BARLOW, H.B. Hubel and Wiesel: Joint Work. In: The Oxford Companion to the Mind (Ed. R.L. Gregory). Oxford University Press (1987) pp313-315.

HUBEL AND WIESEL: JOINT WORK. Their work on the visual cortex opened a new chapter in our understanding of the mechanisms of the brain. It started when David Hubel joined Torsten Wiesel in Steve Kuffler's laboratory at Johns Hopkins in 1958, and continued for twenty years after Kuffler moved his laboratory to the neurobiology department of the Harvard Medical School. Their outstandingly successful collaboration produced a flow of important new discoveries year after year, and these will here be summarized under four headings: the pattern selectivity of single cortical neurones, their binocular connections, their anatomical arrangement, and their normal and abnormal development in early life.

Pattern selectivity. The striate cortex (area 17, or the primary visual area) contains some 10^8 cells, and in 1960 many people felt that recording from them just one at a time would not reveal much about how it all worked. But Hubel and Wiesel claimed that for each cell there was a specific pattern of excitation that would reliably excite it, and this obviously had a major impact. They discovered that the most important characteristics of the stimulus were its orientation, size, contrast (darker or brighter than the background), and which eye it was delivered to. The idea of 'feature detectors' was already a familiar one at that time and examples were known in the frog retina and arthropod visual systems, but theirs were the first examples in the mammalian nervous system, and the implications were revolutionary. Instead of thinking of the striate cortex as a structure with myriads of cells, each taking part in the representation of every visual image, one was forced to recognize that each cell had its own specific stimulus requirements, and that consequently when it became active it 'said' something specific about the nature of the image in its own particular part of the visual field. Not all their ideas about the hierarchical connections of cells or the mechanisms whereby pattern selectivity was achieved have stood the test of time, but theirs were the results that put the idea of feature detectors into the psychological literature.

Binocularity. Cortical neurones are the first cells in the visual pathway that have access to information from both eyes. Hubel and Wiesel found that many of them could be activated through either eye or both together, and that in such cases the stimulus requirements were nearly the same, regardless of which eye was used. In other cases the cell could be activated only through one eye and not through the other, and there were yet other cells that could be strongly activated by one eye but only weakly by the other. They plotted the numbers of cells of each type as the 'ocular dominance histogram', and this turned out to be a sensitive tool for showing the influence of factors that disturb the normal development of cortical connections. It is, however, a potentially misleading tool, for we now realize that the main significance of the binocular connections of cortical neurones lies in the small differences of alignment of the connections from each eye; this is what makes different cells responsive to different disparities and hence gives information about the distance of objects from the eyes. The ocular dominance histogram tells one nothing about this aspect, and it is therefore wrong to deduce from a normal histogram that the cortex is in a normal functional state. Hubel and Wiesel may possibly have been misled by this when assessing the role of experience in formulating the properties of the mature cortex.

Anatomical arrangement of cortical cells. This is the area of their greatest success, for they revealed an orderly arrangement of cortical neurones, constituting a microstructure, that was previously unsuspected. They were fortunate in that many new anatomical methods became available while they were engaged in the task of mapping this microstructure, but they were in the forefront in developing these methods and demonstrating their usefulness. The existence of a map of the visual field on the striate cortex was well known before their work, but this map is only accurate to distances of about one millimetre on the cortical surface. Each square millimetre contains some quarter million cells, and Hubel and Wiesel found first that neurones were grouped according to ocular dominance, each eye supplying irregular, alternating strips of cortex about half a millimetre wide. Orientation was also organized, for the preferred orientation of successively recorded cells tended to shift regularly through a small angle as the recording electrode moved across the cortex, a complete cycle occurring every ½ to 1 mm. It has subsequently been shown that cells preferring a particular spatial frequency (or size) are also clustered, as are those preferring particular colours. The final details of the arrangement of the cells according to their selective properties is not yet (1983) known, but there seems little doubt that Hubel and Wiesel have sketched the skeleton of this microanatomy.

Development. The clinical facts of amblyopia (poor sight not caused by defects in the visual system) have long suggested that visual experience has an important effect on the neural development of the visual system. As early as 1963 Hubel and Wiesel published their first results on this problem, showing that depriving a kitten of the use of one eye by closing its eyelids has the effect of permanently disrupting the connections that eye makes to the cortical neurones. This was shown by the bias of the ocular dominance histogram towards the eye that continued in use, and they were also able to modify the histogram by surgically induced strabismus (squint), and by occluding each eye on alternate days; both of these procedures leave many cells connected to each individual eye, but cause a marked reduction in the number of cells that receive connections from both of them, thus showing that these connections require associated use of both eyes to become firmly established. They later showed that these effects of deprivation only occur up to about 6 weeks of age in the cat, or 6 months in the monkey.

This was the first demonstration of a critical or sensitive period that has physiologically demonstrable consequences and is caused by changes to normal sensory messages. The results have been obtained consistently by many others and they are among the most robust and well-confirmed findings in a field where not all claims have been substantiated. It is interesting that Hubel and Wiesel have consistently argued that experience does no more than preserve innately formed connections, basing this on the apparently normal responses and ocular dominance histograms found in young, visually inexperienced animals. Later results have shown, however, that immature and inexperienced cortical neurones lack the disparity selectivity and fine spatial resolution of adult cells, and that the cortex is therefore far from normal. Hubel and Wiesel have thus provided some of the best evidence for the effects of experience on the cortex, while making some of the most dogmatic statements on the predominance of ontogenetic factors in determining its properties. (See also VISUAL SYSTEM: ENVIRONMENTAL INFLUENCES.)

Hubel and Wiesel's interpretations of their results have often been replaced by others which they, the pioneers, have vigorously resisted; even so, their results themselves have an enviable record of reliability. Furthermore, they led the field over a twenty-year period during which exceptionally rapid progress was made. It must be added, however, that their contribution cannot be finally assessed, for there is as yet no confident understanding of how the striate cortex helps us to see the world around us. David Hubel, Torsten Wiesel, and Roger Sperry received the Nobel prize for their work in neurophysiology, in 1981.

See also BRAIN SCIENCE: SPERRY'S CONTRIBUTION.

H. B.