the extent of the Müller fiber. It is felt, for example, that the Weber-Fechner law and the Purkinje shift are dependent on glial control of excitability.

DISCUSSION

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Recordings of on- and off-discharges and or graded DC potentials in the retinas of fish confirm the existence of wavelength-dependent, opposite physiological responses of a sort consistent with the opponent-process theory of human color vision and with our own psychophysical response measures in humans. Specific interpretations of the records for different fish and for different neural units in the same fish require further exploration by the physiologist and also require supplementary behavioral data on the discriminatory capacities of the organism in question. Outstanding issues of special interest to the psychologist concern the number and significance of independent response systems implied for different species (not always consistently) by photochemical, electrophysiological, and psychophysical measures; the relation of the photopigment system to the electrical records and of both of these to the psychophysical data; the roles of linear and non-linear physiological response elements and the specific forms of the non-linear functions; and the detailed organization of receptive fields at different levels of the visual system and for different physiological states conditioned by different temporal and spatial stimulus parameters.

RECEPTIVE FIELD STUDIES IN THE VISUAL SYSTEM OF NEWBORN AND MONOCULARLY DEPRIVED KITTENS

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The influence of sensory stimulation on the normal development of the visual system was studied in newborn kittens and in animals monocularly deprived of form and light. Single cells were recorded by tungsten micro-electrodes in the lateral geniculate body and striate cortex of anaesthetized animals. Receptive fields of single neurons were examined by shining various patterns of light on a tangent screen facing the animal. Similar receptive field studies in the normal adult cat provided the necessary background for the present work (Hubel & Wiesel, 1, 2, 3).

In newborn kittens (8 to 19 days old) with no previous visual experience cortical cells responded only to stimuli specific in shape, position, and orientation. As in the adult cat (Hubel and Wiesel, 1, 3), the receptive fields of these cells were "simple" or "complex", and cells with the same receptive field axis orientation seemed to be grouped in a columnar fashion. Furthermore, as in the mature cortex, the majority of cells were influenced independently from the two eyes, and had identical receptive fields in corresponding regions of the two retinas. In short, kittens with no previous visual experience had receptive fields and functional architecture similar to those of adult cats. The two groups of animals differed mainly in that cortical cells in young kittens had lower maintained rates of firing and responded less briskly to adequate light stimulation. These findings suggest a highly organized innate development of the visual system.

In another series of experiments kittens were monocularly restricted in visual experience by lid suture or by a translucent contact lens. Deprivation began 0-8 days after birth (before normal eye opening) and continued up to an age 2-3 months, at which time the kittens were used in acute experiments. In recordings from the lateral geniculate body, units driven from the previously closed eye responded well to light stimulation and had the normal concentric receptive field arrangements (Hubel & Wiesel, 2); some cells, however, had unusually large receptive field centres. In cortical penetrations in the same kittens many cells were isolated, but none of them could be influenced from the deprived eye; all cells with normal receptive fields responded only to stimulation of the experienced eye. Thus the deprived eye had lost its ability, present at birth, to influence cortical cells, but had retained its influence on cells at lower levels.

A subsequent histological study of the visual pathways of monocularly deprived kittens showed marked cellular atrophy (30–40%) in the layers of the lateral geniculate body receiving projections from the deprived eye. No similar histological changes could be observed at the level of the retina or the visual cortex. Monocular light and form deprivation therefore caused not only striking physiological changes in the striate cortex but also pronounced atrophy of cells in the lateral geniculate body. Monocular-deprivation experiments in the adult cat did not produce similar anatomical or physiological changes; this suggests that age was an important variable in producing these changes.

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DISCUSSION

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PRESTRIATE CORTEX AND THE ORGANIZATION OF THE VISUAL SYSTEM

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The participation of inferotemporal cortex in visual functions is now known to depend largely on its interaction with the striate cortex via reciprocal cortical connections. The connections between these two "visual areas" appear to be indirect, however—data from neuroanatomy and electrophysiology suggesting that activity in one area can influence the other only through a relay in prestriate cortex. These data lead to the conclusion that the prestriate cortex is an essential link in the visual system; yet, little evidence has been obtained to date of impairment in visual functions following prestriate lesions. Beginning with the work of Lashley in 1948, investigations of the effects of prestriate lesions have uncovered, at most, a mild and transient deficit on visual tasks, in contrast to the severe and lasting deficits seen after either inferotemporal or lateral striate lesions. The following experiments were undertaken to investigate this puzzle.

In the first experiment, monkeys that had been trained to perform a difficult visual pattern discrimination received a two-stage operation consisting of an inferotemporal resection in one hemisphere and an occipital lobectomy in the other. Following retraining on the discrimination, varying extents of prestriate cortex were removed from the previously lobectomized hemisphere. Since the primary visual area on this side had already been completely removed, very extensive prestriate lesions were possible, including complete ablation of the banks and depths of sulci, without the usual concern for incidental damage to the visual radiations. The animals that received large but incomplete prestriate lesions relearned the discrimination without difficulty, whereas those with total lesions (i.e.,