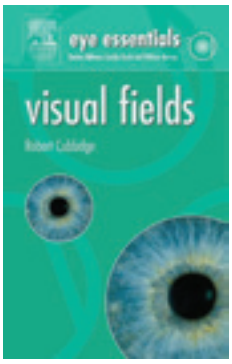
Eye essentials 5

Classification and localisation of visual field defects

In the last of our features based on the Eye Essential textbooks, **Dr Robert Cubbidge** describes the visual pathway and its relationship with the visual field. CET module C2354

This article has been adapted and abridged from *Visual Fields* by Dr Robert Cubbidge, part of the new *Eye Essentials* series. For further information, including ordering, please click on the Bookstore link at www.opticianonline.net



THE DIMENSION of the blind spot is approximately 7.5° high and 5.5° wide and represents the temporal visual field projection of the optic nerve, found approximately 1.5° below and 15° horizontally from fixation. When interpreting visual field defects, knowledge of the arrangement of nerve fibres in the visual pathway is essential.

Depending on the site of damage in the visual pathway, characteristic visual field defects are produced (Figure 1).

Anatomically, the visual pathway begins at the photoreceptors which lie in the outer retina. Here, photons of light are absorbed by the photopigments, which are sensitive to specific regions of the visible electromagnetic spectrum. Light energy is converted into electrical signals which are conveyed along the visual pathway. Should photoreceptors lose sensitivity, a scotoma would form in the visual field.

As the density profile of photoreceptors varies from the centre to the peripheral retina, scotomas would be expected to be larger in the periphery of the visual field than in the centre. Damage to the photoreceptors and choroid can occur in a variety of ways; laser photocoagulation scars, chorioretinal inflammations and degenerations, drug-induced toxicities affecting photoreceptor physiology, and vascular damage occurring within the inner retina. The resulting scotomas usually occur monocularly and would not respect the horizontal and vertical midlines of the visual field. Scotomas which form within a radius 30° from the fovea are termed paracentral scotomas.

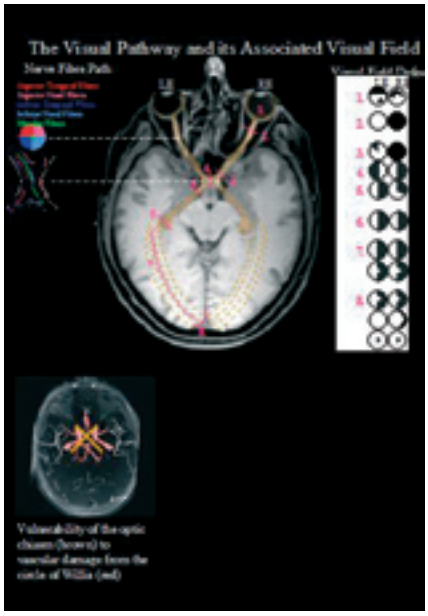


FIGURE 1.

The inner retina consists of the retinal nerve fibre layer which follows a characteristic pattern as it passes towards the optic nerve. The inferior and superior nerve fibres do not cross the horizontal midline of the retina, thereby forming a line of demarcation passing though the fovea, called the horizontal raphé. Nerve fibres in the macular area which travel to the optic nerve form the papillomacular bundle. Those inferior and superior temporal fibres which do not form the papillomacular bundle arch around it as they travel to the optic nerve. Inferior and superior nasal fibres follow a more direct course to the optic nerve as they are not hindered by the papillomacular bundle (Figure 2). The nerve fibres from the nasal retina do not cross those of the temporal retina and thereby form a theoretical vertical line of demarcation which passes through the centre of the fovea. Damage to the retinal nerve fibres gives rise to characteristic arcuate scotomas. Damage to the vascular supply of the inner retina, resulting from branch retinal artery and vein occlusion will typically give rise to large scotomas which are altitudinal in shape (loss in the upper or lower half of the visual field with a sharply-defined horizontal border). If a scotoma forms, resulting from damage to the papillomacular nerve fibre bundle, and is continuous with the physiological blind spot, the visual field defect is described as a centrocaecal scotoma. Scotomas of the papillomacular nerve fibre bundle which are not continuous with the blind spot are described as central scotomas.

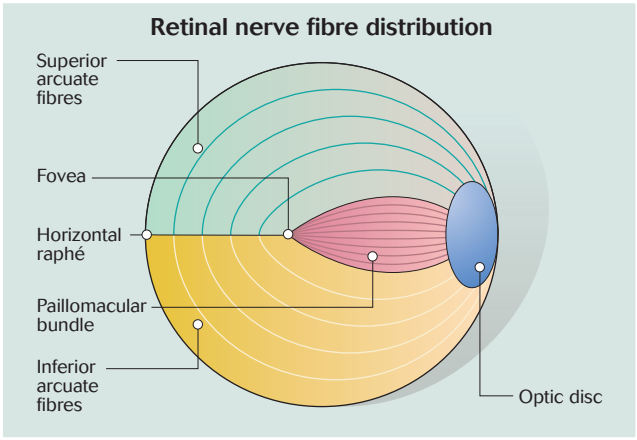


FIGURE 2.

The retinal nerve fibres exit the retina via the optic nerve head. Diseases which affect the optic nerve head give rise to visual field defects which are determined by the path of the retinal nerve fibre layer. A number of conditions affect the optic nerve, including glaucoma, anterior ischaemic optic neuropathy, papilloedema and thyroid optic neuropathy. The formation of a large arcuate scotoma, which extends to the horizontal raphé, will lead to an area in the nasal visual field which has reduced light sensitivity on one side of the horizontal raphé and normal sensitivity on the other. This type of defect is called a nasal step and is one of the characteristic features of visual field

loss in glaucoma. Congenital abnormalities of the optic nerve head, such as optic pits, tilted discs and optic nerve head drusen, may yield arcuate scotomas and nasal steps.

Once the nerve fibres leave the eye and pass into the optic nerve, damage to the visual pathway is not visible with an ophthalmoscope and, in an optometric practice, is only detectable by visual field examination. Reorganisation of the nerve fibres takes place along the entire length of the visual pathway and consequently, the shape of the resulting visual field defect can be used to identify the location of damage in the visual pathway, which is often a result of mechanical compression of the nerve fibres or vascular damage.

At the level of the lamina cribrosa, the nerve fibres have the same orientation as the optic nerve head. A short distance after leaving the optic nerve head, the fibres reorganise and the macular fibres pass towards the centre of the optic nerve. Inferior and superior temporal fibres locate to the inferior and superior temporal aspect of the nerve respectively and similarly inferior and superior nasal fibres locate towards the inferior and superior nasal aspect.

At the optic chiasm, approximately 50 per cent of the nasal nerve fibres, including the nasal macular fibres, cross into the contralateral optic tract. Many of the inferior nasal fibres pass backwards into the optic nerve before looping back and crossing the chiasm, passing into the contralateral optic tract. These looping fibres form the anterior knees of Wilbrand. The posterior knees of Wilbrand are formed by the superior nasal fibres (including the temporal macular fibres) passing into the ipsilateral optic tract before looping back and crossing the chiasm, passing into the contralateral optic tract. Temporal nerve fibres do not cross at the optic chiasm and pass through the temporal aspect of the chiasm into the ipsilateral optic tracts. The optic chiasm is particularly vulnerable to compressive and vascular damage as it lies above the pituitary gland and is also encased by the circle of Willis, a vascular structure in the base of the cranial cavity (Figure 3).

The circle of Willis represents the entry point into the cranial cavity of the major blood supply to the cerebrum. The carotid artery presents a direct pathway into the brain from embolisms originating in the neck and is consequently a common site of stroke. Haemorrhages or aneurysms of the carotid artery in the circle of Willis cause compression of the lateral aspect of the optic chiasm, resulting in damage to the superior and inferior temporal fibres. The corresponding visual field defect would be a unilateral nasal hemianopia (loss of one half of the visual field, respecting the vertical midline), the eye indicating the same side of the optic chiasm affected. Occasionally, an aneurysm may cause so much compression that it displaces the optic chiasm against the corresponding carotid artery on the opposite side of the chiasm. This would result in a bilateral nasal hemianopia. When hemianopias and quadrantanopias (visual field loss in a quadrant, respecting the horizontal and vertical midlines) form bilaterally, they are further classified either homonymous or heteronymous. In homonymous visual field defects, the hemianopia affects the same side of the visual field in both eyes, in other words, either both nasal visual fields, or both temporal visual fields. In heteronymous visual field defects, opposite sides of the visual field are affected, namely the temporal visual field of one eye and the nasal field of the other eye. Heteronymous visual field defects indicate that the site of damage has occurred at the optic chiasm. Homonymous visual field defects indicate that the site of damage to the visual pathway is either at the chiasm or posterior to it.

Inferior to the optic chiasm lies the pituitary gland, located in the sella turcica, a bony cavity of the sphenoid bone. Tumours of the pituitary gland may expand upwards, leading to compression of the inferior aspect of the optic chiasm. In approximately 80 per cent of the normal population, the optic chiasm lies directly above the sella turcica. In cases of pituitary tumour extending upwards through the sella turcica in this population, compression of the crossing inferior nasal fibres occurs, leading initially to a quadrantanopia (visual field loss in an entire quadrant) in the upper temporal visual fields of both eyes, which gradually extends to form a hemianopia (visual field loss in one half of the visual field) in the temporal visual fields of both eyes. Bitemporal quadrantanopias or hemianopias are indicative of visual field loss occurring at the optic chiasm, before the decussation of the nasal fibres has occurred. In 10 per cent of normal individuals, the optic chiasm is located more anteriorly over the sella turcica (pre-fixed).

In these cases, a pituitary tumour would compress the optic tracts first. In the remaining 10 per cent of the normal population, the optic chiasm is located more posteriorly over the sella turcica (post-fixed) causing a pituitary tumour to compress the optic nerve. When a pituitary tumour enlarges upwards in pre- and post-fixed optic chiasms, a junctional scotoma would be expected to form. Craniopharyngiomas are tumours which encroach on the optic chiasm superiorly and posteriorly so that the superior nasal fibres are compressed.

Typically, an inferior bitemporal quadrantanopia would result and as the tumour progresses would extend into the superior visual field, also resulting in a bitemporal hemianopia. Meningiomas are tumours which compress either the optic nerve or the optic chiasm. When compression occurs at the junction of the optic nerve and optic chiasm, the anterior knee of Wilbrand may become affected.

The resulting visual defect is typically a central scotoma in one eye, resulting from compression of the macular fibres, accompanied by a peripheral, junctional scotoma in the contralateral eye.

Within the optic tracts, further reorganisation of the nerve fibres occurs. The distinction between nasal and temporal fibres is lost as they amalgamate. The superior nerve fibres move towards the medial aspect of the optic tract and inferior fibres move towards the lateral aspect. The nerve fibres associated with the macula reorganise between the superior and inferior fibres. Lesions of the optic tracts are rare, but would be expected to produce a homonymous hemianopia or quadrantanopia, although junctional scotomas are possible if the site of the lesion is close to the optic chiasm and interrupts the posterior knee of Wilbrand. When a homonymous defect affects the nasal visual field of the right eye and the

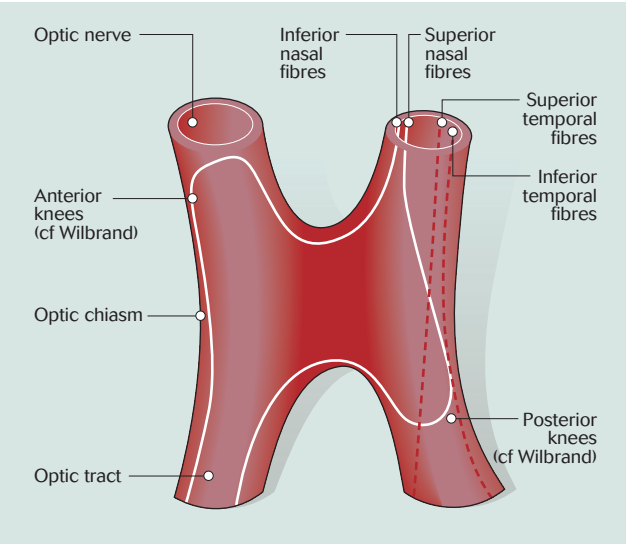


FIGURE 3.

temporal visual field of the left eye, the site of damage to the visual pathway will be beyond the chiasm on the right side. The opposite is true of lesions occurring beyond the optic chiasm on the left side.

The nerve fibres originating from the retina finally synapse with neurones projecting to the visual cortex at the lateral geniculate nucleus (LGN), a knee-shaped structure located in the dorsal lateral aspect of the thalamus. In cross section, the LGN consists of six layers, each receiving inputs from the various portions of the visual field. Nerve fibres originating from the inferior retinal quadrants synapse in the lateral aspect of the LGN, while those originating from the superior retinal quadrants synapse in the medial aspect. Macular fibres synapse in the triangular-shaped wedge created between the superior and inferior fibres. Each of the layers within the LGN receives inputs from only one eye. Crossed nasal fibres synapse in layers 1, 4 and 6, while uncrossed temporal fibres terminate in the remaining layers.

Furthermore, fibres which correspond to the same point in the visual field of both eyes are in alignment within each layer of the LGN, thus forming a retinotopic map, which is a point-for-point localisation of the retinal topography and therefore, the visual field.

Congruence describes the degree of symmetry between two hemianopias or quadrantanopias. If the two hemianopias or quadrantanopias are superimposed on each other and the extent and shape of visual field defect matches exactly, the visual field defect is said to be congruent. When there is not a complete overlap, the defect is termed incongruent. The degree of congruence assists in the localisation of the visual field defect in the visual pathway. Hemianopias and quadrantanopias which are incongruent occur before the LGN and the degree of congruence increases towards the striate cortex, due to the formation of the retinotopic map.

The nerve fibres leaving the LGN form the optic radiations in their route towards the striate cortex. Inferior nerve fibres representing the inferior retina leave the LGN and loop around the lateral ventricle, passing towards the striate cortex, forming the Meyer's loop (Figure 4).

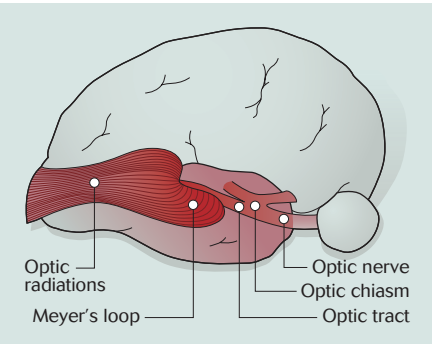


FIGURE 4. Meyer's loop

MULTIPLE-CHOICE QUESTIONS

1 Which of the following statements is true about the papillomacular bundle?
A It comprises nerve fibres from paracentral ganglion cells
B Damage here may result in a centrocaecal field defect
C It is clearly defined along its horizontal midline by a raphé
D Progressive neuropathies, such as glaucoma, selectively damage this area

2 Which statement best describes the path of the inferior nasal fibres as they pass through the chiasm?
A They pass directly through to the ipsilateral optic tract
B They cross the chiasm into the contralateral optic tract
C They cross the chiasm into the contralateral optic tract after a brief passage into the ipsilateral optic tract
D They cross the chiasm into the contralateral optic tract after first passing anteriorly into the contralateral optic nerve

3 Which of the following is unlikely to cause an altitudinal field loss?
A Primary open-angle glaucoma
B Anterior ischaemic optic neuropathy
C Central retinal vein occlusion
D Central retinal artery occlusion

4 Which of the following best describes the field loss expected with a craniopharyngioma?
A Bilateral progressive homonymous defect
B Progressive inferior bitemporal loss
C Bilateral homonymous hemianopia
D Bitemporal superior quadranopia

5 Which of the following is true of post-LGN lesions?
A Pupil defects are likely
B Optic atrophy results
C Field loss is likely to be congruent
D Heteronymous quadrantopias or hemianopias are likely

6 Which of the following terms is least likely to be used in reference to field loss resulting from damage to the occipital cortex?
A Heteronymous
B Macular sparing
C Macular splitting
D Congruent

The deadline for response is November 17

Module C2354 To take part in this CET module go to www.opticianonline.net and click on the Continuing Education section. Online participation allows participants to have an instant decision of success. Successful participation in each module of this series counts as one credit towards the GOC CET scheme administered by Vantage and one credit towards the Association of Optometrists Ireland's scheme.

MEYER'S LOOP

Nerve fibres representing the superior retina form the superior radiations and follow a more direct path towards the striate cortex. Macular fibres pass to the striate cortex in a path between the inferior and superior fibres. Lesions resulting in damage to the optic radiations are extremely rare and are most likely to occur as a result of damage to the vasculature in that area. Lesions resulting in damage to the superior optic radiations result in a homonymous defect which is inferior, quadrantic and wedge shaped, often termed 'pie on the floor'. Conversely, damage to Meyer's loop leads to a homonymous, wedge-shaped defect in the superior quadrants, often termed 'pie in the sky'.

The inferior nerve fibres synapse in the lingual gyrus, which is an area of the striate cortex located just inferior to the calcarine fissure. Superior nerve fibres synapse in the cuneus gyrus which is just superior to the calcarine fissure. Macular fibres synapse in the posterior-most region of the striate cortex. Macular fibres representing the inferior retina synapse in the lingual gyrus and superior macular fibres synapse in the cuneus gyrus. Retinotopic representation of the visual field is also present in the striate cortex, with the macular representation occupying a proportionately larger area than it does in the retina as it is functionally more important to vision.

Due to the high specialisation of nerve fibres in the striate cortex, visual defects occurring at this site will exhibit a high degree of congruence. Vascular disease, strokes and mechanical trauma to the occipital region of the skull are the most common causes of visual field defects in the striate cortex. A number of unique hemianopias occur at the striate cortex, which include homonymous hemianopia where the macular visual field is unaffected (macular sparing) or homonymous hemianopia, affecting only the macular visual field (macular splitting).

◆ *Dr Robert Cubbidge is a lecturer in the Division of Optometry at Aston University*