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Central visual pathways and visuo-motor links

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In this lecture, I will introduce the targets of the eye, and particularly the primary visual cortex, and discuss briefly the connections from visual areas of the cortex to motor areas. I will talk about the nature of the crossing at the optic chiasma, and the primary and secondary targets of the optic tracts. I will introduce these topics in a historical context, and re-affirm the importance of the concept of a receptive field in understanding visual processing by the brain..

Much of the visual system can be thought of as in a series-like organization.

Slide 1: Rhesus monkey retina; low power to show series like arrangement of layers

Receptors: (rods/cones) Inner nuclear cells: (horizontal, bipolar, amacrine) to ganglion cells.

Visual information is imaged on the photoreceptors and is relayed via cells in the inner-nuclear layer to ganglion cells for transmission to the brain.

Within this series-like arrangement, there are at every level, parallel processing mechanisms. Easiest to see at the level of the photoreceptors themselves.

Rods and cones share the image plane: process visual information in parallel.

Slide 2: High power to show rod and cone nuclei

There are ganglion cells with grossly different structure, connections and function. Ratio of receptor to ganglion cells varies greatly at differing loci within the retina, and between species. Sensitivity vs. acuity.

Centre-surround organization of retinal ganglion cell receptive field and scaling of relative intensity.

Slide 3: Cat retina (note tepetum) Note differences in ganglion cell size

Galgion cells axons project to brain

Note large and smaller ganglion cells (m and p cells). Correlated with fibre-diameter.

These different sized cells have different receptive field properties, different targets in the brain and different functions.

Large cells (m cells); respond transiently to changes of illumination in their receptive field; and there are relatively more of them in peripheral retina.

Smaller sized (p cells); respond in a sustained manner to appropriate illumination of their receptive field, have small receptive fields and are most heavily concentrated near the fovea. Much smaller cells "k" cells (konio; dust) and light detection

Melanopsin containing ganglion cells. These cells may receive an input from photoreceptors, but they also have a photosensitive pigment within them. Melanopsin ganglion cells respond to a short wavelength of 484 nm peak sensitivity.

"Tiling of retinal ganglion cells" and the extent of ganglion cell dendritic tree

Slide 4: Cajal; Mammalian retina

The three cell types cover the entire retina. Since there are about 80% p cells, 10% m cells and an estimated 10% k cells, it follows that if the entire retina is covered by the dendrites of these cells, the m and k cells must have larger dendritic territories than the p cell.

Magnocellular/parvocellular division of LGN; Also interstitial cells

<u>Axons of the optic nerve</u>

Axons of the ganglion cell collect at the back of the eye after running along the inner retinal surface as unmyelinated fibres. (Why are they not yet myelinated?)

Blind spot and exit zone.

Slide 5: Monkey eye to show optic nerve (blue-arcs in demo)

<u>On the course of the optic nerve</u>

Optic nerve fibres proceed backwards and seem to unite in the X-shaped Optic Chiasm (Greek X = Chi). The re-sorted fibres after the chiasma are called the optic tract.

At the chiasma the optic nerve fibres arising from ganglion cells in the nasal retina cross; those from the temporal retina remain uncrossed.

The effect of this pattern of crossing is to project the right visual field onto the left hemisphere.

Slide 6: To show location of chiasm at the ventral surface of the brain

There was no agreement on what happens at the chiasma. Some believed in no decussation, some total decussation. (Isaac Newton had suggested the correct arrangement)

There was always the problem of why we see singly with two eyes. Solved in different ways by different authors.

Slide 7: Des Cartes; Chiasm and pineal

Slide 8: Hemi decussation; John Taylor; Frankfort 1750

Left Visual Field is projected onto the right side of the brain.

On the consequences of lesions 1) before the chiasma 2) of the crossing fibres in the chiasma 3) of the optic tract and beyond.

HEMI-AN-OPIAS
Homonymous (right or left)
Heteronymous (bitemporal or binasal)

Mnemonic: a person (with optic tract), visual radiations, or complete unilateral cortical lesion sees only on the side of the lesion.

Partial decussation in dogs, cats and horses. How far lateral is the eye? Principal of Visual Field Representation in mammals.

Slide 9: Tree shrew to show laterality of the eyes

Slide 10: Tree Shrew; LGN and optic tract

<u>On the targets of the optic tract</u>

The targets in terms of relative numbers of fibres in man are:

Lateral Geniculate Nucleus (LGN). The major target in humans
Superior Colliculus
Pretectal Nucleus; role in pupillary control
Accessory optic system
Hypothalamus particularly the suprachiasmatic nucleus. Role in diurnal cycling.

Lateral Geniculate Nucleus in turn relays visual information to the cerebral cortex.

The Laminar Organization of the LGN.

Slide 11: Human LGN (Recall centre surround receptive fields of LGN cells
Strict segregation of input, but perefectly aligned. Problem of the blind spot.

Phenomenon of transneuronal atrophy (Minkowski, 1920)

Slide 12: LGN: Normal monkey

Slide 13: Trans-neuronal atrophy

(Retrograde degeneration of retinal ganglion cells after cortical lesion)

Numbering from ventral to dorsal 1-6
Contralateral eye projects to layers 1, 4 and 6
Ipsilateral eye projects to layers 2, 3 and 5
Note important distinction of
Magnocellular layers (1 and 2) and
Parvocellular layers (3, 4, 5, and 6) laminae
K cell projection to cells within the interlaminar fibre layers.
Receptive fields of cells in the LGN

Magnocellular layers relay m cells; achromatic; transient
Parvocellular layers relay p cells colour-opponent; sustained
K cells as light detectors; other properties

Slide 14: Human colliculus; parasagittal

<u>The superior colliculus</u>

The superior colliculus receives a direct input from the optic tract and from the cerebral cortex.

Importantly involved in the control of saccadic eye movements.

Lesions of superior colliculus produce a transient deficit in initiating eye movements. Large lesion of the entire colliculus leads to a transient fixed gaze; which recovers in a few days.

Lesions of Area 8 of the cerebral cortex (the "frontal eye fields") also produce a temporary deficit in initiating eye movements.

Combined bilateral lesions of both lead to a permanent and severe deficit in initiating eye movements.

<u>Pretectal Nuclei and the pathway for the pupillary reflex</u>

Direct and consensual pupillary reflexes illumination of the eye causes pupillary constriction
Retinal ganglion cells (certain small cells) Pretectal nuclei
Edinger Westphal nucleus in midbrain and thence via NIII to Ciliary ganglion controlling
Radial muscles of the iris.
Melanopsin ganglion cells as another input to pupillary control.

<u>THE GENICULO-CORTICAL PROJECTION</u>

Slide 15: Brodmann, 1905; Monkey cortical areas, lateral

Slide 16: Brodmann, 1905; Medial view

Slide 17: Human Weil stain to show stripe of Gennari

Segregation of the input from the left and right eye in the visual cortex; ocular dominance columns.

We saw that projections from the left and right eyes are segregated in their connections to LGN. This segregation is maintained at the first cortical synapse (in lamina 4 of cortex). The segregation shows up in both histological and physiological experiments.

Inject one eye of a monkey with a labelled amino acid. Taken up and transported to LGN. Some labelled protein taken up by neurons across the synapse and transported by LGN neurons to the cortex. Terminals of left & right eye run in parallel stripes of about 0.5 mm each on the cortex within layer IV.

Slide 17: Ocular dominance columns; Hubel

If one eye is masked in infancy vision is severely impaired in the deprived eye, the ocular dominance columns become asymmetric; and few cells can be activated by the deprived eye. "Take over" is failure to retract terminals.

<u>On the normal growth of the eye in development</u>

Slide 18: Human eye; neonate and adult

Slide 19: Wiesel and Raviola ; Normal and form-deprived eye

The form-deprived eye grows much longer, and is seriously myopic

Cells in more superficial and deep layers of cortex begin the process of fusing the input from the two eyes;

Cytochrome oxidase "patches" or “blobs” in primary visual cortex
Livingston and Hubel showed that colour information is targeted on the cytochrome oxidase patches. But nocturnal primates who lack colour vision also have the cytochrome oxidase patches.

Multiple visual areas

Slide 20: Brodmann; lateral view of monkey brain

Slide 21: Brodmann; Medial view of monkey brain

Is the striate cortex the sole target of LGN axons? Old evidence form the cat, recent evidence in monkeys. Macular sparing “blind sight” and other odds and ends.