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METHODS OF OCULAR EXAMINATION

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The different methods of assessing ocular structure and function are discussed in this chapter. The first section deals with different aspects of subjective visual assessment used in clinical examination, such as visual acuity, colour vision, and visual fields. The visual system also detects other modalities, such as luminance or motion, but these are not normally

investigated in routine clinical examination. The second section illustrates the optical and nonoptical methods of examining the ocular structures. Methods described here have been selected to illustrate the important points and principles of clinical examination of the eye. More specialized techniques are described in subsequent chapters.

THE PHYSIOLOGY OF VISUAL ACUITY

TESTS OF VISUAL FUNCTION

The measurement of visual acuity is the first essential part of any ocular examination and, although the examination technique is simple, the process being assessed is complex and requires the interaction of many factors, both physiological and psychological. Assessment of visual acuity requires the eye to detect the object and resolve it into its component parts. This information is then transmitted to the cerebral cortex where it is matched against existing memory shapes. The patient must then be able to communicate recognition of the object to the examiner. Physiologically, visual acuity measures the capability of the visual system to resolve a target and this is dependent on three main factors: the background illumination, the contrast of the target to the background, and the angle that the target subtends at the nodal point of the eye.

In theory, the eye has a maximal resolution of one second of arc or 20/20 (6/6) acuity. In practice, young people normally have a better acuity than this at 20/15 (6/5), which corresponds to the spacing of individual cones in the foveola. Although visual acuity is primarily a function of cones, one should also consider the degree of visual processing in the retina and, in particular, the receptive fields of the retinal ganglion cells. In the foveola, there is a 1:1 relationship of cones to ganglion cells, but this increases rapidly more peripherally. There is an increasing loss of visual acuity with age so that in old age, 20/30 (6/9) or even 20/40 (6/12) may be considered normal for the patient. While distance acuity is normally measured clinically, near vision is in some ways more important in the daily life of the patient. Near vision is tested by reading test print of standardized sizes with the appropriate spectacle correction and good illumination. Factors of accommodation and magnification are important in the assessment of near vision, and the correlation between distance acuity and near acuity is not always good. Patients with 20/60 (6/18) distance vision can often manage to read print of N5 size providing their macular function is normal. There appears to be a large redundancy of nerve fibres in the visual pathways: probably only approximately 15 per cent of the optic nerve fibres are actually required to be able to read 20/30 (6/9).

is proportional to background illumination. In these patients, an increase in the ambient lighting will give them better vision provided that light scattering by the cataract does not counter this.

In clinical work, the best visual acuity is sought with illumination at the upper photopic levels. Under these conditions, the visual acuity is a measure of cone function and the X ganglion cells that appear to mediate spatial information, in contrast to the Y ganglion cells that are more concerned with changes in illumination and movement of the visual image. The relationship of cone density with visual acuity can be demonstrated graphically, relative to the foveal centre. The curves show a direct relationship between high visual acuity and cone density, showing that the anatomical area responsible for maximum visual acuity is the cone bearing part of the retina, the fovea.

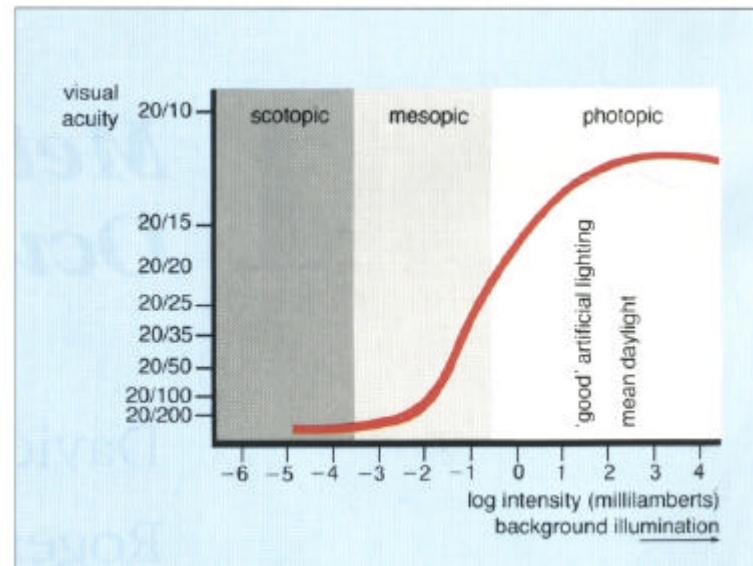


Fig. 1.1 Graph showing visual acuity plotted against background illumination. The best acuity in the scotopic (rod-sensitive) area of the curve is 20/200 (6/60), whereas under photopic (cone-sensitive) conditions, it can increase to approximately 20/1 (6/4). The curve flattens once optimal conditions are reached and then reduces due to the effect of dazzle.

BACKGROUND ILLUMINATION

Background illumination alters the level of retinal adaptation. Low levels of light stimulate the rod system; the receptor density and level of retinal integration of this system are less than that of the cones, and consequently, acuity is also low. At high levels of illumination, the cone system is stimulated and acuity is maximal.

To obtain the best visual acuity, illumination should be in the optimal photopic range. Due to the effect of reduction of retinal illumination by lens opacities, cataract patients may be seeing in the mesopic to low photopic range where the acuity

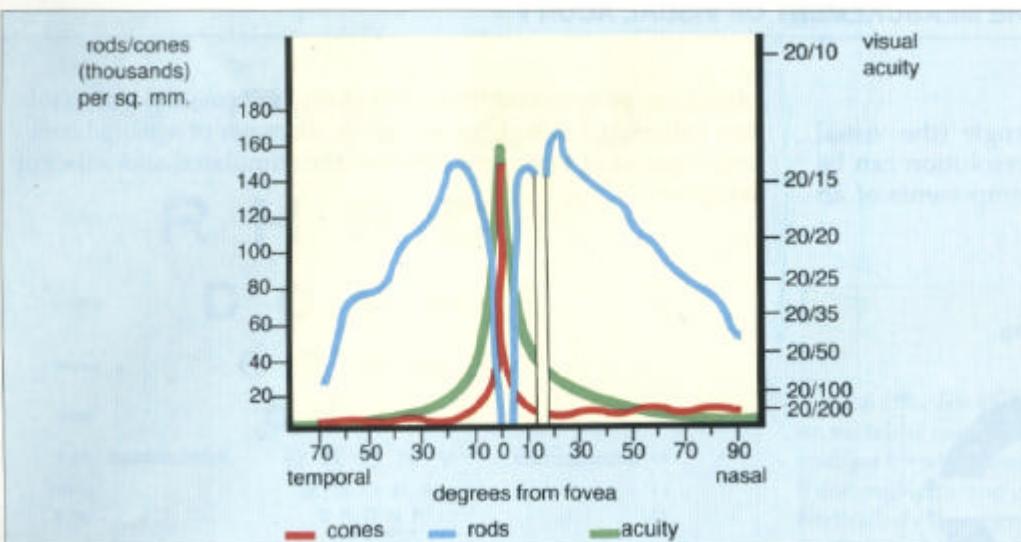


Fig. 1.2 Visual acuity and cone and rod density plotted against degrees from the foveal centre.

CONTRAST

The eye detects objects by responding to the differing levels of illumination at the target edges, or contrast.

Clinical tests have been designed to measure contrast sensitivity - a more physiological assessment of visual function than an acuity chart (which only measures visual function at one point in the high contrast range). The measurement of contrast sensitivity involves the recognition of light and dark stripes or gratings that reflect light in a sine wave pattern and are displayed at variable spatial frequency and contrast values. These patterns can be generated electronically on a TV screen, or, graphically as a clinical test card. They may be adapted in a variety of ways, for example, to test infant vision by preferential viewing techniques (see below). The spatial frequency of the stripes increases along the horizontal axis from left to right (that is, the stripes get closer together) and the contrast

decreases on moving up the vertical axis. As the frequency of the stripes increases to the minimum resolvable acuity (30-40 cycles per second or 1-0.5 minutes of arc), contrast between the stripes decreases, and the highest resolvable frequencies can only be seen with high contrast; beyond this point, the grating appears as uniform greyness. As the spatial frequency reduces, there is insufficient contrast to distinguish the stripes from the background illumination. It is thus possible for patients to retain a good Snellen acuity but have a reduced threshold at lower levels of contrast sensitivity. This may be apparent to the patient as decreased acuity in the affected eye under conditions of reduced contrast, such as on a foggy night. Contrast sensitivity testing may also detect abnormalities in patients with glaucoma, diabetic eye disease, or drug toxicity, which are not detectable using Snellen acuity testing.

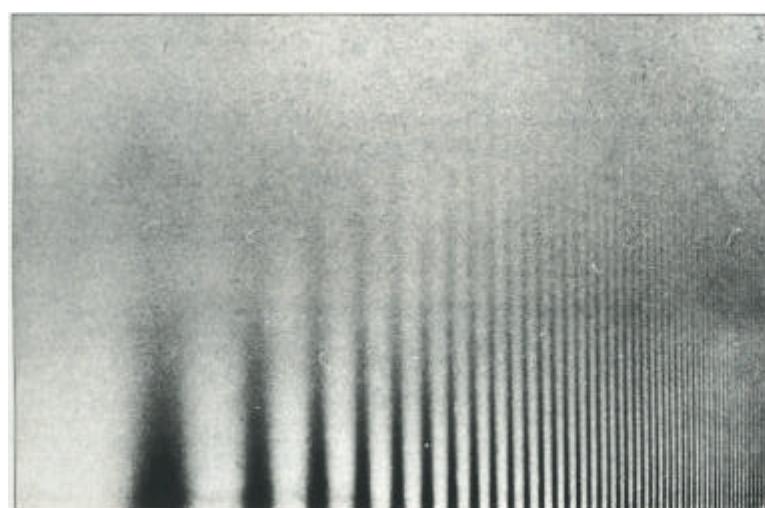


Fig. 1.3 The lines of this clinical test chart demonstrate contrast sensitivity. They are most visible near the centre of the chart but disappear on either side. Towards the left, the stripes become too far apart to be distinguished, and towards the right there is insufficient contrast to see the fine striations between them. In Snellen testing, the black letters on the white background give a contrast level of approximately 80 per cent (see Fig. 1.7). By courtesy of Mr JW Howe.

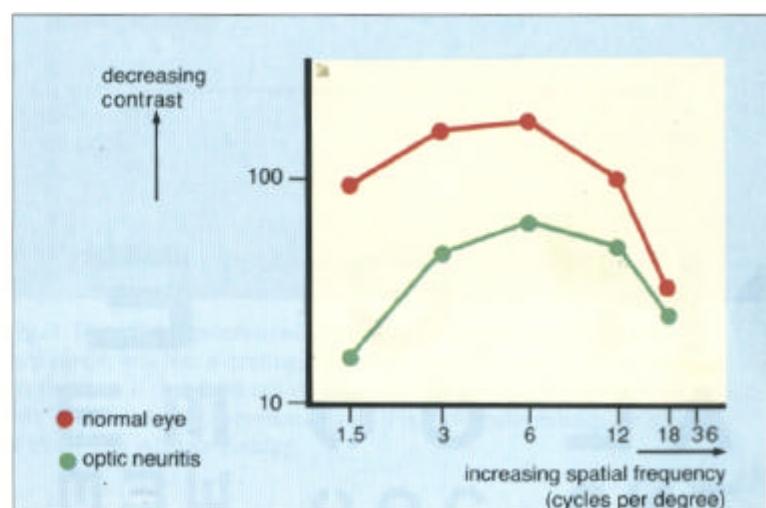


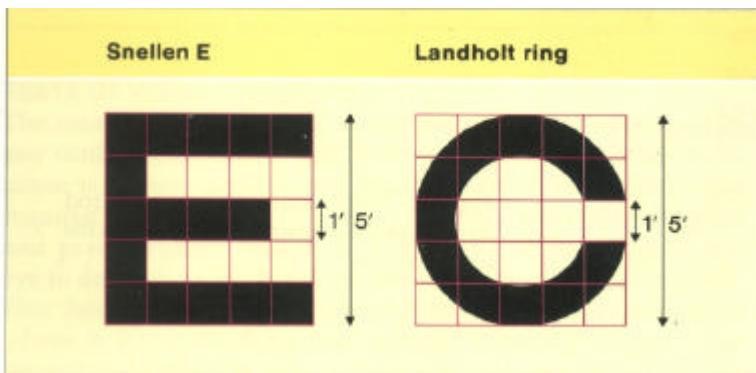
Fig. 1.4 If grating visibility is plotted on a graph, the axes being contrast and spatial frequency, a bell-shaped curve known as a contrast sensitivity curve is formed. For clinical testing, contrast gratings can be constructed in a variety of ways, such as cards of different orientation with the patient identifying the axis of orientation, or a letter chart with letters of decreasing contrast (e.g. the Pelli-Robson chart). At the apex of the curve, changes in contrast sensitivity of 1%, or better, can be detected. The graph shows the curves of a normal eye compared to the fellow eye with optic neuritis.

THE MEASUREMENT OF VISUAL ACUITY

VISUAL ANGLE

All objects in the visual field subtend an angle (the visual angle) at the nodal point of the eye. Visual resolution can be expressed as the visual angle at which the components of an

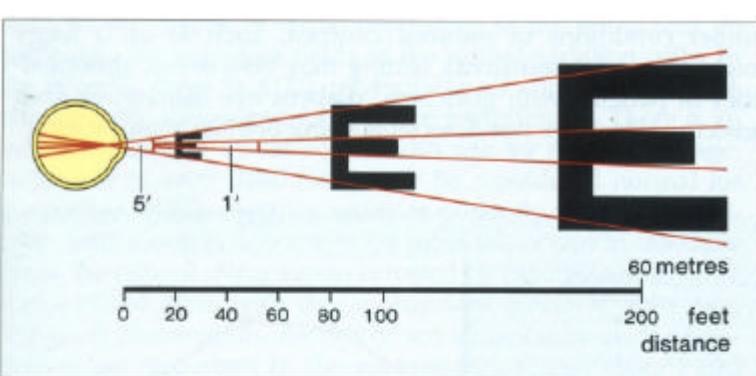
object can be resolved. Experimentally, the smallest detectable line subtends 1 minute of arc, or the diameter of a retinal cone, and contrast of 1 per cent between the stimulated and adjacent receptors.



TEST TYPES

Gratings are difficult to use clinically and are usually reserved for research purposes. More commonly, tests of minimum legible acuity are used to measure the resolvable gap between the elements of high contrast type letters. The letters are arranged so that lines of different visual angles are shown on a decreasing scale. The standard letter designed by Snellen,

Fig. 1.5 Clinical tests to determine visual resolution use Snellen letters, as seen here, in which the visual angle subtended by the component parts of the 20/20 letter is one minute of arc.



when viewed from 20ft (6m) subtends an angle of five minutes at the eye, and each of the gaps within the letter, an angle of one minute, whereas the top letter subtends an overall angle of 50 minutes with individual components of 10 minutes at 6m. Distance visual acuity is tested at 20ft (6m) to eliminate contributions from presbyopia or accommodation.

Fig.1.6 Letters are constructed so that they subtend the same visual angle when viewed at distances up to 200ft. These letters are then mounted on a card and viewed at 20ft (6m). The smallest line of letters that can be resolved by the patient is noted. The test distance is then divided by this line to give a fraction. If the patient sees at 20ft as far as the 40ft line, the visual acuity is expressed as:

$$20\text{ft} = \text{visual acuity of } 20/40 \\ 40\text{ft}$$

This can also be measured in metres: 6/12, as a decimal (0.5), or as the angle subtended by the smallest gap of the letter, for example, two minutes.

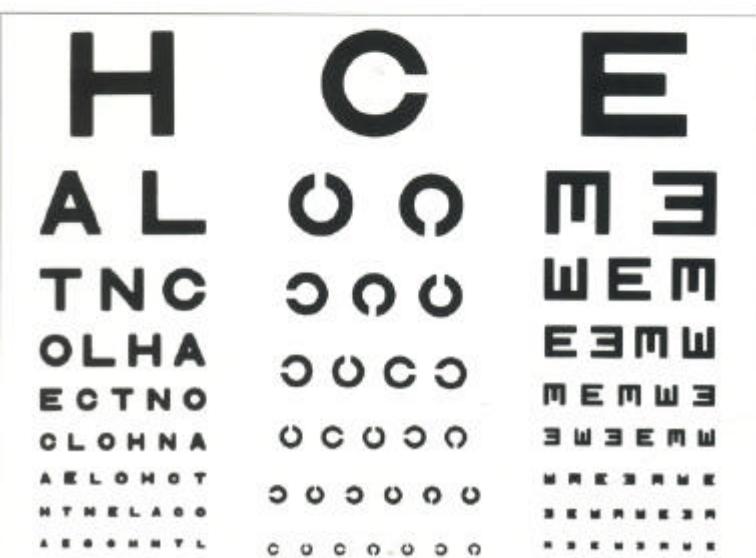
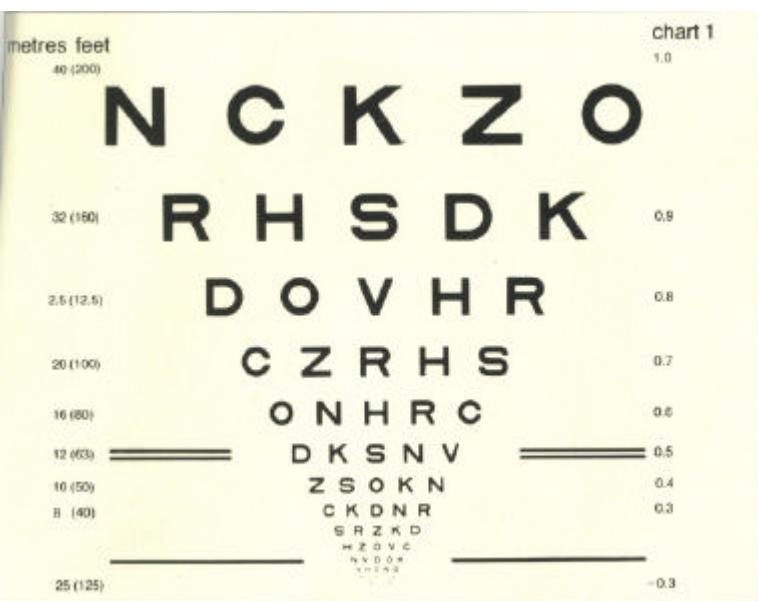


Fig.1.7 Snellen test types also rely on factors such as literacy and legibility; for example, an L is easier to read than an A. Landolt rings avoid this by asking the patient to identify orientation of a gap. They can also be used with illiterate patients; alternatively, patients can be asked to match a cut-out letter 'E' with the same letter at different orientations.



TESTING ACUITY IN CHILDREN

Visual acuity assessment in children presents particular problems, and good results can only be achieved with time and patience and by selecting the right test for the age of the child. A wide variety of techniques are available that range from the detection of vision in a small baby (turning to a face or light, or suppression of optokinetic nystagmus following rotation) to semiquantitative measurements (picking up 'hundreds and thousands' sweets, following small balls). Children over

Fig. 1.8 Snellen charts have the defect of different numbers of letters on each line causing crowding phenomena and nonproportional spacing between letters and lines. The Bailey-Lovie chart overcomes these problems and gives a more accurate assessment of acuity, particularly in patients with poor vision. It is read at 4m and covers Snellen equivalents from 20/10 to 20/200 with rows of five letters and doubling of the visual angle every three lines. If visual acuity is worse than 20/200 the top six lines are read at 1m.

$2\frac{1}{2}$ years of age can manage matching tests (for example, Sheridan-Gardiner; see Chapter 18). Caution is necessary when using Snellen charts with single letters due to the phenomenon of 'crowding' - the ability to see single letters more easily than rows of letters - which can lead to overestimation of the true acuity. Visual evoked responses can be quantified, but the best and most accurate research technique for infants under $2\frac{1}{2}$ years of age are preferential viewing methods.

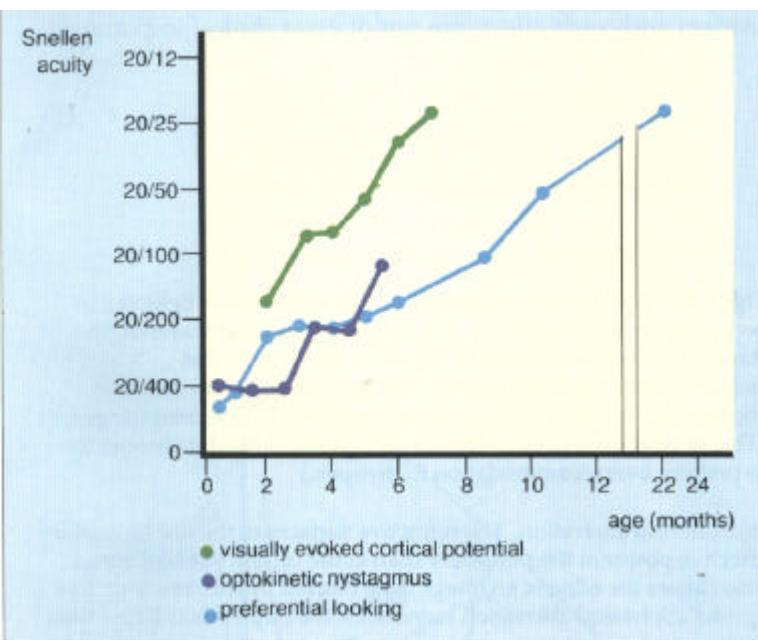


Fig. 1.9 Development of visual acuity with age depends to some extent on which method of testing is used as visual evoked potentials, optokinetic reflexes or preferential looking techniques all give different results. The latter is the most commonly used technique and shows infants do not reach adult levels of acuity until 2 to 3 years of age. By courtesy of the Editor, Survey of Ophthalmology, 25, 325-332, 1981.

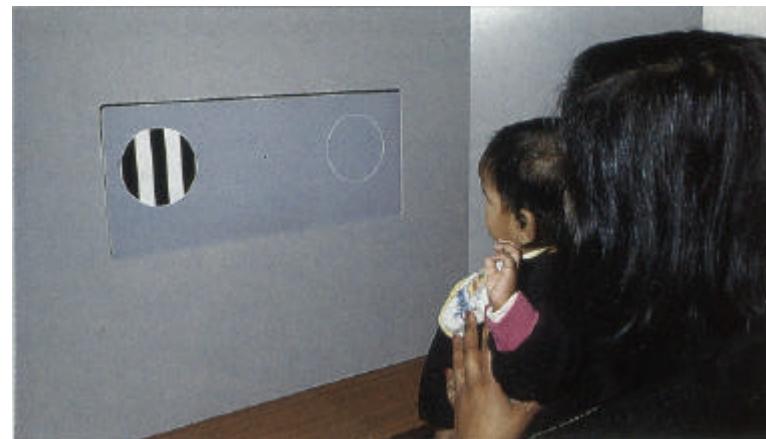


Fig. 1.10 With preferential viewing techniques the child is shown two cards: one has a grating, the other has the same uniform overall luminance. If the child can distinguish the grating he or she looks at this 'preferentially', presumably as it is more interesting. By courtesy of Professor Alistair Fielder.

ASSESSMENT OF POTENTIAL ACUITY

Various methods have been tried to assess visual potential prior to surgical procedures such as cataract surgery. The most widely used technique is to project a miniaturized Snellen chart on the retina. Another method is laser interferometry which avoids the normal focusing mechanisms of the eye. A grating is formed on the retina by diffraction which is detected by the patient. Each technique needs a co-operative patient and neither works well in the presence of dense lens opacities.

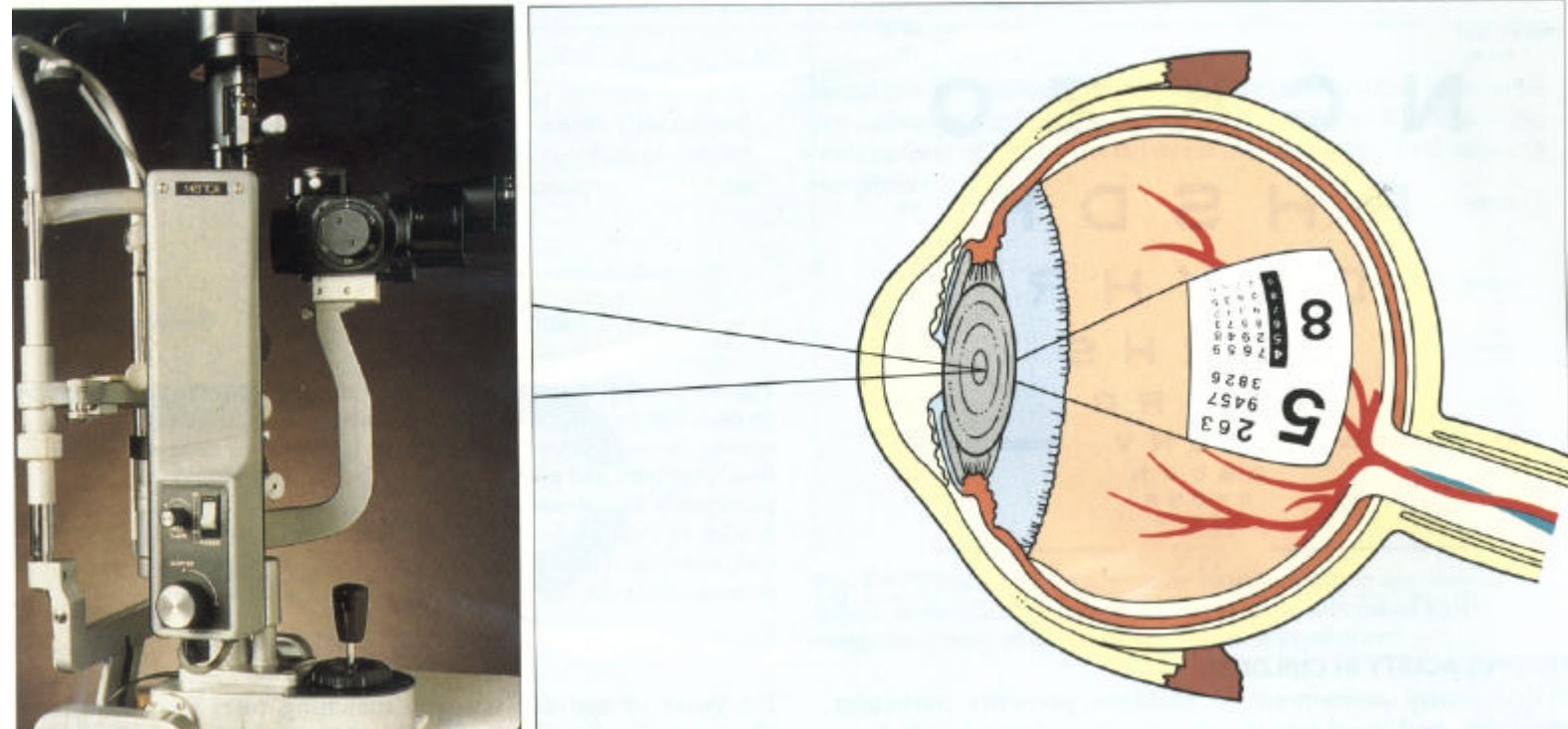


Fig.1.11 The potential acuity meter is mounted on a conventional slit lamp and projects a Snellen type chart onto the fovea through a gap in the lens opacities.

IMAGE DISTORTION BY OPTICAL ABERRATIONS IN THE EYE

Light rays passing through the eye are degraded by the inbuilt aberrations of the system, thereby increasing the blur at the margins of the images; this loss in edge contrast reduces the

resolving power of the visual system. The three main causes of optical degradation are chromatic aberration, spherical aberration, and diffraction. Other aberrations such as oblique astigmatism and coma effect, are not of great clinical importance.

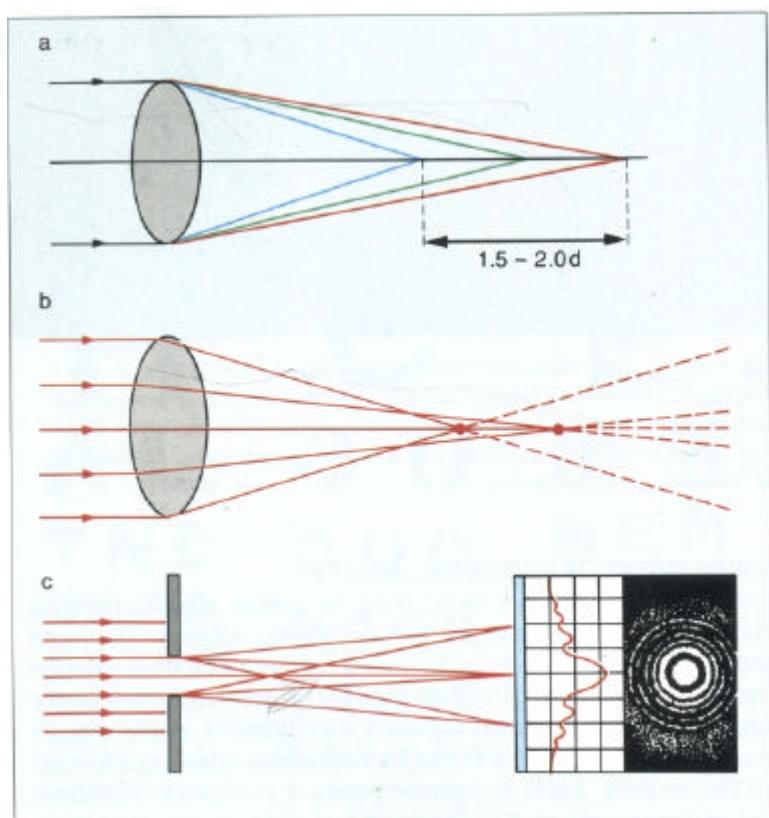
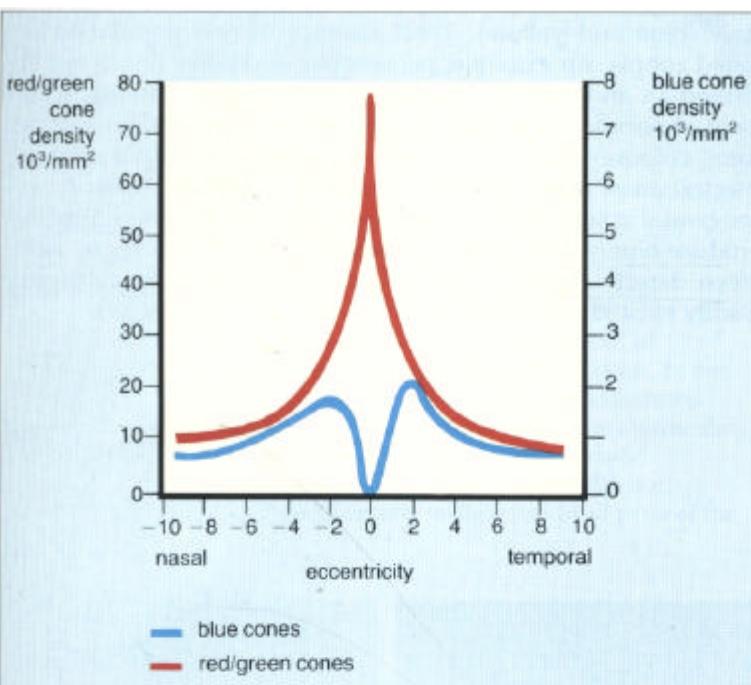


Fig.1.12 (a) Chromatic aberration. The refraction of light varies according to its wavelength. It is increased for short wavelengths (blue) and decreased for long wavelengths (red) so that polychromatic white light is focused as a coloured blur, and the contrast at the image edge becomes degraded by coloured fringes. (This aberration is used to clinical advantage in the duochrome test to prevent overaccommodation in myopes.)

(b) Spherical aberration. The refractive surfaces of the eye have more effective power at the periphery than at the central paraxial zones. This causes the edge of an image to be blurred by the resulting 'line spread'. Spherical aberration increases if the pupil size is larger than 3mm.

(c) Diffraction. Light projected through an aperture passes through the centre but is absorbed and re-transmitted at the edges. The wave fronts of re-transmitted light then cause interference patterns that increase the spread of the image focused beyond the slit. Experiments show that diffraction spread increases if the pupillary aperture is less than 3mm. Since larger pupillary apertures increase chromatic and spherical aberration, the best compromise is achieved with a pupil diameter of 2.4mm; this correlates well with visual acuity plotted against pupil diameter.

COLOUR VISION



Objects reflect different wavelengths of light and give rise to the sensation of colour. Colour appreciation is a function of cone receptors that respond to light in the visible spectrum; each of the three populations of cones has its own spectral sensitivity range. Different spectral frequencies stimulate each of the cone populations to a different degree so that all colour within the visible spectrum can be matched by differential stimulation. Apart from spectral sensitivity, colour brightness (luminosity) and saturation (amount of white light present) must be taken into account in colour testing.

Fig. 1.13 Colour perception is maximal in the centre of the retina but perception disappears and then, in the periphery, all colour perception is absent. There are no blue cones in the fovea and they are less numerous than red-green cones elsewhere in the retina.

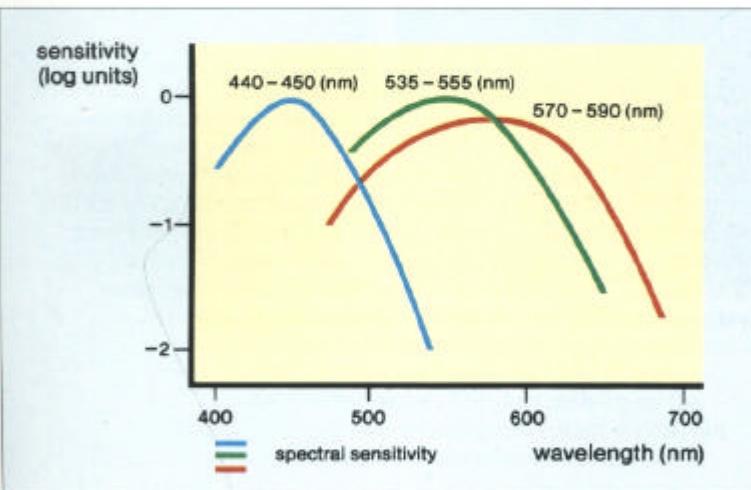


Fig. 1.14 Investigation of the **spectral sensitivity curves** of the human retina shows peaks at 440-450nm (blue), 535-555nm (green) and 570-590nm (red). This diagram illustrates the way in which the ranges of wavelength of cone sensitivities overlap; the curves have a gentle slope on the short wavelength side and a rapid fall on the side of long wavelength, that is, towards red.

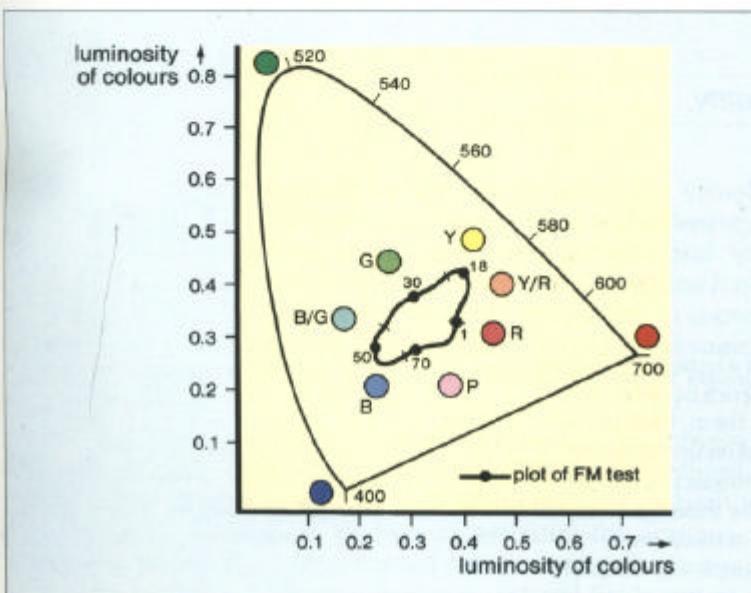


Fig. 1.15 Any colour in the visible range can be matched by a mixture of three reference wavelengths; the intensity of the colour is balanced by the algebraic sums of the intensities of the reference wavelengths, so that:

$$\text{Required colour} = I_1 k_{\text{red}} + I_2 k_{\text{green}} + I_3 k_{\text{blue}}$$

where I_x is the individual intensity of each colour.

A universally accepted reference system for the matching of colours is that set out by the Commission Internationale de l'Eclairage (CIE). This system may be represented by a chromaticity diagram. The three reference wavelengths are 450nm, 520nm, and 650nm, and any colour can be matched by varying the luminosity of each wavelength, or by the addition of white light.

CLINICAL TESTING OF COLOUR VISION

There are many types of equipment available for clinical testing of colour vision. The Farnsworth Munsell (FM) '100' hue test for comprehensive testing and the Ishihara pseudo-isochromatic test plates for red-green defects are most commonly used.

The D15 test is an adaptation of the Ishihara plates for rapid graphical display of red-green defects. Other pseudochromatic test plates such as the Hardy-Ritcher-Rand (HRR) series or the City University System, have the important advantage of extending the test into the blue spectrum. If pseudo-chromatic plates are to be used properly, they must be viewed under standard white light conditions. Very sophisticated, but expensive, computerized TV systems are now available for in-depth analysis of colour defects.

There are three major groups of colour anomalies: protan deficiency (red), deutan deficiency (green), and tritan deficiency (blue and yellow). Total absence of one population is called anopia, for example, protanopia. A relative deficiency is termed an anomaly, for example, protanomaly. Patients who have abnormal cone populations will not be able to match some colours visible to a normal patient but within certain spectral areas may have normal colour matching. Apart from congenital colour defects, acquired macular disease tends to produce blue/yellow defects, while in optic nerve lesions, red/green defects appear as an early and important clinical sign, readily elicited with the Ishihara plates (see Chapter 19).

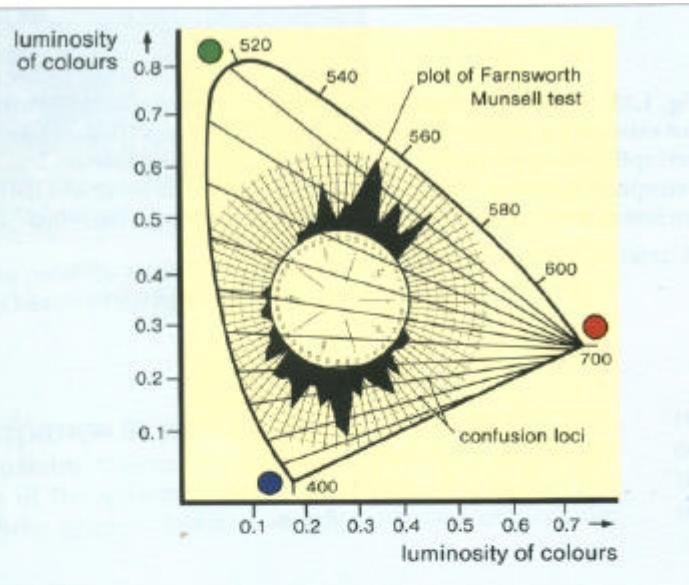


Fig. 1.16 By plotting colour matches on a CIE chart, the anomalous results will show in great detail, as can be seen in this diagram where the colour confusion loci are shown for protanomaly (radiating from the red locus). These are lines along which separation of colours is not possible by a patient with red deficiency. The time taken for this test precludes its use as a clinical method. This diagram has been overlaid by an FM scoresheet from the same patient (see Fig. 1.18). Note the axis of orientation has been rotated so that the colour system of the CIE system and FM tests are congruent.



Fig. 1.17 A more useful clinical test is the Farnsworth Munsell test in which a series of coloured tiles (84 in number) are arranged in four separate trays. In the test, the difference between the tiles is graded so that there is one unit of 'just noticeable difference' between them. Each of the four trays covers a different range of the colour spectrum. Trays of tiles are taken one at a time and jumbled; the patient views these under a standard white light and re-arranges the tiles in chromatic order between two reference tiles placed at each end of the tray. The misalignment of the tiles from their correct position in the chromatic series is then scored and marked on a standard chart, and the greater the displacement, the higher the score. The test is considerably speeded up by computerized reading and plotting.

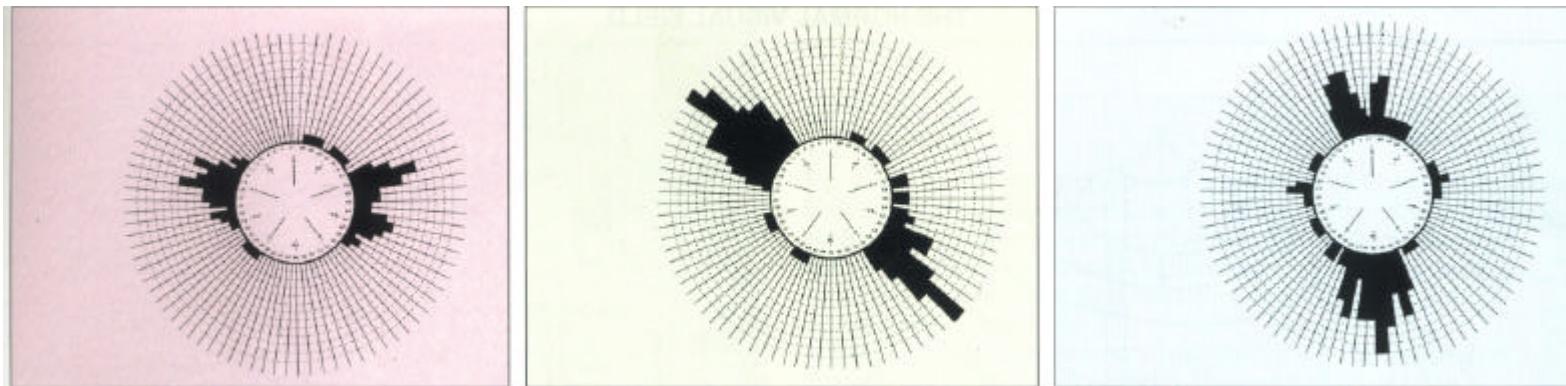


Fig. 1.18 In a normal person, only one or two tiles would be misplaced, and the scoresheet would appear as a small circle. In the different colour anomalies, however, the chart becomes distorted along a particular axis. The axis of distortion is typical for a particular colour deficiency, and examples of the axis for protanomaly, deutanomaly, and tritanomaly are shown. Patients with nonspecific acquired colour defects usually make errors in all parts of the wheel.

The FM scoresheet can be superimposed upon the CIE confusion loci diagram shown in Fig. 1.16 demonstrating that the axis of the scoresheet is tangential to the confusion loci of the CIE diagram. One should note that the FM test does not pick up the confusion between colours opposite each other in the circle since these tiles are in different trays and the opportunity for confusion does not arise.

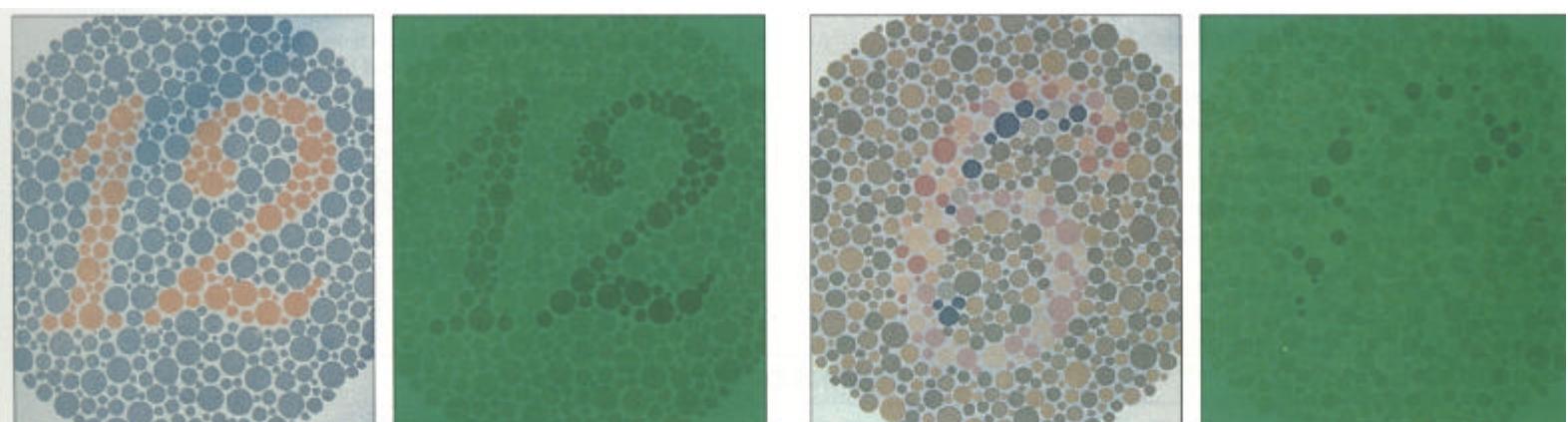


Fig. 1.19 A more rapid test for red/green confusion (which is the most common colour defect) is the Ishihara pseudo-isochromatic test plates. These are a series of test plates where a matrix of dots are arranged to show a number in the centre. The dots making up the numbers are visible to people of normal red/green colour vision, but are confused with adjacent colours by those who are red/green

deficient. The colour dots are designed to be isochromatic so that dots making the letters cannot be perceived by contrast difference. A trial and test plate are displayed, with and without, a green filter. The green filter makes the test number almost disappear, but the trial plate number is still easily visible.

VISUAL FIELDS

The area in space perceived by the eye is called the visual field. Visual fields are performed for diagnosis of early disease, or localization of lesions within the visual system and to monitor the progress of these lesions with time. The retina has a variable sensitivity, and the visual fields are plotted to show this. Lines (isopters) connect points where a target of the same size and brightness is first perceived, that is, points of equal retinal sensitivity.

The area of the visual field depends on the size, brightness, and colour of the target and its contrast to background illumination. Psychological factors will influence the patient's concentration, and good fixation is essential for accuracy. Refractive errors must be corrected when testing the central field, but have little influence on the peripheral fields outside

the central 30°. Small pupil sizes (less than 2mm) and nuclear sclerosis will simulate constriction of the field area. The visual field can be tested by many types of apparatus, either static or kinetic, although some instruments have been designed to use both forms of testing. Kinetic perimetry involves the detection of a moving target, while static perimetry involves the detection of a stationary target of increasing brightness. Occasionally, a stationary target cannot be perceived whereas an equivalent moving one can; this is known as the Riddoch phenomenon. While kinetic fields have the advantage of producing a readily interpreted 'map', static fields produce numerical data that can be handled statistically so that, for example, changes within the field can be more precisely followed.

THE NORMAL VISUAL FIELD

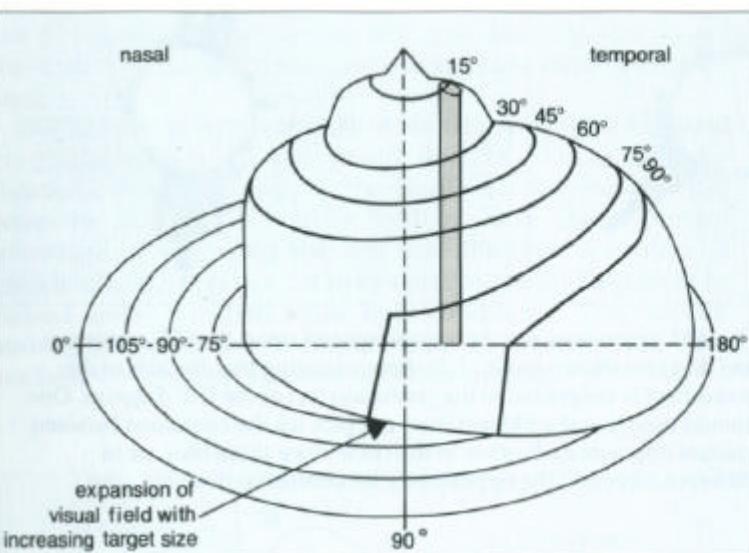


Fig. 1.20 The plot of the visual field isopters can be represented in a three dimensional form called Traquair's Island, in which the isopters appear as contour lines on the island. The visual field and the slope of the field contour is not static but varies with the background illumination. Under mesopic conditions, the gradient of sensitivity away from the central areas is much more gentle than under photopic conditions where the peripheral retina is desensitized and foveal function is more acute. For this reason, it is important that comparisons of the visual field are made under similar conditions of retinal adaptation.

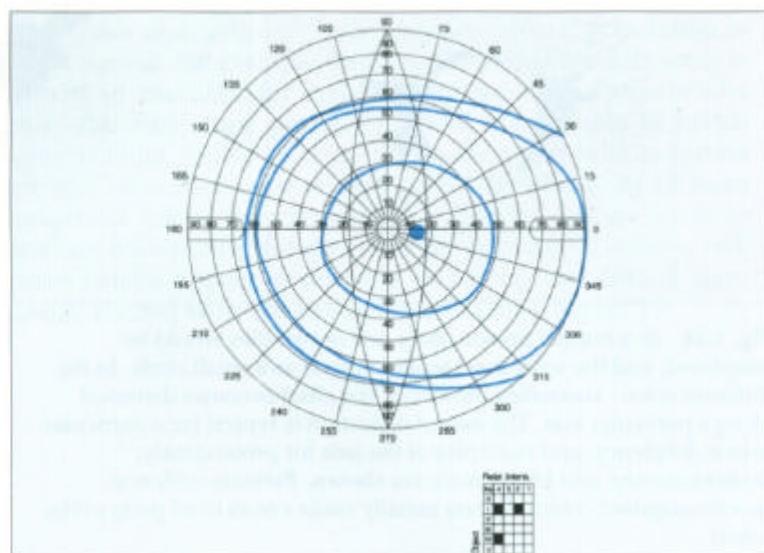


Fig. 1.21 A typical visual field as plotted on a Goldman perimeter (see Fig. 1.23). The visual field which is marked off in degrees from the fovea, is not circular but displaced laterally and downwards. The upper and medial limits are approximately 60, the temporal, 100, and the inferior, 75. In the temporal field, the exit of the optic nerve is marked by t

prominence of the brow and the nose may cause artefacts in the nasal and superior visual field that the examiner must be aware of and able to correct.

CLINICAL TESTING OF VISUAL FIELDS

CONFRONTATION FIELD TESTING



Fig. 1.22 Visual fields can be tested by many means, the simplest being confrontation. The technique involves the examiner sitting opposite the patient with a distance of approximately 1 m between them. They cover opposite eyes with the palms so that the uncovered eyes have mutually congruent fields. The examiner then introduces a test target into the field (fingers, hand, red bottlecap) until the target is perceived by the patient. The patient's and examiner's field should be congruent so the presence of a defect is noted by the absence of patient response when the object is visible in the examiner's field. A red target is especially useful for detecting neurological defects in the central field, since the retrobulbar pathways are particularly sensitive to red, as they are mainly concerned with macular vision (central 30° of field). If the patient is asked to compare the quality of colour between quadrants, very early defects such as a bitemporal hemianopia, can be subjectively detected. With practice, a confrontation field can be obtained from almost any patient and produces good localising information.

KINETIC PERIMETRY

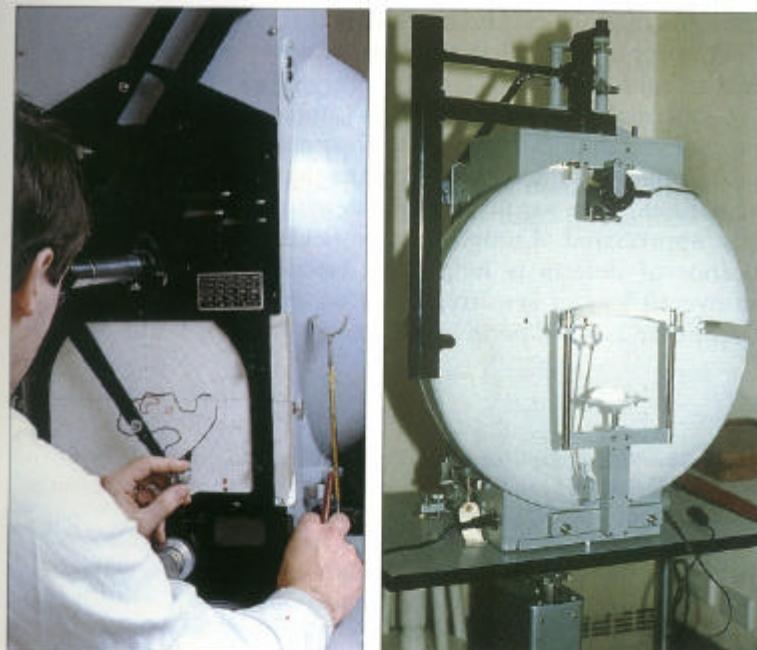


Fig. 1.23 The Goldmann perimeter is usually used to produce a kinetic field but can be adapted for some basic static perimetry. It is made up of a hemispherical bowl that is uniformly illuminated and onto which are projected target lights of varying size and brightness. Target size, brightness, colour, background illumination, and fixation are all controlled.

The patient sits at the machine with the eye to be tested fixed on the centre of the hemisphere (right). Fixation is checked by an observation telescope mounted at the central fixation point. The target lights are then introduced by the projector into the visual field of the patient, while a pantograph arm moves across a standard recording chart. As the patient signals perception of the target, the examiner marks the chart and eventually plots the isopter to the particular target. The test is usually undertaken at several isopters of target size and brightness, thus producing a kinetic field that demonstrates the area and density of field loss. A static assessment can be made by flashing the target light within the appropriate isopter.

STATIC PERIMETRY



Fig. 1.24 Many different types of static perimetry have been developed, principally for glaucoma testing. A rapid assessment of the

Friedmann analyser, which is a good example of the techniques of static perimetry. This machine is a suprathreshold, multiple presentation, semi-automated, static perimeter. It consists of a screen with a series of spot targets set in a black background. The background illumination is 4asb (mesopic). The spots are the same intensity but of differing sizes, increasing in size from the central spot to the peripheral spots. This has the effect of ensuring that retinal sensitivity is the same across the tested part of the visual field. The patient is placed at a distance of 330mm from the target screen. At the beginning of the test, the macular threshold is established by varying the illumination of the flash seen in

the macular threshold. If a point is missed it is retested again, until it is seen, establishing a point of decreased or total loss of retinal sensitivity.

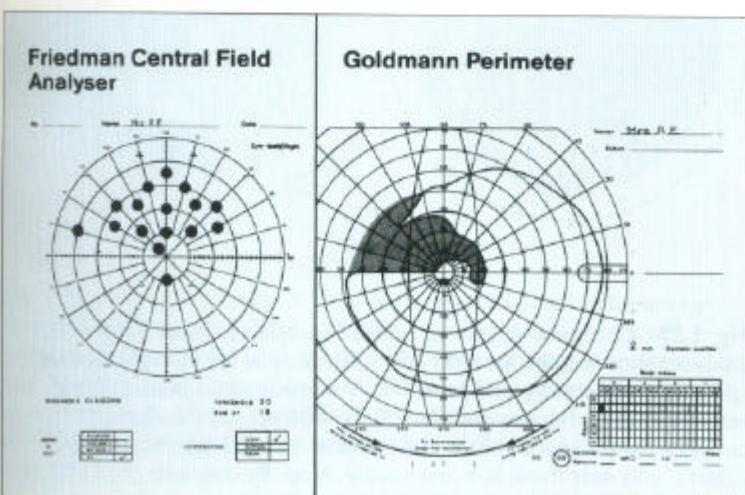


Fig. 1.25 This shows a Friedmann field of a patient compared to that obtained on a Goldmann perimeter. Target size and illumination is recorded on the table at the bottom right hand corner of the Goldmann field. Both tests require good concentration from the patient and a skilled operator, but produce standardized fields for long term follow up.

COMPUTER-ASSISTED PERIMETRY

The ultimate development of static perimetry has been the advent of computer-assisted perimetry, which has made numerical, rather than pictorial, representation of data possible, and has allowed statistical assessment and comparison of visual fields. In computerized perimetric practice, retinal sensitivity is measured at a particular location in decibels (db). The equivalent of 1 log unit of retinal sensitivity is 10db, total sensitivity ranging from 0-40db. A reduction of more than 4db from the age-matched value is required before a change can be said to be due to a significant loss in retinal sensitivity. Normal patient variability within the test (short

term fluctuation) can be assessed for the whole of the visual field or for individual spots. The greatest variability is seen at and around scotomata.

Sequential visual fields may be stored and compared. The normal variation in the patient's response from one test to the next (long-term fluctuations) means that a sequence of several visual fields are required before deterioration can be statistically appreciated. Comparison of fields and statistical significance of defects is helped by calculation of indices such as overall loss of sensitivity and an estimation of focal loss. Computer-assisted perimetry is discussed further in Chapter 7.



Fig.1.26 With computer-assisted perimetry, a computer program controls the strategy of the entire test. Some technician supervision is still required, but any variability in technician performance is removed. In the two most widely available computer-assisted perimeters (the Octopus and the Humphrey machines), static targets of fixed size but of variable intensity are presented. These targets are presented in a random fashion at each retinal co-ordinate within a bowl perimeter. These co-ordinates have been selected for their discriminating potential. Background illumination is photopic (21.5asb) in the Humphrey, but mesopic (4asb) in the Octopus machine. Fixation is automatically monitored and displayed on a TV screen to the side. Throughout the procedure, the software programme checks and re-checks that fixation is maintained, and produces a score of the patient's reproducibility of responses. The duration of the test depends on the number of questions asked of the patient and the speed of the patient's response. To perform well, the patient needs to be familiar with the type of test and not to be intimidated by it. The increased testing time in some of the more complex test strategies means that patient fatigue may be a factor influencing the result. However, 'pause buttons' allow patients to rest should they feel tired.

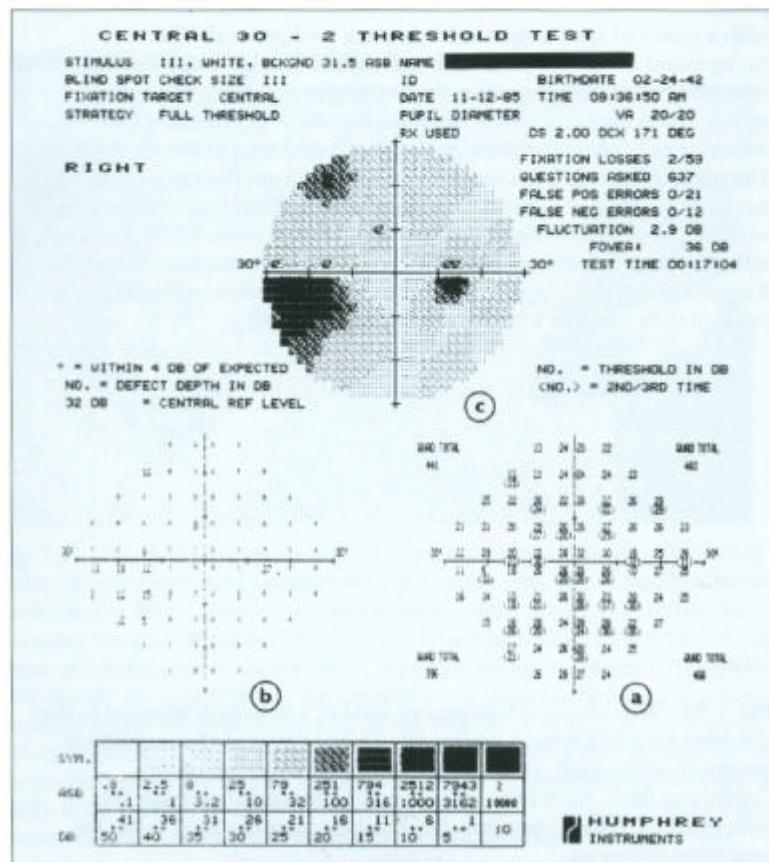


Fig. 1.27 Computer print-out from a Humphrey visual field analyser showing the location and sensitivity of the 76 tested retinal spots in the 30-2 programme. Chart A represents the actual retinal sensitivity at each locus and chart B the difference in decibels between the patient's values and those of an aged match control. Chart C converts these to a 'grey-scale' map. By courtesy of Humphrey-Zeiss Ltd.

EXAMINATION OF THE EYE

SLIT LAMP (BIOMICROSCOPE)

The slit lamp (biomicroscope) is the fundamental tool in the clinical examination of the eye. It consists of a moveable light source and a binocular microscope that is used to illuminate and view the eye. In its basic form, it is used to examine the

anterior segment but is easily adapted for examining the posterior segment. Methods of examination include direct illumination, scleral scatter, retroillumination, and specular reflection. Ancillary lenses are needed to view the fundus or angle of the anterior chamber.

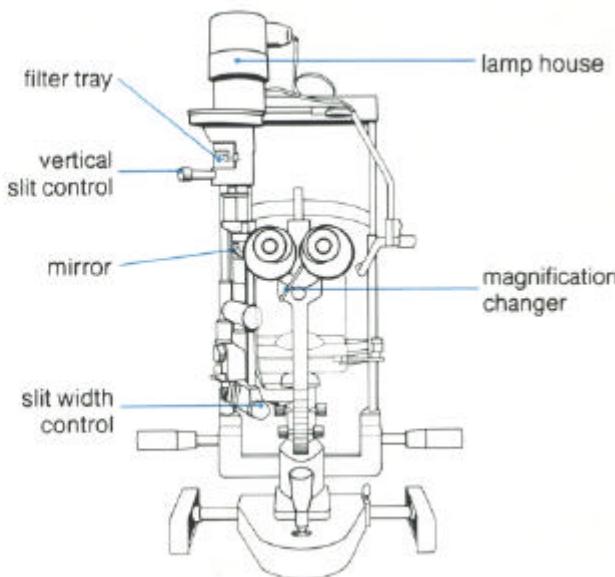
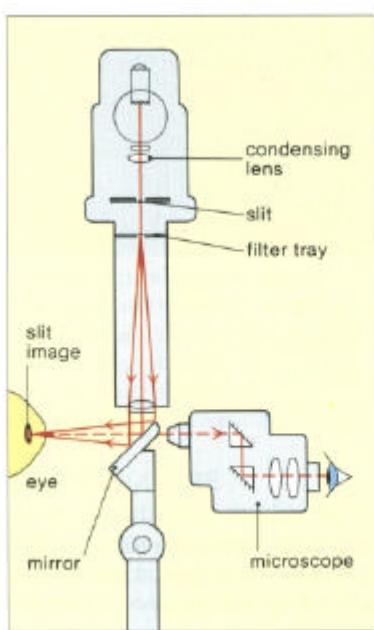
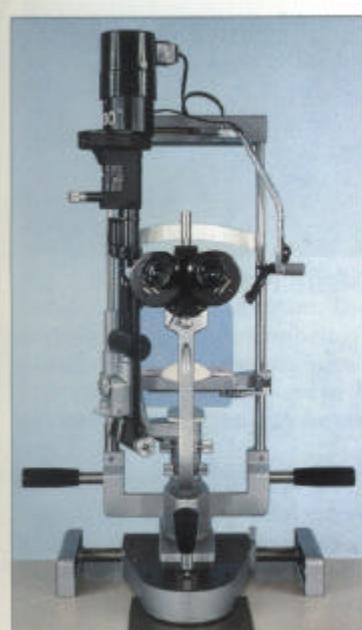


Fig. 1.28 A slit lamp, together with its optics. Light arising from a tungsten filament lamp in the lamp house passes through a condenser to a variable slit mechanism that allows the length and width of the slit to be altered at will. Below this is a tray for various filters to be inserted in the light path. The beam is directed into the eye by a mirror and focused so that the focal plane is the same as that for the viewing microscope. The angle between the illuminating beam and the viewing microscope, can be varied at will. The microscope incorporates a two-stage magnification changer that alters the objective lenses without moving the focal plane. Height and focusing is altered by means of a joy-stick control. The different ways in which ocular features can be viewed using the slit lamp are illustrated in the following figures.

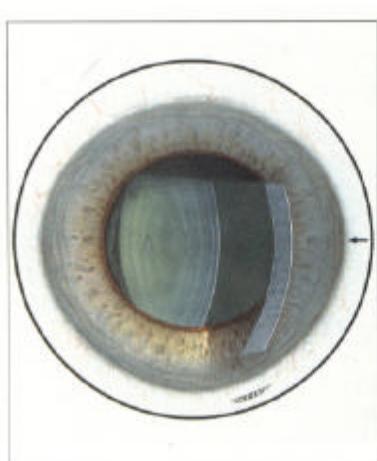


Fig. 1.29 Direct illumination. The differences in detail obtained by using full aperture illumination (left) as opposed to that of the slit beam (right) are shown. The slit beam produces a narrow optical section of the anterior segment which throws the various anatomical components into relief. From the slit-beam painting, it can also be seen that the anterior vitreous gel is clearly visible using this form of examination.

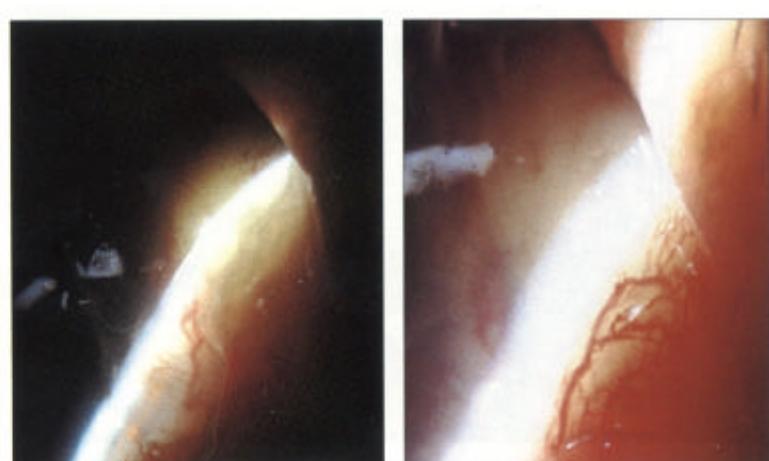


Fig. 1.30 Scleral scatter. Some features on the eye do not show up well with direct slit-beam illumination, and in these cases it is often better to offset the beam of light so that the feature is illuminated by scattered light from the surface of the eye. This is illustrated here: on the left, the blood vessel is illuminated directly by the slit beam (only a narrow portion of it can be seen corresponding to the width of the slit) as compared to the offset-beam picture on the right where the vessel is thrown into relief.

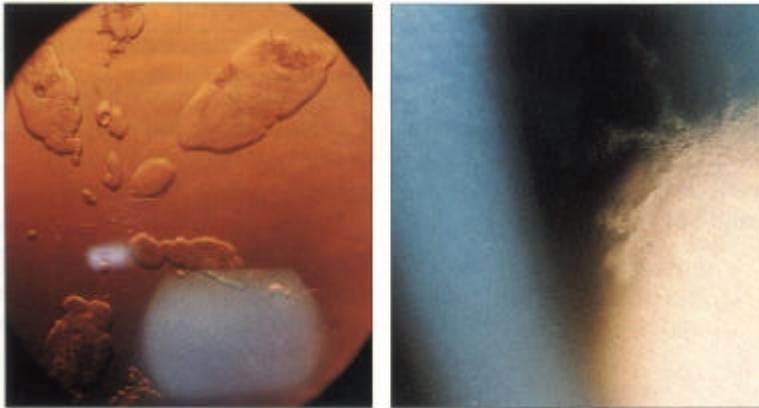


Fig. 1.31 Retroillumination. Another form of illumination that highlights special features within the eye is that of retroillumination. On the left, light that has been reflected from the retina and shows as a diffuse red glow, highlights a cataract which has formed after the introduction of silicone oil into the vitreous cavity. In the picture on the right, light reflected from the iris surface illuminates a dendritic ulcer in the corneal epithelium. The swollen epithelial cells involved in the infection are shown particularly well through the retroilluminated cornea.

SPECULAR MICROSCOPY

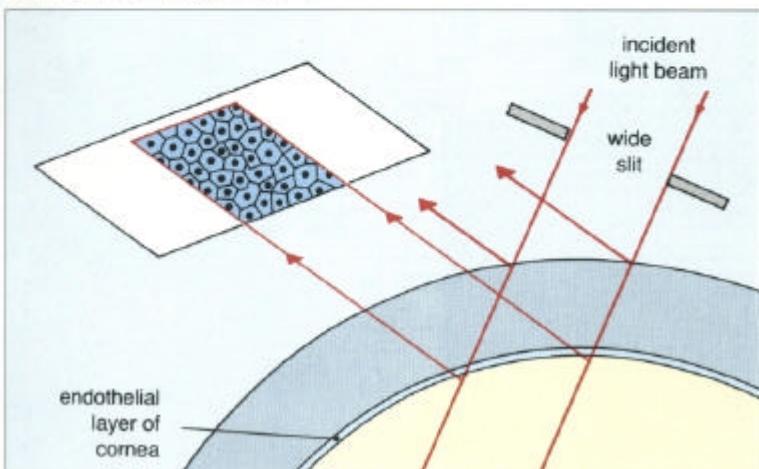


Fig. 1.32 Specular reflection. When a beam of light traverses a heterogeneous optical medium, most of the light is transmitted, but at each optical interface, a proportion of light is reflected (specular reflection).

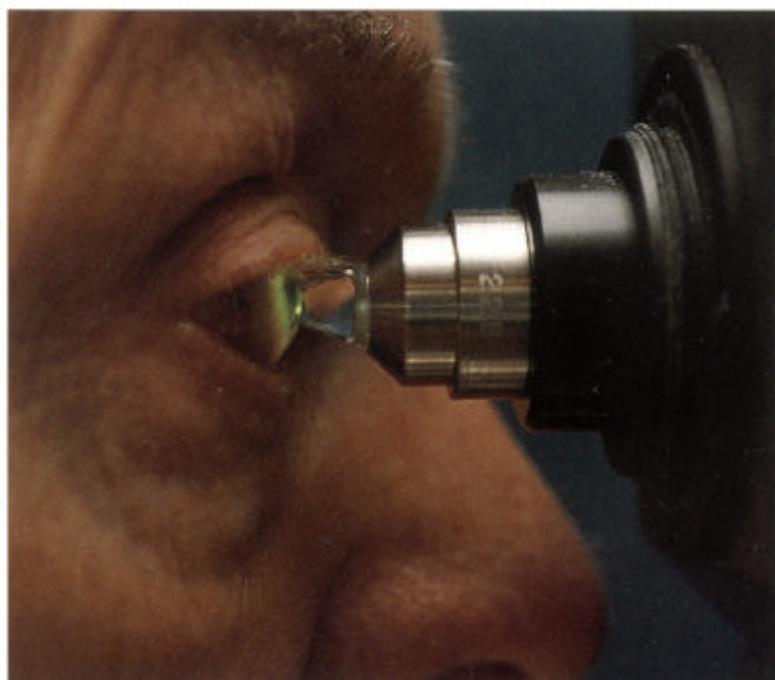
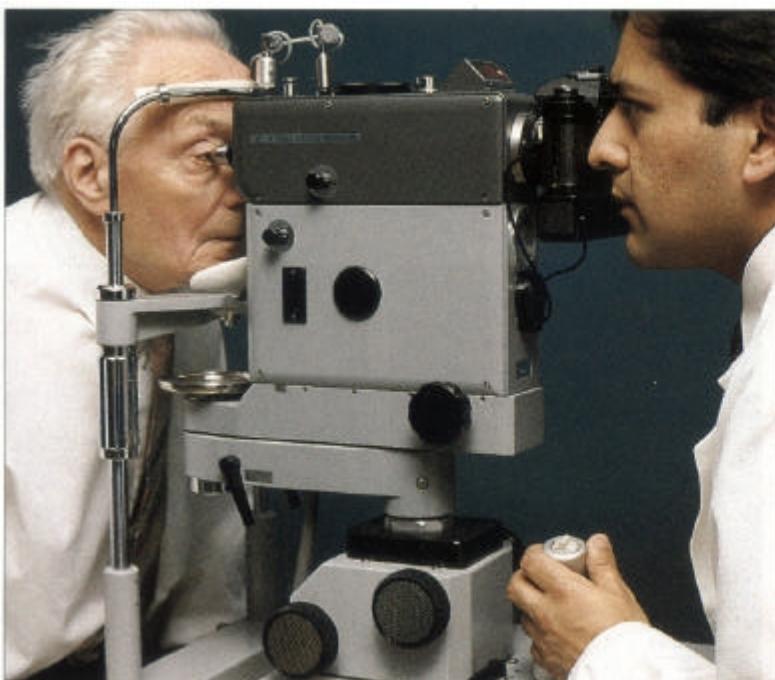
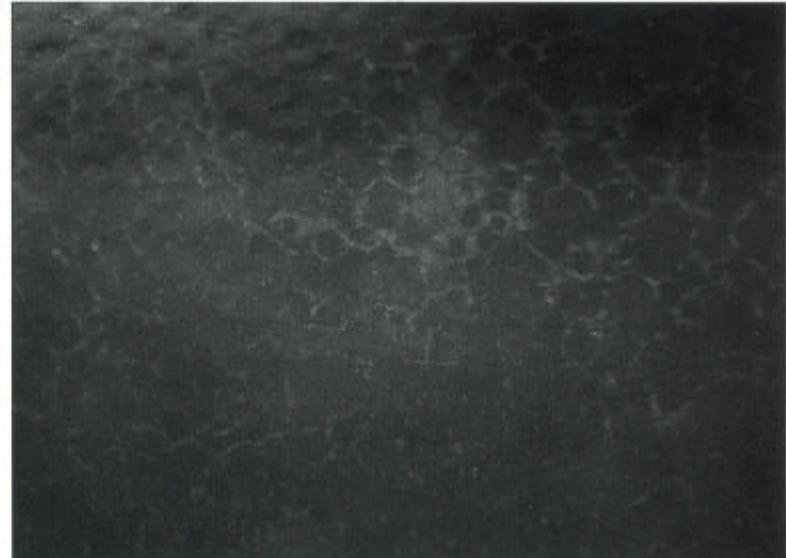


Fig. 1.33 This phenomenon is employed as a particularly useful technique for examining the corneal endothelium, which can be seen on routine slit-lamp biomicroscopy, although better views are obtained with specialized specular microscopes such as the Keeler-Konan instrument shown here, which uses a corneal contact technique.

To obtain good specular reflection, the angle of illumination is adjusted to provide a specular image of the endothelial cell layer displaced away from the relatively intense reflection from the epithelial surface. If the latter is too bright, it may interfere with visualization of the endothelial specular reflex, and the luminosity of the incident light should be lowered by reducing the height or width of the slit beam. By courtesy of Mr Sanjay Shah.



Fig. 1.34 This photograph (left) shows the typical appearance of healthy corneal endothelium. The technique can be used to monitor both the density and morphology of endothelial cells (see Chapter 6) as well as the corneal epithelium or anterior lens surface. In addition, by adjustment of the specular microscope, a nonspecular reflection may be obtained which allows a pseudo three



dimensional view of posterior corneal changes (relief mode) by a mixture of marginal and indirect illumination from deeper structures (right). This view can aid in the interpretation of pathological changes that disrupt the normally smooth posterior corneal surface.

MEASUREMENT OF THE CORNEAL CURVATURE Measurement of corneal curvature is essential for the fitting of contact lenses and the assessment of the eye for refractive surgery, correction of excessive astigmatism, or for the correct calculation of intraocular lens power. It is also useful in the

follow-up of corneal diseases, such as keratoconus. A simple piece of equipment for the qualitative examination of the corneal surface is Placido's disc, and this can be quantified with computerized keratometry (see Chapter 6).

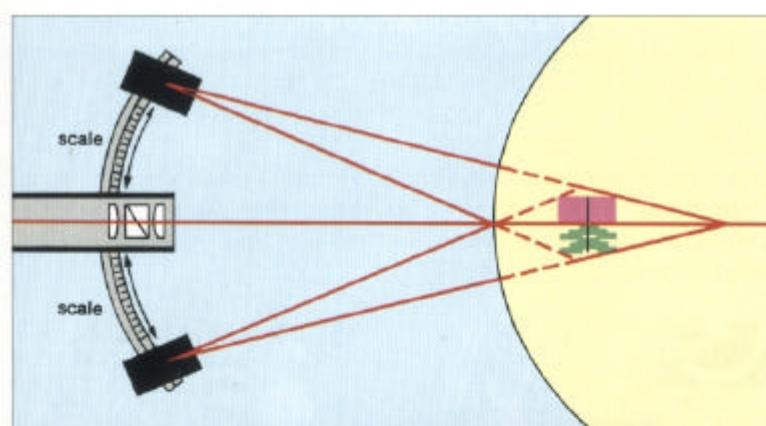


Fig. 1.35 Regular corneal curvature is measured using a keratometer of which there are two basic types (Schiotz or Helmholtz). The Schiotz keratometer is essentially a microscope with a fixed working distance so that when the cornea is in focus, the apparatus is a fixed distance from it. There are two illuminated objectives (bottom picture), green and red; these are mounted on a curved track to keep them equidistant from the cornea on either side of the central telescope. To prevent any relative movement of the images when viewing the cornea, the instrument incorporates a doubling device so that both images move together. When the images (mires) of the two coloured objectives are seen on the cornea in apposition, the end point has been reached and the corneal curvature can be read directly from a scale on the arms supporting the objectives, either in millimetres of radius or dioptres. Alignment of the horizontal bars in the mires allows the axis of astigmatism and the corneal curvature in the other meridian to be measured by rotating the objectives around the axis of the telescope.

When measurements of the corneal curvature are taken in conjunction with ultrasonic measurements of the length of the eye, the theoretical power of an intraocular lens implant can be calculated.



Fig. 1.36 The photokeratoscope projects the image of illuminated concentric rings on the corneal surface. By courtesy of Mr D O'Bart.

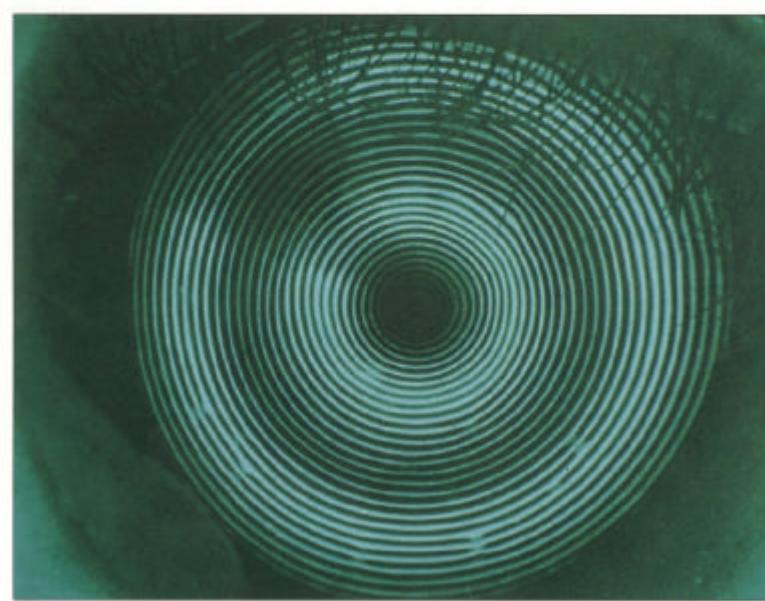


Fig. 1.37 The reflected images and any distortions are viewed through a video system and analysed by computer to produce a topographical map of the anterior corneal surface giving quantitative information on the corneal curvature, astigmatism and its meridians. By courtesy of Mr D O'Bart.

EXAMINATION OF THE ANGLE OF THE EYE

Due to the corneal curvature, reflected light from the angle of the anterior chamber reaches the cornea with an angle of incidence greater than the critical angle and so is reflected internally rather than being transmitted outside the eye. In

order to see the angle structures, various optical devices have been made which allow either direct (for example, Barkan goniolens) or indirect (for example, Goldmann single-mirror lens) viewing.

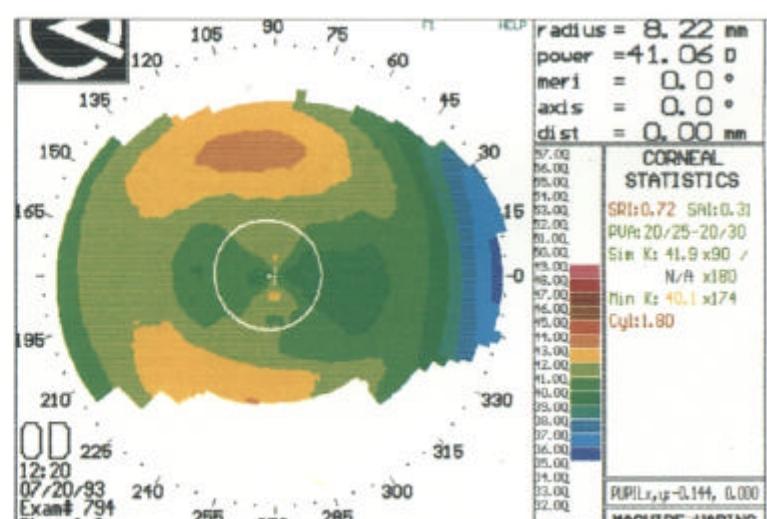
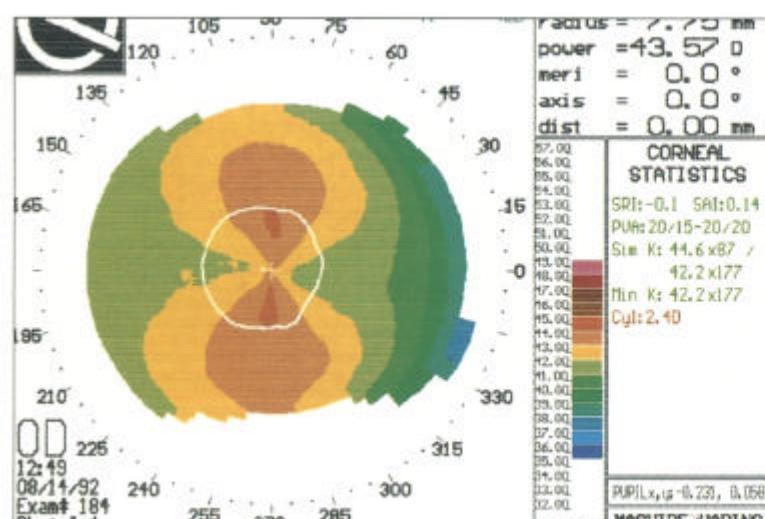


Fig. 1.38 This technology is especially useful in the assessment of refractive corneal surgery. These charts show a cornea prior to photokeratectomy with an excimer laser (left). The isopters are graded in 1D steps and show with the rule astigmatism of 2.4D. Following photoablation (right) the astigmatism has been reduced to 1.8D with the rule with a reduction of myopia of 2.5D. By courtesy of Mr D O'Bart.

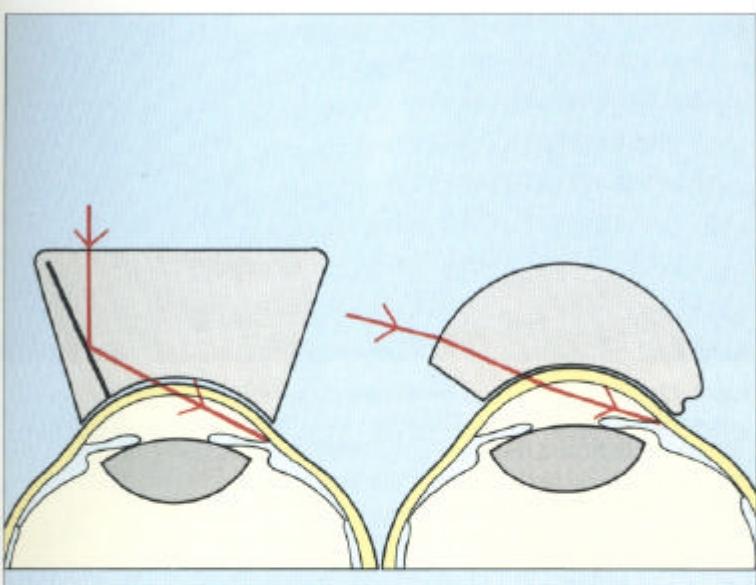


Fig. 1.39 The optics of indirect and direct gonioscopy are illustrated. Direct gonioscopy is used for the operation of goniotomy. Indirect gonioscopy can be combined with corneal depression !(indentation gonioscopy) to assess whether the angle can be opened by the displaced aqueous.



Fig. 1.40 The indirect gonioscopy lens is a solid perspex contact lens within which is mounted a small mirror so that the structures of the angle of the eye can be easily viewed. This figure shows a Goldmann gonioscope lens in situ on the patient's eye; the structures that are visible by this technique are reviewed in Chapter 7. The full circumference of the angle can be inspected by rotating the contact lens on the surface of the eye.



Fig. 1.41 Some lenses have a shallower radius of curvature on the corneal surface and hence do not require fluid between the lens and the cornea; however, this makes corneal wrinkling more likely. In addition, lenses can have several mirrors, thereby eliminating the need to rotate the lens (for example, Zeiss 4-mirror goniolens). Such lenses will indent the cornea, shallowing the anterior chamber and deepening the periphery. Such indentation gonioscopy is invaluable in assessing primary angle closure glaucoma.

MEASUREMENT OF INTRAOOCULAR PRESSURE

The pressure within the eye may be measured by the use of a tonometer. There are various models of this but applanation tonometry is used most commonly in clinical practice. This works on the principle that a force required to flatten a given area of corneal apex will be proportional to the intraocular pressure (IOP) that maintains the corneal curve. The applanating surface of the commonly used Goldmann tonometer is 3.06mm^2 at which the effect of surface tension cancels out the rigidity of the cornea. It indents the eye less than 0.2mm, displaces 0.5,1 of aqueous, and increases the IOP by approximately 3 per cent, which is not clinically significant. The

Perkins tonometer is a derivative hand-held instrument that can be used for supine patients. The measurement of outflow resistance (tonography or measurement of facility of aqueous outflow) can be obtained from the decay curve of IOP over a five-minute period following the placement of a 5-7.5g weight on the cornea. The test was used to identify patients at risk of developing glaucoma but measurements of outflow facility are subject to error because the effects of expulsion of blood from the choroid and distensibility of the sclera are difficult to quantify and obscure a reduction in outflow facility so tonography is no longer used.

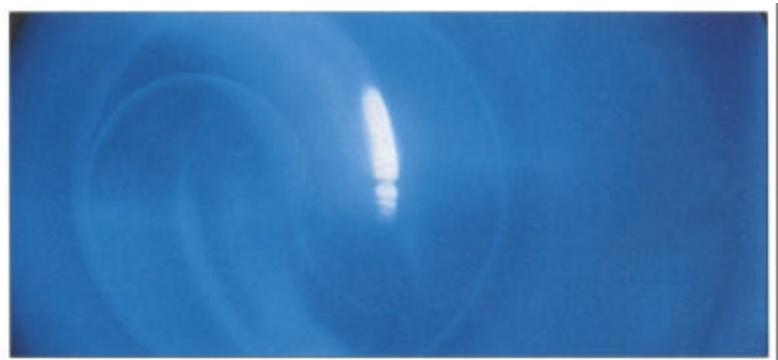
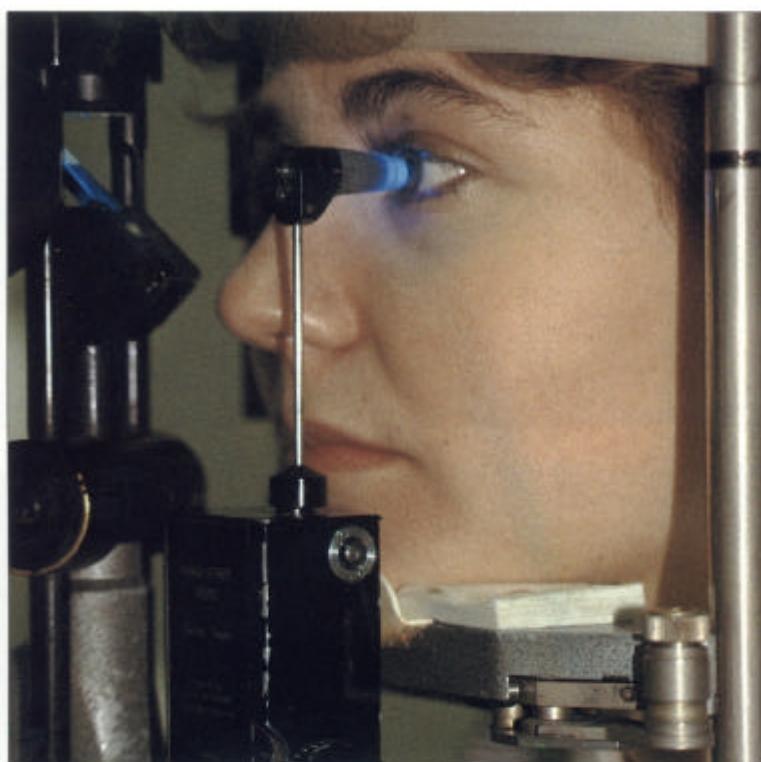


Fig. 1.42 The applanation head has a clear centre that incorporates a prismatic doubling device. The prism is illuminated obliquely with cobalt blue light and the cornea is viewed co-axially through the applanation head (left), the tear film having been stained with fluorescein to identify the meniscus around the applanating head. The applanation head is gently brought to rest on the surface of the anaesthetized cornea; its force is increased by revolving a graduated wheel at the base of the instrument that is calibrated in millimetres of mercury. The figure on the right shows the end point at which the IOP is measured. One can see the split image of the tear film meniscus around the tonometer head outlined by the semicircular fluorescein rings that have edges that just overlap. If the pressure on the tonometer head is too low, the split rings do not overlap; if it is too high, they overlap by more than the thickness of the meniscus.



Fig. 1.43 Other instruments in use include those based on the Mackay-Marg tonometer. This tonometer measures the force required to keep the flat plate of a plunger flush with a surrounding sleeve against the pressure of corneal deformation. The surface area indented is smaller than the Goldmann tonometer and is less affected by corneal scarring. It can also be used for supine patients.



Fig. 1.44 A noncontact tonometer is an alternative device that generates a puff of air that deforms the cornea. The time taken to produce a set amount of corneal flattening is measured, and this time is proportional to the IOP. The reliability of this type of tonometer is reduced in higher pressure ranges but it has the advantage of no contact with the eye, thus preventing any risk of cross infection and obviating the need for topical anaesthesia, and is now widely used as a screening device.

OPHTHALMOSCOPY

There are two types of ophthalmoscope, the direct and indirect. The direct ophthalmoscope incorporates a light source focused directly onto the retina through a small angled mirror, that either fills half or the whole of the aperture. The mirror centre is unsilvered so that the illuminated retina can be seen through it. Between the returning light rays and the examiner's eye,

there is a revolving magazine of lenses that usually range from +30 to -30 dioptres, which correct any inherent refractive error of either the patient or the examiner. Changing the focus in the eye allows the ophthalmoscope to be used to view, not only the posterior segment, but also opacities in the media, especially in the retroilluminated lens.



Fig. 1.45 The direct ophthalmoscope in use with the examiner viewing the patient's right eye with his right eye, which would be reversed when viewing the left. Pupillary dilatation is essential for the best retinal view.

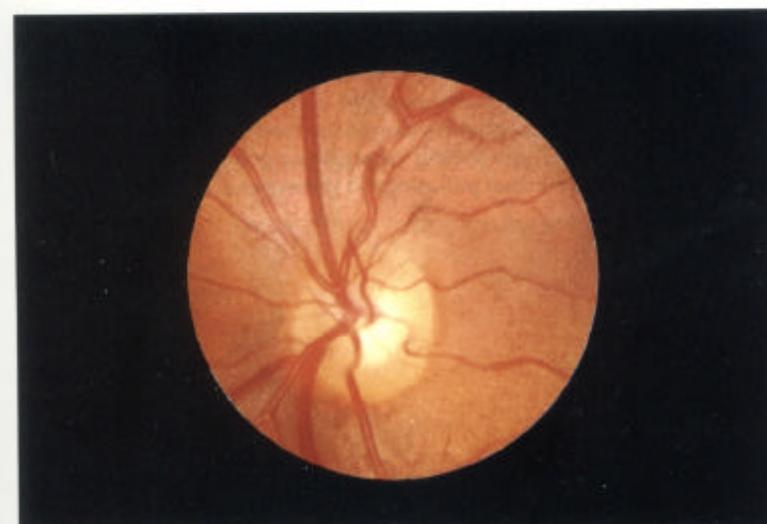


Fig. 1.46 The field of view with the direct ophthalmoscope is quite small, approximately 6° with a magnification of $\times 15$; the image is erect and real. A green or 'red-free' filter is particularly useful in observing detail of the nerve fibres and small vessels.

The indirect ophthalmoscope uses a light source directed into the patient's eye by an adjustable mirror, and the reflected light is then gathered by a condensing lens (normally of the power of either +20 or +28 dioptres) to form a real inverted image of the retina. The size of the image varies according to the power of the indirect lens; the greater the power of the lens, the smaller the image. A +14 lens magnifies the retina by

approximately $2\frac{1}{2}$ times. Indirect ophthalmoscopy has the advantages of providing high intensity illumination, stereopsis, and a wide field of view, as well as allowing a dynamic assessment of vitreoretinal pathology. Its disadvantages are that the image is inverted, and skill is needed to use this instrument.

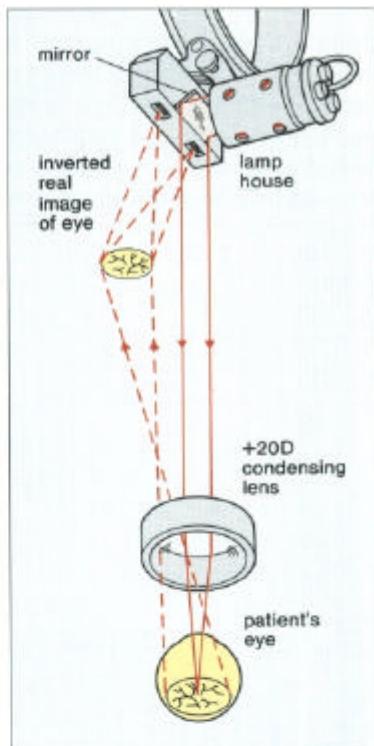


Fig. 1.47 The examiner can be seen using the instrument holding the condensing lens at an appropriate distance from the patient's eye. He is standing behind the patient so that the inverted image that is seen corresponds to the normal erect appearance.

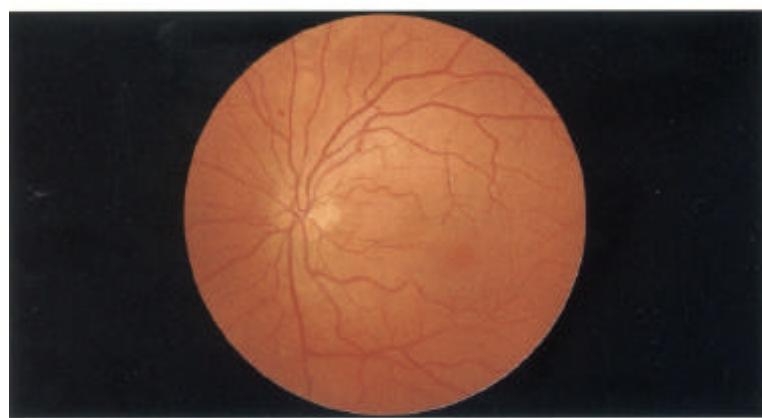


Fig. 1.48 The image size and field of view of the fundus as seen through the indirect ophthalmoscope using a +28 dioptre lens. There are additional benefits when using a lens of high dioptric value. A clear view of the fundus may be obtained with a relatively small pupil size if full dilatation is not possible. If the patient is not cooperative, the large field enables a rapid assessment of the fundus to be obtained, and the large overall view gives a good geographical assessment of vitreoretinal pathology at the expense of loss of detail.

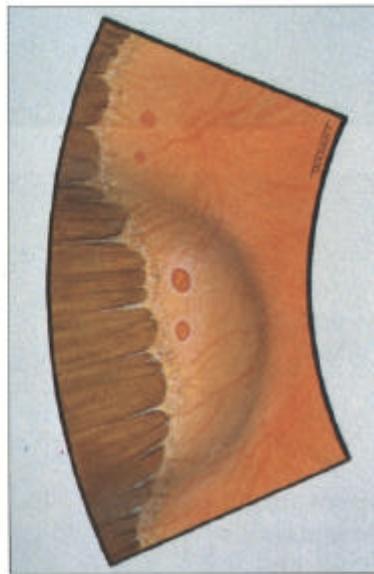


Fig. 1.49 Further detail, especially at the retinal periphery, can be seen by augmenting the examination with the use of an indentor that pushes peripheral retinal areas into the field of view of the instrument. Indentation can be performed through the eyelid but this may be difficult, particularly at the inner canthus. Local anaesthesia is required when direct indentation of the globe is performed. This technique may also help to highlight any pathology, such as shallow retinal separations, and movement of the indentor allows dynamic forces to be assessed.

Lenses for fundus examination

Other techniques using the slit lamp can be used to examine the posterior segment of the eye. Lenses used include mirror

lenses, direct fundus viewing lens, the Hruby lens, or a +78 or +90 dioptre lens. All these devices allow stereoscopic examination and laser treatment of fundus lesions.

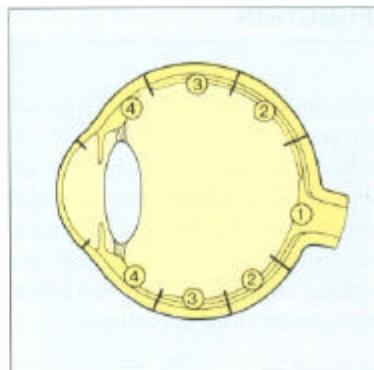


Fig. 1.50 The Goldmann 3-mirror contact lens is made up of a central viewing area that has a concave surface which is placed on the anaesthetized cornea, any curvature disparity being overcome by the use of optical coupling with saline or hyromellose. Similar areas of the retina can be seen as with the indirect ophthalmoscope, with the exception that the extreme periphery is more difficult to visualize. A 3-mirror has the advantage of providing high magnification but a smaller field of view. There are now many modifications of this principle which allow better views of the fundus.

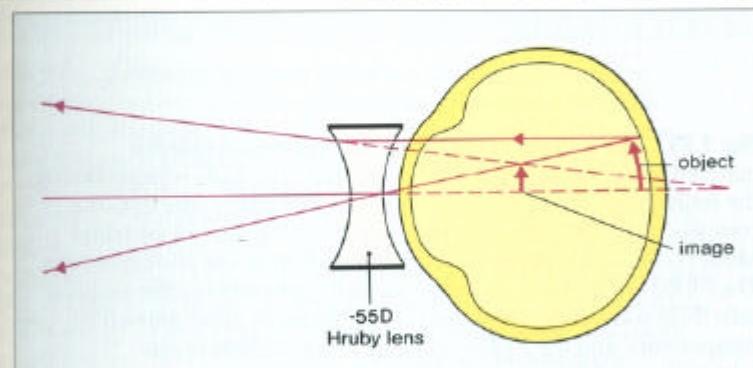
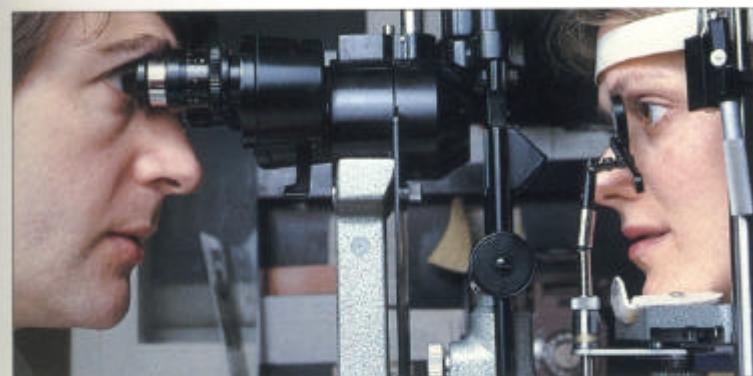


Fig. 1.51 The Hruby lens can be used as an alternative noncontact method. This is a -55 dioptre lens that is placed close to the corneal surface and negates the inherent refraction of the eye. It produces a real erect image in front of the retina that has to be viewed at moderately high magnification to obtain a good image size. The closer the lens is to the eye, the larger the field of view. The ray diagram illustrates the optics of the Hruby lens. An advantage of this system against convex indirect lens systems is that it gives better magnification in the axial plane.

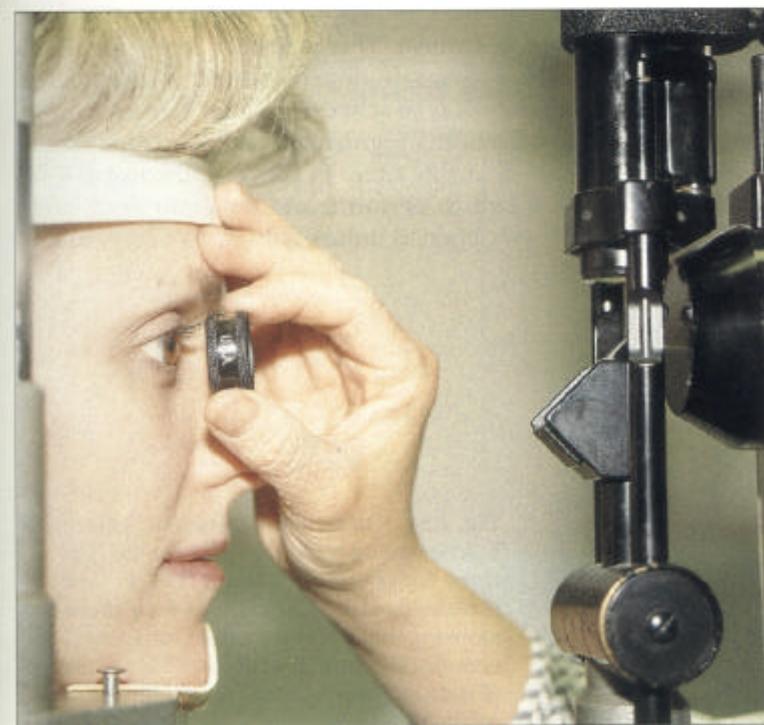
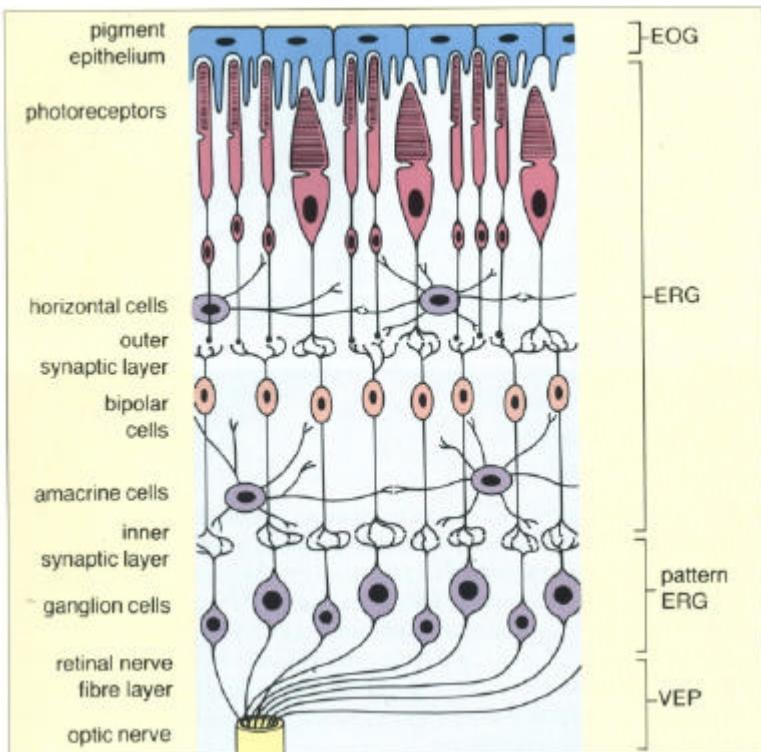


Fig. 1.52 'Indirect' slit-lamp microscopy is now commonly performed using a +90 or +78 dioptre lens. The optics of this lens are similar to the optics of indirect ophthalmoscopy. The lens provides an inverted real image of the fundus, with a maximum field of view of to obtain the maximum field, and the focus position of the slit lamp is approximately 25cm back from the normal position. This lens gives an excellent view of the posterior pole, but has the disadvantage that depth perception is not as good as with a Hruby lens so that, for instance, shallow serous detachment of the retina is not as obvious.

ELECTRICAL TESTS OF RETINAL FUNCTION

The electrical response generated by the eye to light as a mass potential (that is, a whole eye response) can be used to assess retinal function, both clinically and experimentally. Electrodiagnostic tests are particularly useful in the differential diagnosis of inherited retinal dystrophies and have applications in the assessment of visual function in eyes with opaque media and of drug toxicity on retinal function as well as in the investigation of discrepancies between visual symptoms and ocular signs. Tests in common clinical practice consist of

the electro-oculogram (EOG), the electroretinogram (ERG), the pattern ERG (PERG), and the visual evoked potential (VEP) which is a test of conduction in the retrobulbar visual pathways. Dark adaptation is sometimes used in conjunction with these tests. Techniques for electrodiagnostic tests have only recently been standardized, and the responses and normal values still differ between laboratories due to variation in equipment and technique.



DARK ADAPTATION

This measures the increase in retinal sensitivity with time in the dark adapting eye and is due to regeneration of photoreceptor pigment. The visual threshold to a flash of light is plotted against time after pre-adaptation to a standard bright flash. Normally, after approximately seven minutes of adaptation, the sensitivity of the scotopic system (rods) overtakes that of

the photopic system (cones). This is known as the cone-rod break. After 25–30 minutes, rhodopsin has fully regenerated and retinal sensitivity has reached its peak. Defects in rod metabolism, such as retinitis pigmentosa, will produce abnormally high thresholds at this time. In practice, the test is time consuming and difficult to perform, and the equivalent information can usually be obtained more easily by EOG and ERG.

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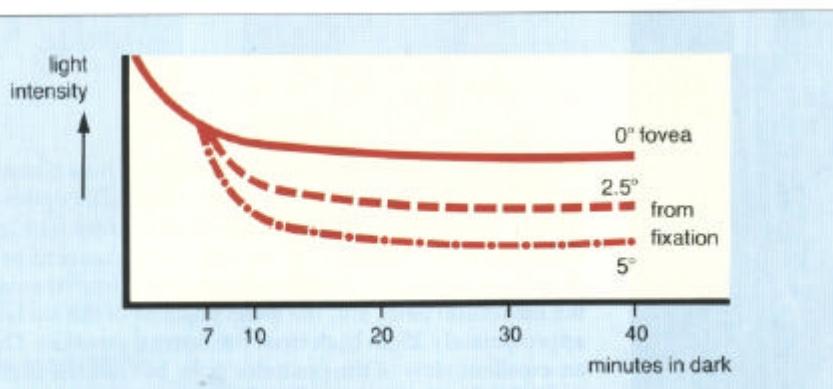


Fig. 1.54 Dark adaptation curve. Threshold light intensity is plotted against time. The three lines indicate different retinal thresholds

dark adaptation increases eccentrically from the fovea as the population of rods increases. The cone-rod threshold at seven minutes is shown.

ELECTRO-OUCLOGRAM

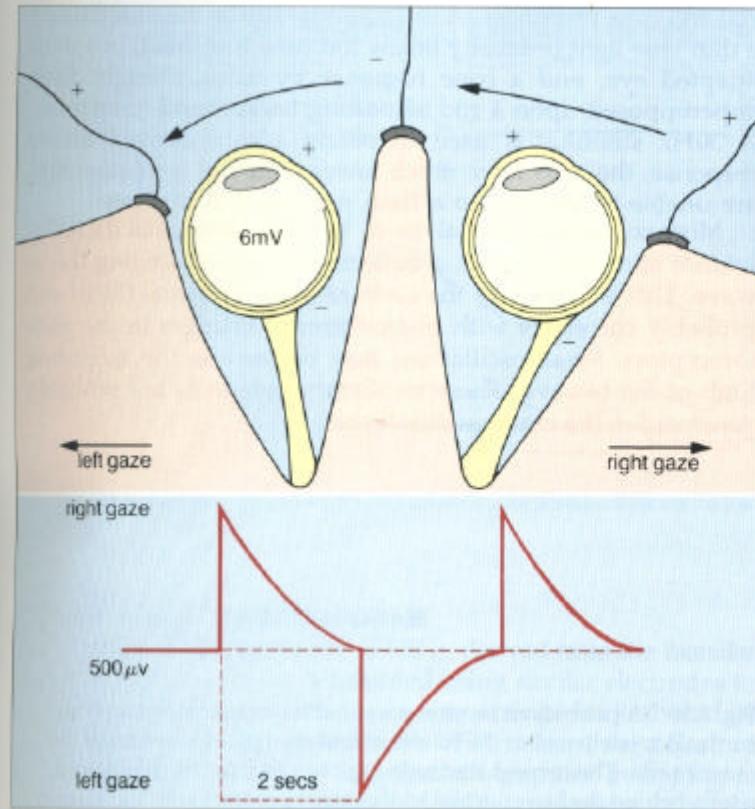


Fig. 1.55 Within the eye itself, there is a standing potential of approximately 6mV between the retina and the cornea, with the cornea positive to the retina which arises from interactions in the retinal pigment epithelium. This potential can be measured by placing electrodes on the skin at the medial and lateral canthi. The patient is asked to fixate target lights that alternate from right to left, causing

Movement of the

potential, relative to the electrodes induces a current that is amplified and recorded. The potential, measured in this way, varies according to the level of background illumination becoming lower with dark adaptation and higher in photopic conditions. The test takes approximately 50 minutes to perform and can be easily modified to measure horizontal eye movements.



Fig. 1.56 Clinically, the pupils are fully dilated and the potential is measured in the dark for 12-15 minutes, during which time the potential falls to a minimum. The patient is then exposed to intense light, and the rise in potential is measured at its peak. The ratio of potential measured in light and dark is converted to a ratio. Low ratios indicate disease at the level of the retinal pigment epithelium.

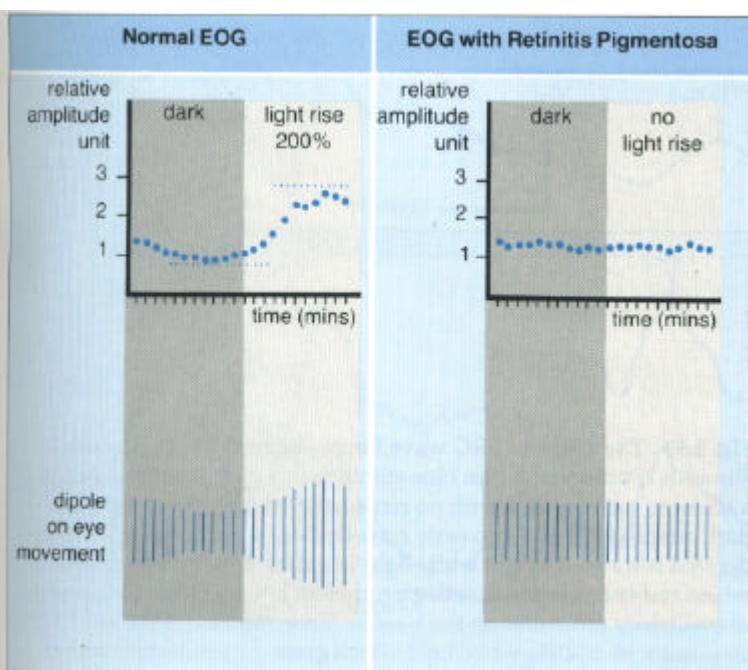


Fig. 1.57 Measurement of the EOG requires the active co-operation of the patient, and the ability to make horizontal eye movements. Although readings are not affected by the opacities in the ocular media, dense cataracts prevent compliance as the patient cannot see the fixation lights. Low responses can be found normally in myopes and in the elderly, and also after ocular surgery or injury. Typical tracings of a normal patient compared to a sufferer of retinitis pigmentosa are illustrated. The test is particularly useful in the diagnosis of Best's disease (see Chapter 16).

ELECTRORETINOGRAM

The ERG measures the mass retinal potential to a flash of light using a corneal electrode and neutral electrodes placed on the skin around the orbital margin. Specialized techniques can be used to record the ERG from focal areas of the retina such as the fovea.

Due to many different methods and techniques used to record the ERG, there is no typical response. However, there is usually a biphasic wave with an initial negative trough (a wave), followed by a larger positive peak (b-wave). Measurements are usually taken of the latencies (or implicit times) of the a and b-wave peaks and also of the a and b-wave amplitudes. The ERG varies with the stimulus duration, intensity, colour, and the state of retinal adaptation.

The great value of the ERG lies in its ability to differentiate rod and cone responses. A rod response can be measured using a dim blue light (intensity below the cone threshold) in a dark adapted eye, and a cone response by using a bright flash superimposed upon a rod saturating background luminance. A 30Hz stimulus is used to obtain a cone-derived flicker response; the rods have much lower temporal resolution and are unable to respond to a flash presented at this rate.

More sophisticated analysis of the ERG shows that if a really intense stimulus is used, a deflection occurs preceding the a-wave. This is known as the early receptor potential (ERP) and probably correlates with photochemical changes in the photoreceptors. Small oscillations may be seen on the ascending limb of the b-wave. These oscillatory potentials are probably generated in the inner nuclear layer.



Fig. 1.58 A patient can be seen prepared for examination, with an earth electrode taped to the forehead and reference electrodes at the outer canthi. The corneal electrode itself is a thin foil of gold placed gently behind the lower eyelid so that it is in contact with the cornea; it is important that this does not touch the lid skin. In infants, the ERG can be recorded under general anaesthesia. Surface active electrodes can be used in noncooperative infants to give adequate recordings, and are also used in cases of ocular trauma where a corneal electrode would be inappropriate.

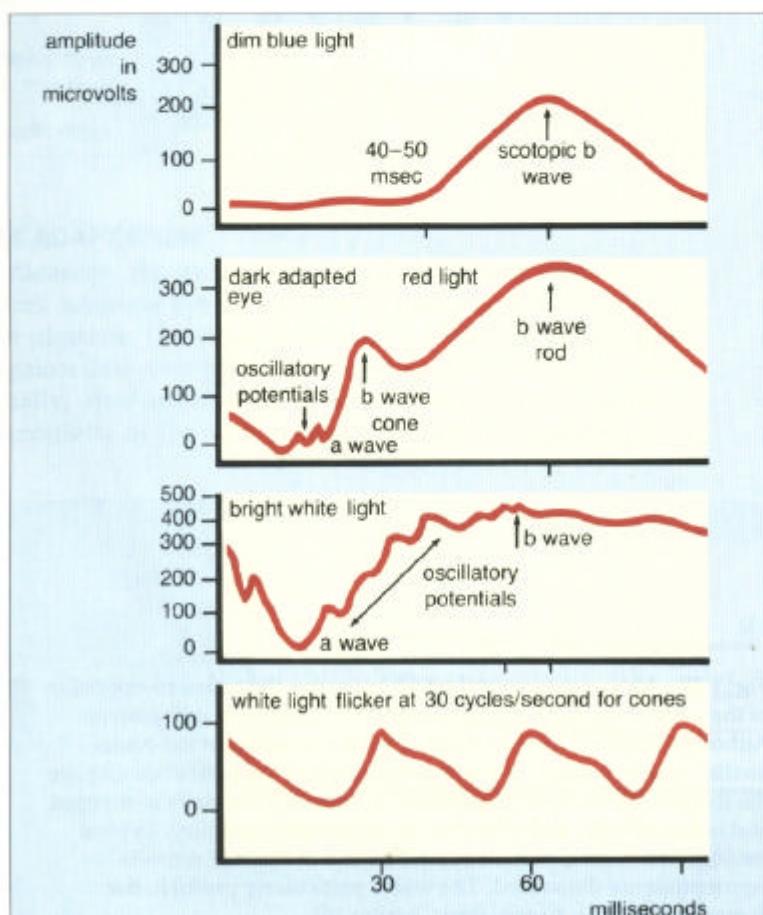


Fig. 1.59 The different ERG wave forms obtained by altering the stimulus conditions. A dim blue stimulus in a dark adapted eye gives a scotopic rod response with no recordable a-wave. A red light in a dark adapted eye gives an early cone-derived b-wave and a later rod-derived b-wave. A bright white light in a dark adapted eye gives a mixed rod-cone response with a prominent a-wave. Note the presence of oscillatory potentials on the b-wave. Cone function is usually assessed with a 30Hz white light which gives a cone-derived flicker response.

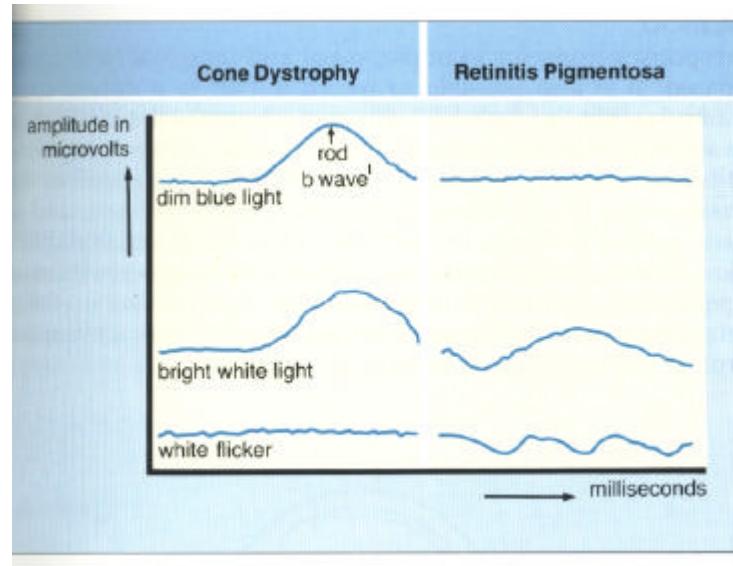


Fig. 1.60 Comparison of ERG responses in a patient with a cone dystrophy and a patient with retinitis pigmentosa. In a cone dystrophy (left), the scotopic rod response is normal, the bright white light flash gives an ERG typical of a rod-dominated response with no a-wave and an increased latency b-wave similar to the scotopic rod response. The 30Hz cone-derived flicker response is absent. In the retinitis pigmentosa patient (right) the converse is seen. The scotopic rod response is not recordable and the 30Hz cone response is normal. Many cases of retinitis pigmentosa, however, show involvement of both rod and cone systems.

PATTERN ELECTRORETINOGRAM

The pattern electroretinogram (PERG), derived from the macular and paramacular cones, is recorded using similar electrodes to the flash ERG. The patient views a reversing checkerboard or grating, similar to that used for the VEP, rather than a flash of light. The signal is of low amplitude; computer averaging is essential, and much attention to detail is necessary to obtain technically satisfactory recordings. Although dependent upon stimulus and recording techniques, the normal PERG to a high contrast checkerboard pattern consists of two main components, a prominent positive component, P_{50} , at approximately

52msec, followed by a larger negative component, N_{95} , in the region of 93msec. In some subjects a small negative N_{35} component is visible. Recent work suggests that N_{95} is generated in the ganglion cells and, although often normal in optic nerve disease, can be affected selectively due to retrograde axonal degeneration. It is likely that at least some of the P_{50} component is generated in more distal retina. The P_{50} component is invariably affected in macular disease, and PERGs therefore have the ability to distinguish between outer and inner retinal dysfunction, and between maculopathy and optic neuropathy.

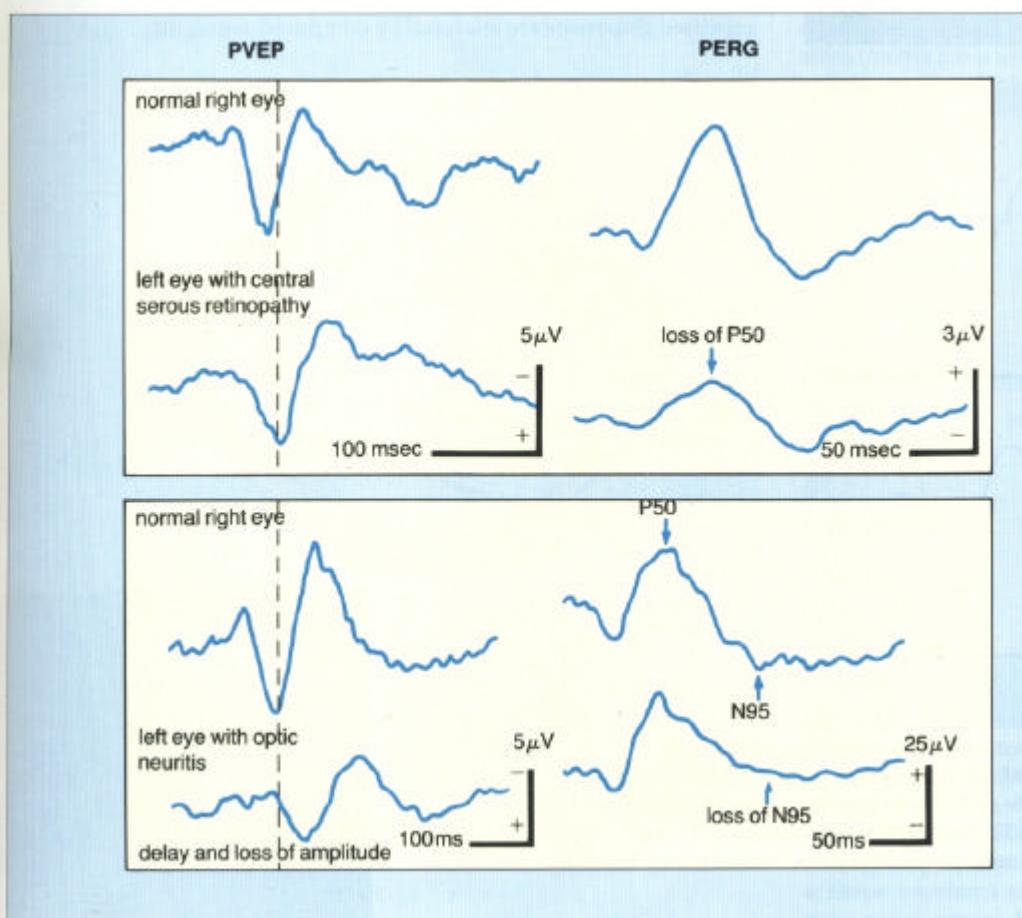


Fig. 1.61 PERGs and pattern VEPs (PVEP) in a patient with macular dysfunction and a patient with optic nerve dysfunction. The patient with a central serous retinopathy has a delayed PVEP, but the PERG shows a reduced, delayed P50 component with preservation of the $N_{95}:P_{50}$ amplitude ratio. The lower traces are from a patient with multiple sclerosis, and a markedly delayed PVEP from the left eye even though the patient has had no symptoms to suggest optic nerve disease. This demonstrates the ability of the PVEP to detect subclinical optic nerve demyelination. Note the normal P50 component in the PERG and the selective loss of N_{95} amplitude typically found if the PERG is abnormal in optic nerve disease.

VISUAL EVOKED POTENTIAL

The visual evoked potential is the electrical response of the cortex to visual stimulation, and is extracted from the higher voltage electroencephalogram by using repeated stimulation and computer averaging. The VEP, as with the PERG, varies with stimulus and recording parameters, but the normal pattern VEP to a slowly (approximately 2 cycles/sec) reversing black and white checkerboard with no overall luminance change contains a prominent major positive peak at about 100 msec known as the P_{100} component. The amplitude and latency of the P_{100} component are measured. With a suitable stimulus parts of the visual field can be selectively stimulated and

responses from, for example, nasal and temporal fields compared. It is also possible to record a VEP to a diffuse flash stimulus, but the flash VEP shows much greater interindividual variability than the pattern VEP. It is derived from peripheral fibres in the optic nerve. The flash VEP is most useful in the assessment of noncooperative or unconscious patients; and in any patient in whom the pattern VEP is not recordable. VEPs are used in the detection and diagnosis of optic nerve disease, particularly subclinical demyelination, and are also useful in the assessment of chiasmal function. They also have a valuable role in the detection of nonorganic visual loss.



Fig.1.62 The response is recorded by placing occipital and reference electrodes on the scalp (electrodes placed over the left occiput will record responses from the right occipital cortex), and repeated responses are analysed by computed averaging.

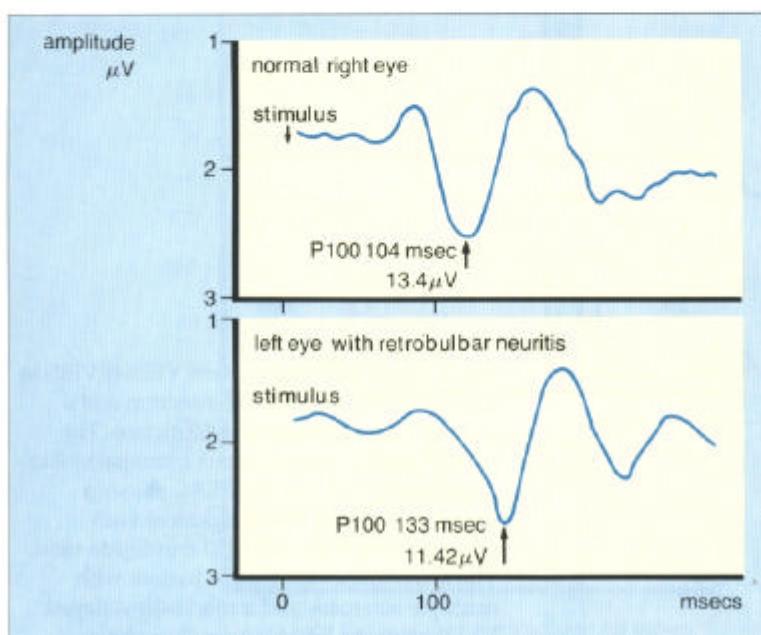


Fig.1.63 The amplitude and latency of the major positive deflection (P_{100} peak) from the stimulus can be measured and the wave form studied. In this recording the normal eye has a P_{100} peak with a latency of 104msec and an amplitude of 13.4H.V. The recording of the fellow eye following retrobulbar neuritis shows a delay of 133msec with an amplitude of 11.4tV. With clinical improvement, the amplitude increases with improvement of visual acuity but the delay in the response remains.

OCULAR IMAGING

Nonvisual ocular imaging may be achieved by ultrasound, computerized tomography (CT) scanning, or magnetic resonance imaging (MRI).

ULTRASONOGRAPHY

A scan ultrasonography is used to obtain accurate measurements within the eye, for example in planning corneal refractive surgery, the calculation of intraocular lens power or documenting size of intraocular masses.

B scan ultrasonography uses A scans placed together. It provides the best way of imaging the intraocular contents, particularly in the presence of opaque media, and has a major role in the differential diagnosis of intraocular space-occupying lesions, and in the analysis of vitreous opacities and retinal detachment. In some cases, analysis of the echo pattern can be correlated with the clinical appearance of the lesion and allows a tissue diagnosis to be made, for example, choroidal haemangioma (see Chapter 9).

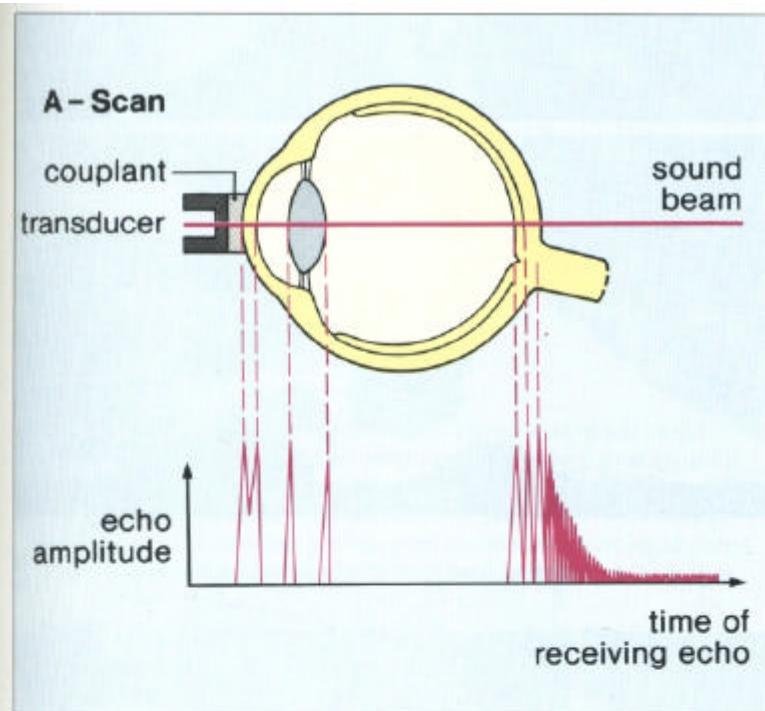


Fig. 1.64 A transducer is placed on the anaesthetized cornea and emits the ultrasonic beam which detects the reflections from tissue interfaces. Peaks can be identified from the corneal endothelium, the anterior and posterior surfaces of the lens and the retina. Usually the instrument contains a computer which monitors peak sizes and rejects non axial scans. Distances can be measured extremely accurately but the speed of sound varies in different media and this can make a material difference to measurements. Appropriate adjustments have to be made therefore for cataractous lenses, aphakic or pseudophakic eyes.

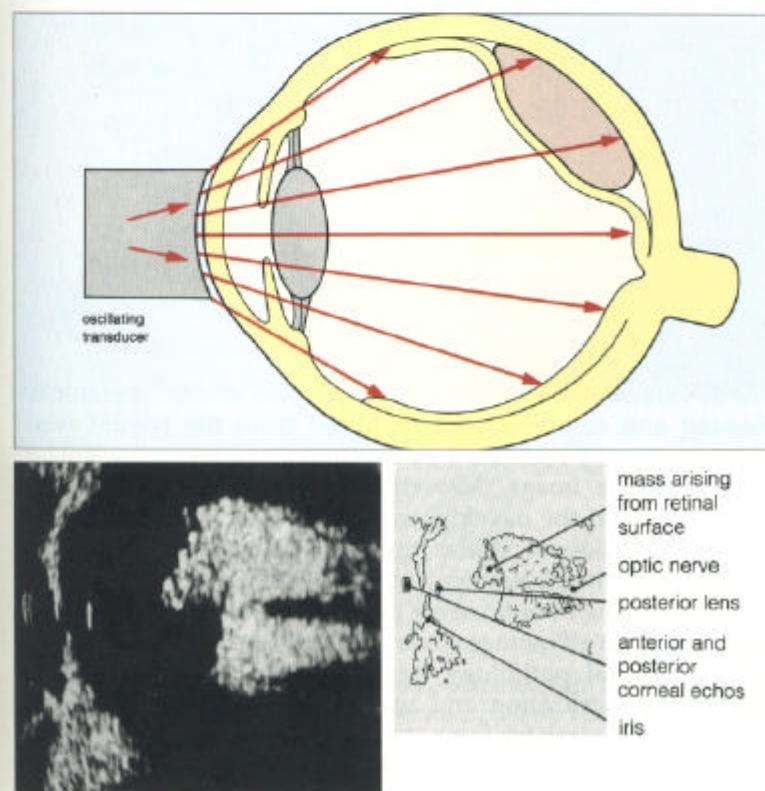


Fig. 1.65 If the A-scan linear echoes are displayed as points of light that has an intensity proportional to the echo amplitude, and the eye is scanned across several planes, a cross-sectional image is formed known as a B scan. This method allows both static and dynamic examination of the ocular contents and is very useful in the assessment of retinal and vitreous pathology. Ultrasound is reflected at tissue interfaces and, therefore, homogeneous areas such as the optic nerve appear dark on the scan because of their low reflectance.

COMPUTERIZED TOMOGRAPHY (CT) SCANNING

In spite of the advances in MRI, CT scanning still appears to be the technique of choice if the orbit and globe have to

be visualized. Visualization of the bony orbital walls makes orientation much easier and calcification, which is a helpful diagnostic marker in some diseases, can be easily visualized.

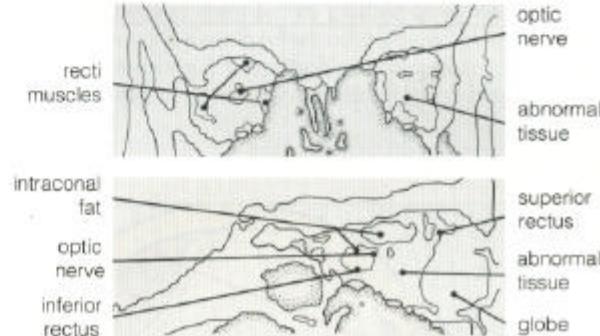
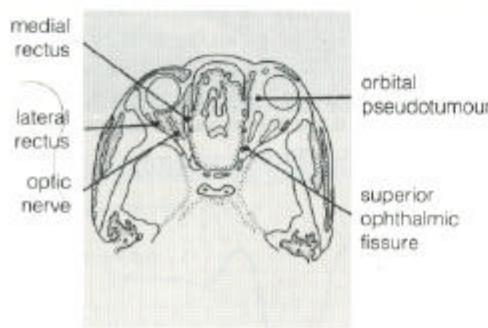
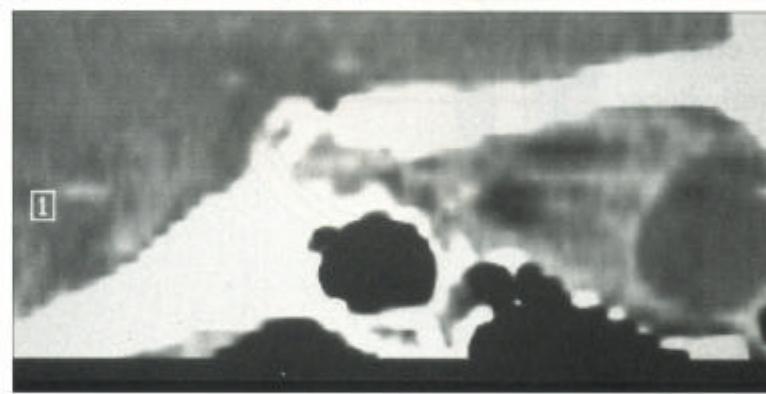


Fig. 1.66 Axial and coronal high-resolution CT scans of the orbit demonstrate the orbital bone tents. Coronal and sagittal cuts are extremely useful in the assessment of lesions in the inferior or superior orbit and the orbital apex, and for planning surgery.

MAGNETIC RESONANCE IMAGING (MRI)

Magnetic resonance imaging measures two complex composite parameters known as the T_1 and T_2 times which depend on proton density as well as the tissue components and the magnetic properties of their environment. Every tissue has characteristic T_1 and T_2 times which are altered in disease. The conventional MRI image is mainly derived from protons in extra- and intracellular water and fat. Protons in proteins or calcified tissue are tightly bound and do not contribute greatly to the image and for this reason calcification cannot be seen on MRI scans. For examination of the orbit routine MRI scanning does not offer the anatomical definition of high resolution CT scanning unless specialized, and time-consuming research techniques with surface coils and high powered magnets are

used. Considerable expertise on the part of the operator is needed and co-operation is required from the patient who must remain still with good fixation to prevent ocular movement degrading the image. Nevertheless, MRI offers remarkable versatility, and the development of the technique has uses in the visualization of ocular tumours, particularly malignant melanomas, the assessment of vascular flow in the orbit, as well as imaging of optic nerve demyelination or tumours. MRI has significant advantages over CT scanning in the assessment of intracranial pathology (see Chapter 19), giving better anatomical localization and tissue diagnosis, particularly of lesions in the pituitary fossa, cavernous sinus and brainstem.

There are many ways of obtaining an MRI image but at present spin echo techniques are most widely used.

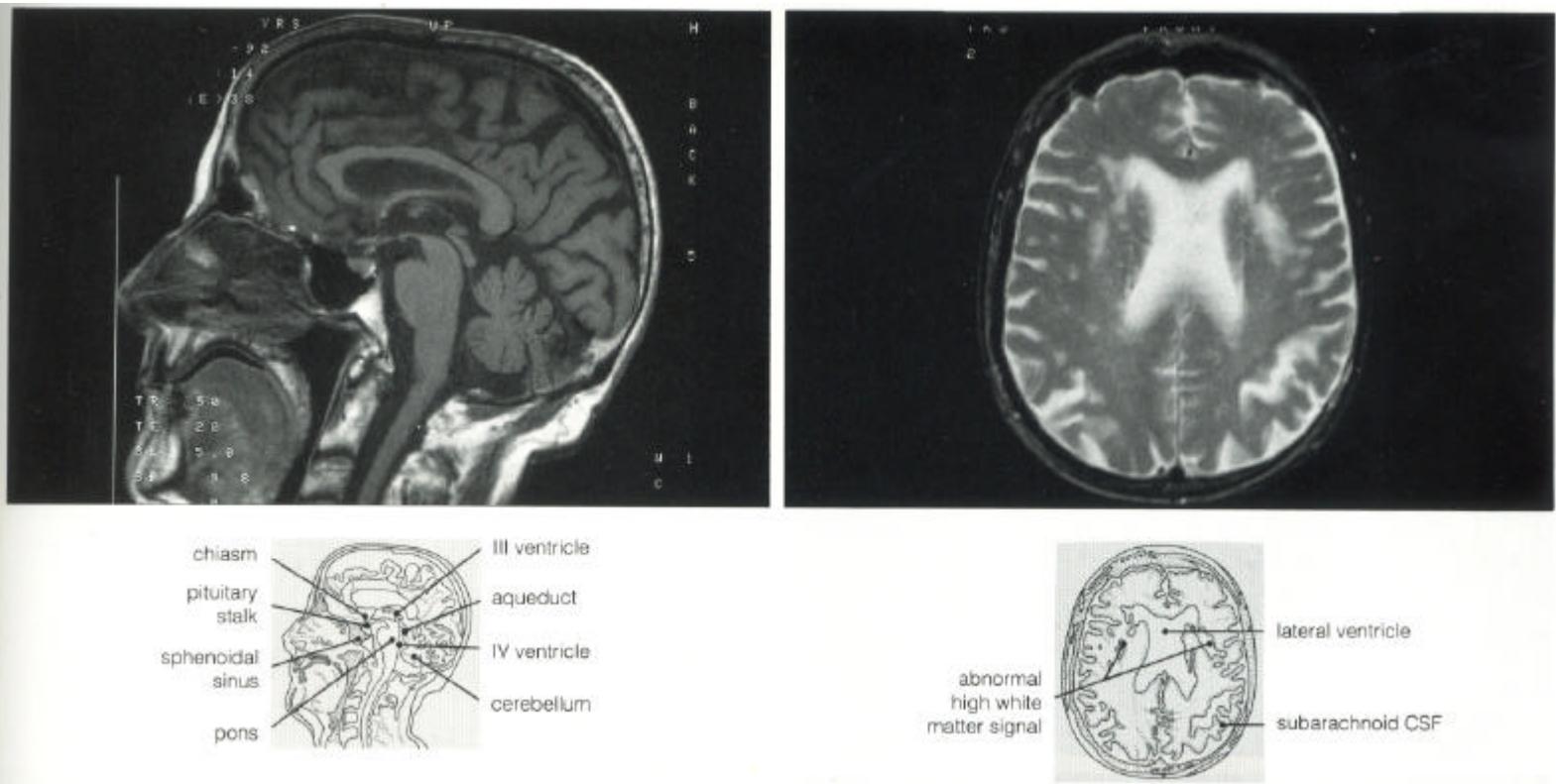


Fig.1.67 T_1 weighted scans produce excellent anatomical detail. The CSF produces a low intensity signal with good contrast against the surrounding brain as seen in this sagittal section. T_2 weighted scans have a high intensity signal from CSF and water. Anatomical detail is less easily seen but pathological lesions are often highlighted more easily as in this axial scan which shows scattered white matter

lesions typical, but not diagnostic of, multiple sclerosis. Scans could, in theory, be made over a wide range between the extremes of absolute T_1 and T_2 times but in practice the radiologist chooses appropriate T_1 and T_2 weighting for the clinical situation under investigation. Some indication of the tissue diagnosis can be made from the relative T_1 and T_2 intensity signals of a lesion.

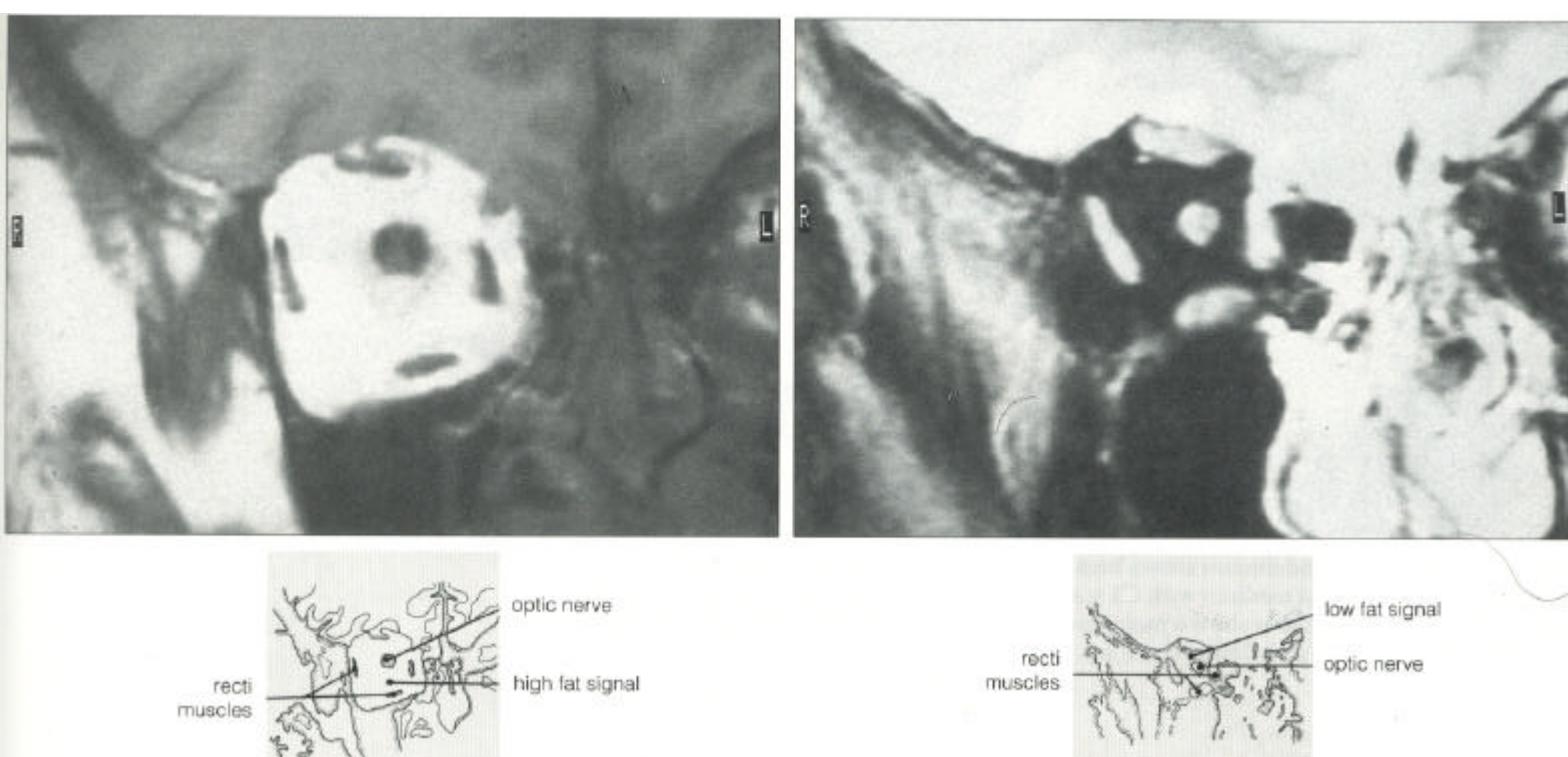


Fig.1.68 Excellent orbital views can be obtained with MRI by using surface coils but this is time consuming and requires a cooperative patient. With conventional sequences the orbital fat produces a high signal which masks the optic nerve (left). Specialized fat suppression techniques allow the optic nerve to be visualized and this has proven to be of exceptional value in the investigation of optic nerve disease (right) (see Chapter 17).

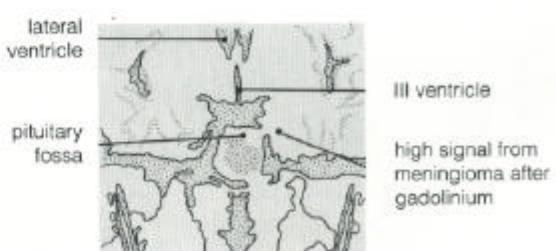
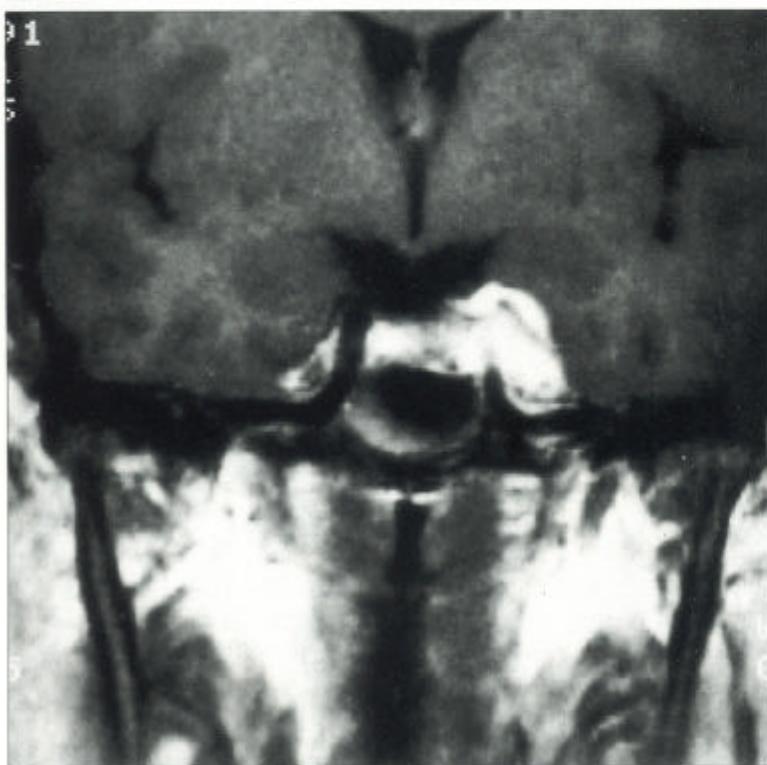
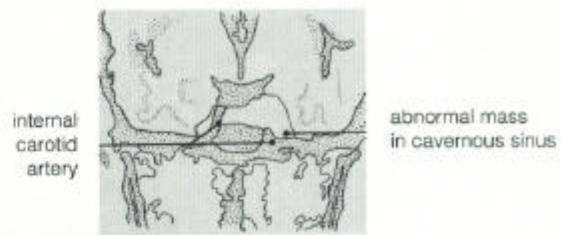
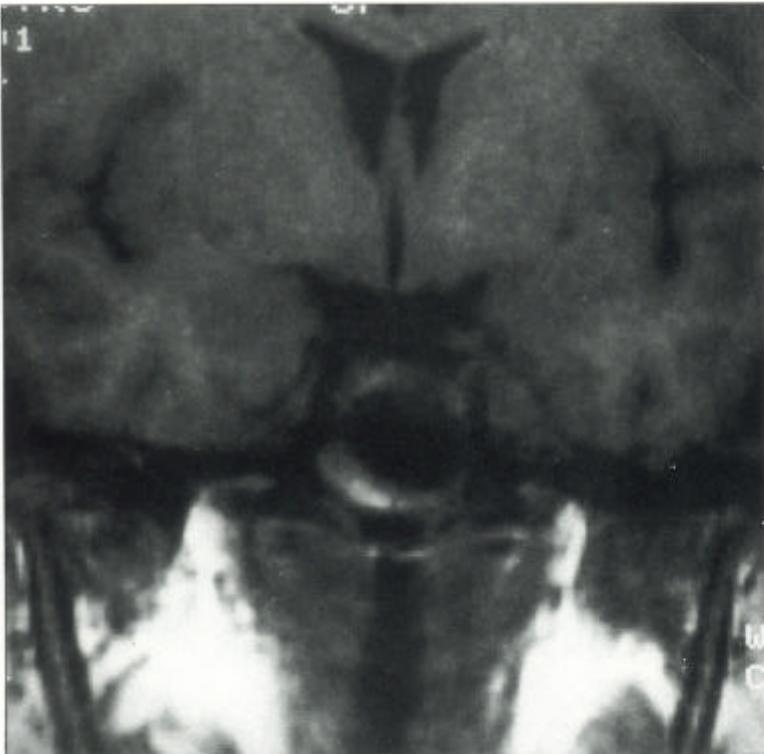


Fig. 1.69 Intravenous gadolinium shows breakdown of the blood-brain barrier in MRI in a way analogous to contrast medium with CT scanning. It is particularly useful in assessing the extent of a lesion. These slides show a meningioma invading the cavernous (top) sinus which enhances markedly after gadolinium (bottom).

INDIA