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CHAPTER 10 VISUAL AND PUPILLARY PATHWAYS

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The synaptic organisation of the retina demonstrates that messages must pass from the receptors to the bipolars and from the bipolars to the ganglion cells. In addition to these pathways there are also many interconnections within the inner and outer plexiform layers and these allow activity arising in one part of the retina to influence ganglion cells in the surrounding retinal area.

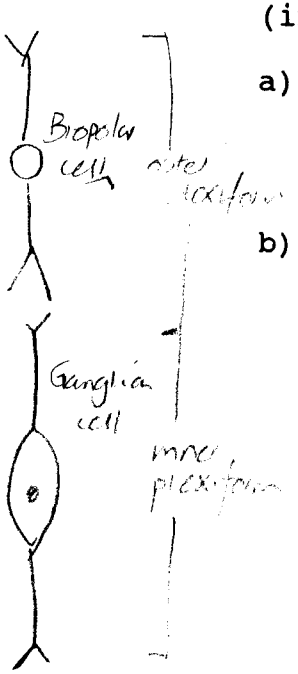
1. AFFERENT SYSTEMS

In general it is possible to recognise two parallel but overlapping afferent systems, one providing maximum acuity of vision for resolution of details of patterns and a second, less suited for acute vision, but capable of greater sensitivity.

a) The one-to-one system is concerned chiefly with the central fovea. Each cone here sends its inner process into the outer plexiform layer to synapse with the dendrites of a single bipolar cell. The cell bodies of these bipolar cells lie chiefly in the middle zone of the inner nuclear layer. The axons of these cells extend into the inner plexiform layer to connect with one ganglion cell.

b) The Diffuse System. In the extramacular retina the rods and cones outnumber ganglion cells by more than 100 to one. This system provides the basis for summation of the responses of a large number of photoreceptors.

2. ASSOCIATIONAL AND CENTRIFUGAL SYSTEMS



In addition to the centripetal systems, associational and (in some species) centrifugal elements are also present.

a) The cell bodies of the horizontal cells occupy the outer part of the inner nuclear layer providing a basis for lateral interaction (inhibition or excitation) within the retina.

b) The amacrine cells. Their cell bodies lie in the inner part of the inner nuclear layer and are generally post-synaptic to bipolar terminals and pre-synaptic to ganglion cells. They also make feedback contacts on to bipolar cells and lateral contact with each other.

3. NEUROGLIA

The neuroglial cells of the retina are also well demonstrated in Golgi preparations. The most important elements are the cells of Muller. The large polyhedral nuclei of these cells are found chiefly in the inner nuclear layer. The cells extend from the inner limiting membrane outward to the inner segments of the photoreceptors, forming a scaffold which supports and appears to insulate the retinal neurons, filling all the available space between them. These cells send fine fibrillae to surround the nerve fibres and provide thin membranous sockets which enclose their cell bodies. The internal ends of the cells spread out broadly and are in close apposition to the external side of the internal limiting membrane. These cells should be compared to the astrocytes of the central nervous system.

THE VISUAL PATHWAYS

The optic nerve

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The optic nerve is an integral part of the central nervous system. It is surrounded by three sheaths:

1. Dural sheath which is continuous with the dura of the brain posteriorly and with the sclera anteriorly.

2. The arachnoid which consists of blood vessels and connective tissue.

3. The pia is the most vascular of the three sheaths, accompanying capillaries as they enter the substance of the nerve. These pial extensions subdivide the nerve into compartments through which the nerve bundles travel.

   The subarachnoid space is continuous with the intracranial subarachnoid space and the cerebrospinal fluid circulates from one to the other.

The nerve is 50 mm in length from the globe to the optic chiasm. Approximately 35mm of nerve lies within the orbit, 5mm within the optic canal and 10mm within the intracranial cavity anterior to the chiasm.

The nerve fibres arise as axons of the ganglion cells and course, unmyelinated, as the nerve fibre layer of the retina toward the optic nerve. These fibres enter the substance of the nerve and pass through the lamina cribrosa where they acquire myelin.

The nerve fibres within the optic nerve are arranged so that the fibres from one retinal quadrant lie in the corresponding quadrant of the nerve.

The optic chiasm and tract

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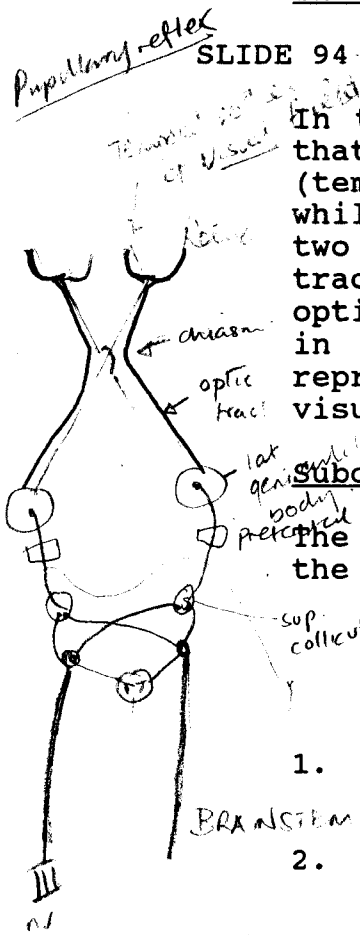


In the optic chiasm there is a segregation of fibres so that fibres from the nasal portion of the retina (temporal part of the visual field) cross the midline while the others stay on the side of their origin. The two components, crossed and uncrossed, join in the optic tract. The four quadrants that are represented in the optic tract are not the same four quadrants represented in the optic nerve. The whole ipsilateral retina is represented in the optic nerve, whereas the contralateral visual field is represented in the tract.

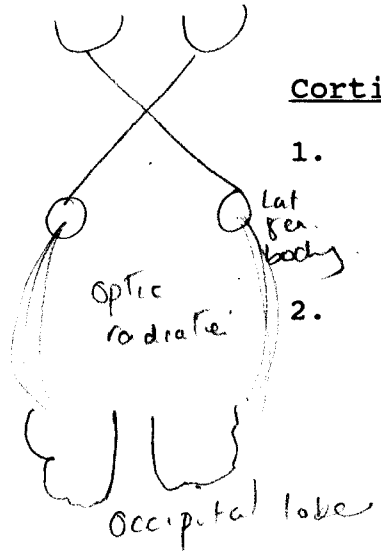
Subcortical centres and relays

The optic tract sends fibres to a number of centres in the brain stem:

1. the superior colliculus
2. the pretectal nuclei
3. the dorsal lateral geniculate nucleus

1. The superior colliculus is concerned with reflex movements of the head and eyes.

2. Pretectal nuclei. Fibres that pass from the optic tract to the pretectal nuclei are concerned with the pupillary light reflex. The pretectal nuclei are poorly defined cell groups lying between the superior colliculus and the thalamus. The visual cortex sends direct fibres to the pretectal nuclei so that there is a pathway for cortical control of the pupil. The efferents from the pretectal nuclei supply the Edinger-Westphal Nucleus and the preganglionic cells of the sympathetic system.



3. The lateral geniculate nucleus is the thalamic relay for visual impulses that pass to the cerebral cortex.

Cortical connections:

1. Nerve fibres pass from the lateral geniculate nucleus to the visual cortex as the optic radiation, which passes through the white matter of the temporal and parietal lobes.

2. The primary visual cortex (area 17) has a characteristic structure, with a well-marked lamina IV within which one can recognise a prominent layer of myelinated fibres, the Stria of Gennari. This area of cortex receives an essential projection from

the dorsal lateral geniculate nucleus and this projection is organised in such a manner that the macular region of the retina is represented posteriorly and the upper retinal quadrants are represented on the upper banks of the calcarine fissure. The macular representation occupies a relatively large portion of the visual cortex. This extensive cortical representation of the macula is of great clinical importance, as it explains certain seemingly paradoxical situations, namely:

a) Patients are little aware of their peripheral visual field, most of which may be lost from glaucoma or retinal detachment without the patient noticing it. In such a situation, a relatively small amount of cortical function is impaired and we should expect little awareness from the patient.

b) A tiny retinal lesion at the fovea is immediately evident to the patient. This is more easily understood if we realise that this tiny retinal lesion produces dysfunction of a very large area of the cortex.

3. Visual association areas. Two further cortical areas (18 and 19), which lie adjacent to area 17, are involved in the further visual processing. Specific areas have been defined within these areas related to stereopsis, analysis of movement and colour perception. Further connections to the temporal lobe are particularly involved with form analysis, object recognition and visual memory, whereas connections to the parietal lobe are involved in the analysis of spatial relationships and movement.

THE PUPILLARY REFLEXES

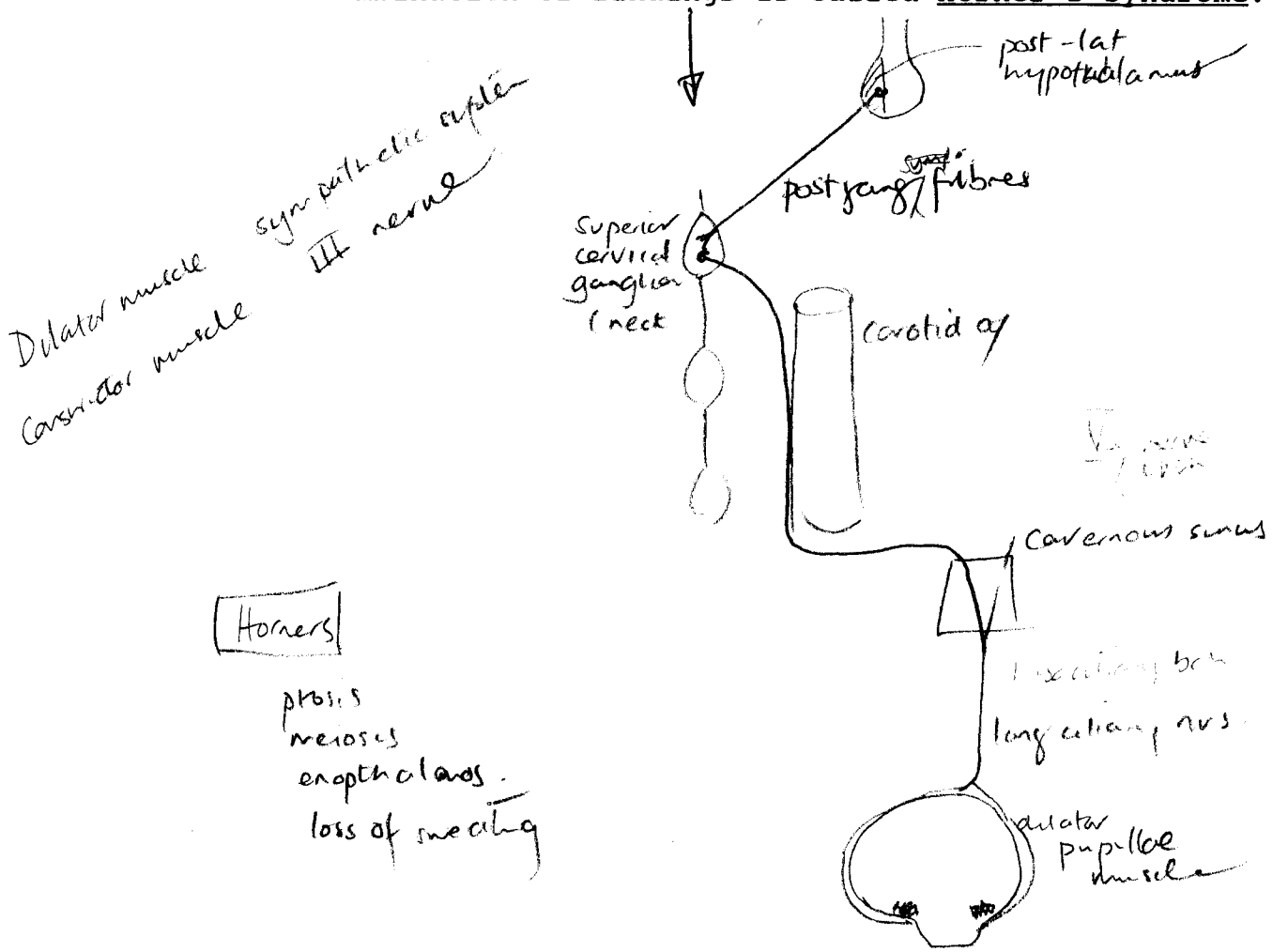
1. The function of the pupil is to control the amount of light entering the eye, hence an increase in light intensity causes it to constrict. This action is called the light reflex and is mediated by subcortical pathways as follows:

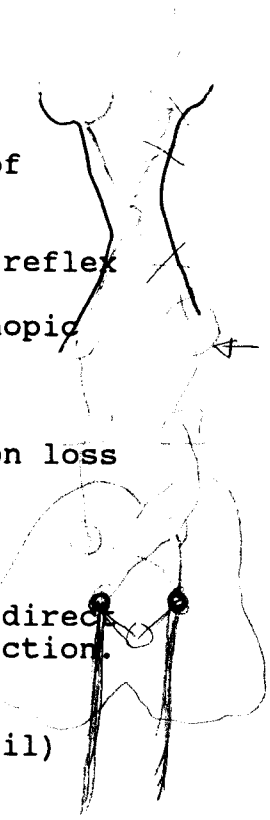
Impulses in response to light pass via the optic nerve to the optic chiasm where some cross over to the contralateral optic tract and some continue in the ipsilateral optic tract. (It is in part for this reason that the light reaction is not only direct, but also consensual, that is, if one eye is stimulated with a light, the opposite pupil also constricts). The impulses continue up the optic tracts but leave them just before the visual fibres synapse in the lateral geniculate nucleus. They pass instead to the pretectal nucleus of the midbrain and synapse. The impulse is then relayed to both the contralateral and ipsilateral Edinger-

Westphal nuclei. The efferent pathway begins in the Edinger-Westphal nucleus, from which fibres pass via the third (oculomotor) cranial nerve to the ciliary ganglion. Postganglionic fibres pass via the short ciliary nerves to the sphincter muscle of the iris.

2. Constriction of the pupil also occurs whenever the eye looks at something close. This is called the accommodative response.

3. The dilator muscle is innervated by the sympathetic system. Reflex dilatation of the pupil occurs with activation of the sympathetic system, as with fear or excitement. Fibres originating in the posterolateral hypothalamus pass to the superior cervical ganglion in the neck, where they synapse. From here the post-ganglionic fibres pass along the carotid artery to the cavernous sinus, where they join up with the ophthalmic division of the trigeminal nerve (Va). They travel along its nasociliary branch to reach the globe by way of the long ciliary nerves, which innervate the dilator pupillae muscles. Injury anywhere along this chain causes ptosis, meiosis, apparent enophthalmos and loss of sweating of the face and neck. This combination of findings is called Horner's Syndrome.





Summary of lesions affecting the pupillary pathways.

Lesions of retina Lesions of optic nerve	-	Loss or depression of direct and opposite consensual reaction. Retention of near reflex
Lesion of optic tract	-	Contralateral hemianopic loss of reaction (Wernicke's)
Lesion of optic tract beyond the point at which the pupillary fibres leave optic tract	-	No pupillary reaction loss
Lesion between decussation of pupillary fibres and Edinger-Westphal nucleus	-	Loss of ipsilateral direct and consensual reaction. Near reflex intact. (Unilateral Argyll-Robertson pupil)
Lesion of all fibres from pretectal nucleus to Edinger-Westphal nucleus	-	Loss of all light response. Retention of near reflex. (Complete Argyll-Robertson pupil)
Lesion of cranial nerve III	-	Absolute ipsilateral pupillary paralysis.
Lesion of ciliary ganglion	-	Ipsilateral loss of light reflex with retention of near reflex. (Unilateral Argyll-Robertson pupil)

Summary of lesions affecting the visual field

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Lesion of retina	-	Impairment of corresponding area of field in same eye
Lesion of optic nerve	-	Loss of field, especially central, ipsilateral eye
Lesion of optic chiasm	-	Bitemporal hemianopia
Lesion of optic tract	-	Homonymous hemianopia
Lesion of optic radiation	-	Homonymous hemianopia
Lesion of visual cortex	-	Homonymous hemianopia.