at a single cell level.

The cat and monkey visual cortex revealed some very intriguing information as we probed single neurons with David's tungsten microelectrode; we discovered that a given cortical cell was, to our amazement, specific in responding only to contours of a specific orientation and, in addition, that the majority of cells were binocular but preferring the left or the right eye in about the same proportions. Furthermore, cells with similar properties were organized in columns, which we called ocular dominance and orientation columns, using a term first formulated by Vernon Mountcastle to describe the organization of cells in the somatosensory cortex.

We started to wonder about the development of such intricate cellular properties and how cells with similar properties came to aggregate in to columns. We knew that kids born with cataracts never recovered full vision after removal of the cataracts and fully restored optics. Actually, such cases have been mentioned in the nature-nurture debate and we thought it would be of interest to learn the basis of the complex circuit we had discovered in the cat and monkey primary visual cortex. Our approach was simply first to record from single cortical cells in new born animals with no visual experience. Indeed the cells were amazingly similar to the ones recorded in the adult animal: they were specific to the orientation of contours, had precise binocular responses and had the typical columnar organization. Our conclusion was that at least in the monkey and cat the early part of our central visual pathway was wired and ready to function at the time of birth.

Next we wanted to know why the children operated for congenital cataracts had poor vision since the circuit should have been there at birth. First we contemplated of raising the animals in the dark but this idea was rejected because of lock of the space, money or patience for such elaborate a procedure. Instead we thought of occluding one eye by lid suture and use the other eye as a normal control. This approach of suturing the lids at various ages and for different length of time became our standard procedure in studying the effect of visual deprivation in kittens and neonatal monkeys.

From these experiments we learned that early in life there is a critical period during which time the neural connections present at birth can be lost or modified by visual deprivation. In the monkey the occlusion of one eye for only a few days during the first few weeks after birth caused marked and permanent changes in the visual cortex and acuity of vision; few cells responding to stimulation of the occluded eye and there was a nearly complete dominance of the open eye accompanied by dramatic changes in the ocular dominance columns. The susceptibility declined with age so that at 12 months of age the monkey was resistant to the effects of lid closure. In the old days children with congenital cataract were operated on at 3 to 5 years of age and in view of our animal experiments, it is not surprising that the vision was not fully restored in these cases. During the last few years the cataracts are being removed shortly after birth and with help of contact lenses and implanted lenses these children have been found to have good vision in the operated eye. Cataracts acquired in adult life can be removed after decades and vision is still promptly restored again consistent with our animal results.

From this we should not draw the conclusion that the visual system or other parts of the brain can not make changes in neuronal circuits all through life but that the emphasis should be on the fact that early in life the neuronal pathways are highly sensitive to environmental influences. The now classical experiments by Michael Merzenich on the changes with practice in the representation of individual digits on the somatosensory cortex clearly demonstrate adult plasticity, which since has been shown in other systems. This is not a big surprise since we are able to acquire new knowledge all through life but nonetheless the neural basis of memory, learning and consciousness remains questions to be answered by future generations of neuroscientists.