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OCULAR EXAMINATION TECHNIQUES AND DIAGNOSTIC TESTS

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I. General principles

A. Physical examination and evaluation of the ocular system

Physical examination and evaluation of the ocular system are greatly facilitated by a number of techniques that may be performed in the office, using equipment readily available through any optical or medical supply house. Some of the more complicated techniques, however, must be performed by a specialist in a hospital setting. These techniques are discussed with a view to (a) their indications, (b) how they are performed, so that the referring examiner can explain to a patient what might be expected, and (c) the necessary information to aid the examiner in management of the patient.

B. Order of examination.

Order of examination. Examination of the eye and its surrounding tissues with and without special aids may yield valuable information for the diagnosis and treatment of primary ocular disease or disease secondary to systemic problems. So that nothing is overlooked, a systematic routine should be adopted and particular attention given to those factors that brought the patient to testing in the first place. With time and increased experience, an examination that initially may take a somewhat prolonged period of time can be shortened significantly with no loss of accuracy and frequently with increased accuracy of perception. Individual chapters should be referred to for related detail.

C. The general order for nonemergency examination is as follows:

1. **History.** Present complaints, previous eye disorders, family eye problems, present and past general illnesses, medications, and allergies.
2. **Visual acuity.** Distant and near without and with glasses, if used, and with pinhole if less than 20/30 is obtained.
3. **Extraocular muscle function.** Range of action in all fields of gaze, stereopsis testing, and screening for strabismus and diplopia.
4. **Color vision testing.**
5. **Anterior segment examination** under some magnification if possible (loupe or slitlamp), with and without fluorescein or rose bengal dyes.

6. **Intraocular pressures (IOPs).**
7. **Ophthalmoscopy** of the fundi.
8. **Visual field testing.**
9. **Other tests** as indicated by history and prior examination:
 - a. Tear film adequacy and drainage.
 - b. Corneal sensation.
 - c. Transillumination.
 - d. Exophthalmometry.
 - e. Keratometry.
 - f. Keratometry.
 - g. Gonioscopy.
 - h. Corneal topography.
 - i. Corneal pachymetry.
 - j. Specular microscopy.
 - k. Confocal slit-scanning microscopy.
 - l. Fluorescein and indocyanine green angiography.
 - m. Electroretinography (ERG) and electrooculography (EOG).
 - n. Ultrasonography.
 - o. Radiology, tomography, magnetic imaging.
 - p. Keratocentesis.
 - q. Scanning laser retinal nerve fiber analysis.

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Procedures **e.** through **o.** are done by specialists in eye care, and referral should be made if such testing is indicated.

II. Routine office examination techniques

A. Visual acuity.

Determination of visual acuity is a test of macular function and should be part of any eye examination, regardless of symptomatology or lack thereof.

1. **Distant visual acuity.** Visual acuity is examined one eye at a time, the other eye being occluded. Pressure on the occluded eye should be avoided so that there will

be no distortion of the image when that eye is tested subsequently. If the patient normally wears glasses, the test should be made both with and without corrected lenses and recorded as “uncorrected” and “corrected” (sc or cc).

- a. **The chart** most commonly used for distance vision with literate patients is the Snellen chart, which is situated 20 ft (approximately 6 m) away from the patient and diffusely illuminated without glare. At this distance the rays of light from the object in view are almost parallel, and no effort of accommodation (focusing) is necessary for the normal eye to see the subject clearly. The Snellen chart is made up of letters of graduated sizes; the distance at which each size subtends an angle of 5 minutes is indicated along the side of the chart. The farther one is from an object, the smaller the retinal image. By combining the two factors of size and distance, it is possible to determine the minimum visual angle, i.e., the smallest retinal image that can be seen by a given eye. A normal visual system can identify an entire letter subtending an angle of 5 minutes of arc and any components of the letter subtending 1 minute of arc at a distance of 20 ft. Some patients, however, may resolve letters subtending even smaller visual angles. The vision of a normal eye is recorded as 20/20, or 6/6 in metric measurement. If the patient is able to read down only to the 20/30 line, the vision is recorded as 20/30. If the patient is unable to read even the large E at the top, which subtends an arc of 400 degrees, he or she may be moved closer so that the distance measurement is changed. The visual acuity may then be recorded as 10/400, for instance, if the patient is able to read this letter at 10 ft from the chart.
- b. **Pinhole vision** is tested if the patient is unable to read the 20/30 line. A pinhole aperture is placed in front of the eye to ascertain any improvement in acuity. The use of a pinhole will correct for any uncorrected refractive error such as nearsightedness, farsightedness, and astigmatism (regular or irregular from corneal surface abnormalities) without the need for lenses. Through the pinhole a patient with a refractive error should read close to 20/20. If the pinhole fails to improve the patient's visual acuity score, the examiner must suspect another cause for the reduced vision, such as macular or optic nerve disease.
- c. **Preschool children or patients who are unable to read** should be shown the Illiterate E chart, which is made up entirely of the letter E facing in different directions. Patients are instructed to point their finger in the direction of the bars of the E. Children as young as 3 years of age may be able to cooperate in this testing. Another form of testing is with Allen cards, which are small cards with test pictures printed on each one; at a distance of 20 ft, a visual acuity of 20/30 may be tested. If the patient is unable to identify the pictures at that distance, the distance at which the picture is identified is recorded, e.g., 10/30, 5/30, and so on.
- d. **If a patient is unable to identify any letter** on the chart at any distance, visual acuity is recorded as counting fingers (CF) at whatever distance the patient is able to perform this function, e.g., CF 3. Vision less than CF is

recorded as hand motion or light perception (LP). If an eye is unable to perceive light, the examiner should record no light perception rather than the misleading term *blind*.

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- e. **Tests of light projection** may demonstrate normal retinal function when vision is extremely poor and the **examiner is unable to see the retina**, as in the presence of mature cataract or severe corneal scarring.

This test is done by covering the other eye completely and holding a light source in four different quadrants in front of the eye in question. The patient is asked to identify the direction from which the light is approaching the eye. A red lens is then held in front of the light and the patient is asked to differentiate the red from the white light. If all answers are correct, the examiner may be reasonably certain that retinal function is normal. It is important to note that normal retinal and macular function may be present despite abnormal LP due to unusually dense anterior segment disease, which prevents light sufficient to give the retina proper stimulation from reaching it.

- f. **The potential acuity meter (PAM)** is a reasonably accurate device for differentiating between visual loss from anterior segment (corneal scarring, cataract) and macular disease. It allows a preoperative prediction for what the potential postoperative vision might be. For example, if the vision is 20/400 by routine testing but 20/40 with PAM, one can, in most cases, assume good macular function and good correction of vision once the anterior segment defect has been corrected. Conversely, if the vision is 20/400 both by regular and PAM testing, one can assume that almost all of the visual loss is due to macular disease and that anterior segment surgery or medical therapy will be to no avail. The PAM attaches easily to a standard slitlamp and projects a Snellen acuity chart into the eye using a 1.5-mm-diameter pinhole aperture. In cases in which the cornea is clear but cataract obstructs vision, the patient is tested at different points on the cornea in an attempt to project through clearer areas in the lens and allow the best possible reading.
- g. **Macular photostress test.** Very early macular dysfunction, whether from spontaneous or toxic degeneration, may be detected by the macular photostress test. The patient looks at a flashlight held 2 cm from the eye for 10 seconds. The time it takes for visual recovery to one line less than the visual acuity determined prior to this test is measured. Normal time is about 55 seconds. Recovery taking longer than this (90 to 180 seconds) indicates macular dysfunction, even though the area may appear anatomically normal.
- h. **Macular function** may be tested in the presence of **opaque media** by gently massaging the globe through closed lids with the lighted end of a small flashlight. If the macula is functioning normally, the patient will usually see a red central area surrounded by retinal blood vessels. If macular function is abnormal, the central area will be dark rather than red and no blood vessels will be seen.

- i. **Legal blindness.** Visual acuity correctable by glasses or contact lenses to 20/200 or less in both eyes, or visual fields in both eyes of less than 10 degrees centrally, constitutes legal blindness in the United States. Its presence requires that the patient be reported to the Commission for the Blind in the patient's home state. Report forms are short and readily available from the Commission.
2. **Close visual acuity** is usually measured using a multipurpose reading card such as the Rosenbaum Pocket Vision Screener or the Lebensohn chart. The patient holds the chart approximately 35 cm from the eye and, reading separately with each eye with and without glasses, reads the smallest print he or she is able to identify. This may then be recorded directly from the chart as 20/30, 20/25, or as Jaeger equivalents J-1, J-2. In patients older than the late 30s, the examiner should suspect uncorrected presbyopia if the patient is unable to read a normal visual acuity at 35 cm, but is able to read it completely or at least better if the card is held farther away. Abnormally low close vision in an elderly patient without reading

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glasses is meaningless per se, except for comparative purposes in serial examinations of the severely ill.

B. Extraocular muscle function

The movement of the eyes in all fields of gaze should be examined (see Chapter 12, sec. I. and sec. XI.).

1. **In the primary position of gaze** (i.e., straight ahead) the straightness, or orthophoria, of the eyes may be ascertained by observing the reflection of light on the central corneas. The patient is asked to look directly at a flashlight held 30 cm in front of the eye. Normally, the light reflection is symmetric and central in both corneas. The asymmetric positioning of a light reflex in one eye indicates deviation of that eye. Location of the reflex on the nasal side of the central cornea indicates that the eye is aimed outward, or exotropic; location of the reflex temporal to the central cornea indicates that the eye is deviated inward, or esotropic. Each millimeter of deviation is equivalent to 7 degrees or 15 diopters (D) of turn. A paretic or paralyzed extraocular muscle is the cause of such ocular deviation. Vertical deviation may be determined by noting the location of a light reflex above or below the central cornea. In some patients, the light reflex will be slightly inside or outside the central cornea due to a normal difference between the visual axis and the anatomic axis between the central cornea and the fovea. This angle is referred to as the **angle kappa** and is positive if the eye appears to be deviating outward, and negative if the eye appears to be deviating inward. No ocular movement will occur on cover-uncover testing if the apparent deviation is due to angle kappa alone (see Chapter 12, sec. III.B.).
2. **Cardinal positions of gaze.** The patient is asked to look in the six cardinal positions of gaze, i.e., left, right, up and right, up and left, down and right, and down and left.

Congruity (parallelism) of gaze between the two eyes should be noted as well as the extent of the excursion. The examiner should check for restriction of gaze in any direction or for double vision in any field of gaze due to restriction of one eye. Occasionally, involuntary movement may occur in normal patients at the extremes of gaze; this movement is referred to as *end-gaze* or *physiologic nystagmus*.

Nystagmus is a short-excursion, back and forward movement of the eye that may be fine or coarse, slow or rapid. Occasionally, fine rotational nystagmus may also be observed. Except in end-gaze nystagmus, this rotational nystagmus may bear further investigation (see Chapter 12, sec. XI. and XIII.).

3. **The near point of conversion (NPC)** is the point closest to the patient at which both eyes converge on an object as it is brought toward the eyes. This point is normally 50 to 70 mm in front of the eye. The moment one eye begins to deviate outward, the limit of conversion has been reached. An NPC greater than 10 cm is considered abnormal and may result in excessive tiring of the eyes on close work such as reading or sewing.
4. **Stereopsis** is tested grossly by having the patient touch the end of one finger to the tip of the examiner's finger coming in horizontally end to end. Past pointing may indicate lack of depth perception in the absence of central nervous system (CNS) disease. More refined testing is done using the Wirt test fly, circle, and animal figures with three-dimensional (3-D) glasses. Stereopsis may be graded from the equivalent of 20/400 (large fly) to 20/20 (nine circle depth perception) using this commercially available test. Simultaneous perception of four red and green lights while wearing glasses with a red lens over one eye (eye sees only red) and a green lens over the other (eye sees only green) indicates a more gross but significant form of fusion. This test is the Worth four-dot test and is also available commercially.

C. Color vision testing

1. **Purpose.** Demonstration of adequate color vision is mandatory for certain jobs in a number of states and for obtaining a driver's license. Jobs affected are armed services trainees, transportation workers, and others whose

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occupations require accurate color perception. Color vision, particularly red perception, may be disturbed in early macular disease, whether toxic or idiopathic degenerative, and in optic nerve, chiasmal, or bilateral occipital lobe disease. Some of the earliest and reversible drug toxicities, such as that from chloroquine and avitaminosis A are detected by repeated color vision testing; regression and progression may also be documented. These tests are designed for:

- a. **Screening defective color vision from normal.**
- b. **Qualitative classification** as to type of defect. Protans and deutans are red-green deficient and are found in 4.0% of all males and 0.4% of all females; tritans and tetartans are very rare and are blue-yellow deficient.

- c. **Quantitative analysis** of degree of deficiency: mild, medium, or marked.
2. **Technique.** The progressively more subtle and difficult polychromatic plates of Ishihara, Stilling, or Hardy-Rand-Ritter are made up of dots of primary colors printed on a background of similar dots in a confusion of colors or grays. These dots are set in patterns, shapes, numbers, or letters that would be recognized by a normal individual but not perceived by those with color perception defects. Patients are shown a series of plates, the number of correct answers is totaled in various color test areas, and the type and severity of any deficiency are thus defined. The anomaloscopic 100 hue test detects earlier, more subtle changes.

D. Anterior segment examination (see frontispiece)

1. **Magnifying loupes.** The external examination of the eye itself is greatly facilitated by the use of a bright light source, such as a flashlight or transilluminator, and a magnifying loupe. Many different kinds of loupes are available, but basically they may be divided into two categories. One form is worn as a spectacle loupe and has magnification ranging from 2× to 5×, with working distances ranging between 20 and 35 cm. These magnifying spectacles may be mounted on the normal prescription glasses if these are worn by the examining physician. The second form of loupe is a headband loupe, which can range in power from 1.75× to 5.25× with working distances ranging between 20 and 50 cm. Loupes are of great help in evaluating not only local tissue changes and location of corneal abrasions and staining, but also in minor surgical procedures and the removal of corneal foreign bodies. Handheld magnifiers do not leave both hands free for other purposes.
2. **Slitlamp biomicroscopy of anterior segment and fundus.** Biomicroscopy involves examination of the external ocular structures and the front of the eye to a depth of the anterior vitreous using a specially designed microscope and light source. Slitlamps are most commonly stand-mounted, but for bedside exam, handheld lamps are available. Use of a slitlamp is indicated in any condition in which examination is facilitated and made more accurate by a well-illuminated and highly magnified view of the anterior segment of the eye, e.g., corneal ulcerations, iris tumors, cataract evaluation. Patient and examiner are seated on either side of the slitlamp, the patient placing the chin on a chin rest and the *forehead against a frame* while the examiner views the eye through the microscope. By moving the microscope in and out with a hand control, the examiner can adjust the depth of focus so that the object of interest is brought clearly into view. The general order of examination is to start with the lids and then progress to the conjunctiva, cornea, anterior chamber, iris and pupil, lens, and anterior vitreous. The fundi are seen by use of double aspheric 60, 78, or 90 D lenses handheld before the eye. The examiner shines the slit beam straight through the (usually) dilated pupil to focus on the retina, thus obtaining a stereoscopic but inverted view. This is useful for evaluating macular edema, optic nerve lesions, or other posterior pole lesions. It is less useful for the peripheral retina beyond the equator. Other techniques for views of the deeper vitreous, retina,

and optic nerve are described below.

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- a. **Special dyes** such as fluorescein to detect ulcerations or rose bengal to detect dead and dying cells on the ocular surface may be used. With fluorescein, a cobalt filter is swung into place to delineate clearly the areas of epithelial absence. A white or green light is used for rose bengal staining.
- b. **The slitlamp beam** may be widened to a full circle to illuminate the entire front of the eye or narrowed to a tiny slit that will assist the examiner in determining the thickness of various anterior segment structures. The tissue illuminated by the narrow beam is referred to as an *optical section* and represents an optical cut through the various depths of tissue. The cornea and lens under magnification and illuminated by the intense narrow beam of focal light passing from the slitlamp may be seen to be made up of multiple layers of different optical densities. Layers seen in a normal cornea are epithelium, stroma, and endothelium; those in a normal lens are cortex and nucleus. Opacities and other local pathologic processes can be located with great accuracy in the anterior segment using the slitlamp.
- c. **The slitlamp beam may also be narrowed to a single fine point of light** that can be focused through the front of the eye to reveal changes in the density of the **aqueous fluid** in the anterior chamber. Such changes are particularly significant in the presence of intraocular inflammation or trauma. Cells or increased protein in the aqueous or cells in the vitreous, invisible with ordinary illumination and magnification, may be seen using the narrow beam of the slitlamp (the Tyndall phenomenon). In a normal person the aqueous humor is clear or optically empty, but with increased protein content, as in intraocular inflammation, the beam is visible and referred to as aqueous flare. Its intensity may be measured by a subjective rating used by the observer, ranging from 0 to 4+ (see Chapter 9, sec. III.).

E. Anterior ocular structures

1. **Eyelids and palpebral fissures.** Under good lighting conditions the lashes and eyebrows should be inspected for the presence of inflammation, scaling, or dandruff, and the lashes also for orientation, i.e., being turned in or out, misdirected, missing, or present as more than one row. Focal changes in pigmentation are also important to note. The observer should inspect the general appearance of the lid margins as to color, texture, swelling, position, and motility. Note should be made of signs of inflammation, pouting of the meibomian gland openings, rash, unusual vascularity, or old scars. The normal lid margins should overlie the corneal limbus by 1 to 2 mm above and below with no exposure of sclera. Voluntary lid closure should be complete with no inferior exposure. Involuntary blinking should occur every 3 to 6 seconds with complete closure of the lids. Both upper lids should elevate well on upward gaze and drop on downward gaze. The space between the upper and lower

lid margin ranges normally between 9 and 13 mm. This measurement is not so critical as is a disparity in the size of this measurement between the two eyes in a given patient. The lid margins should follow the globe synchronously on downward and upward gaze without evidence of lid lag. The borders should have good anatomic apposition to the globe with the tear puncta (upper and lower punctal openings are located 2 to 4 mm temporal to the medial canthus in contact with the tear film that they drain).

2. **Lid eversion.** The upper lid may easily be everted for inspection of the palpebral conjunctiva by having the patient look down while the examiner grasps the lashes with one hand, pulling out and down, pressing on the lid with a cotton-tipped applicator stick 1 cm above the edge of the lid margin, i.e., at the superior border of the tarsal plate, and flipping the lid over the stick (Fig. 1.1). In the presence of pain, a topical anesthetic may assist in this part of the examination. To restore the everted upper lid, the examiner simply asks the patient to look up and simultaneously pulls the lashes down gently. The lower palpebral conjunctiva is easily seen by

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pressing down over the bony maxilla to pull the lid down with a finger and asking the patient to look up.

Fig. 1.1. A: Technique of lid eversion. **B:** Foreign body is easily located with the everted lid held against upper orbital rim. An internal cartilaginous tarsal plate holds the lid firm.

3. **The main lacrimal gland** is situated at the superotemporal quadrant of the orbit. It may be seen as a globulated pink mass under the upper eyelid when the patient is asked to look down and nasally, and traction is placed on the upper outer eyelid. Tears are carried from this gland as well as from the accessory lacrimal glands in the conjunctiva from the superotemporal quadrant of the eye down toward the infranasal area, where tears pass through the lacrimal canaliculi via the puncta and down into the lacrimal sac. From there they enter the nasolacrimal duct opening under the inferior turbinate of the nose. Tears flow down the back of the throat, occasionally giving patients the taste of medication instilled into the conjunctival cul-de-sac.
4. **The bulbar (eyeball) conjunctiva** is examined by gently separating the lids and asking the patient to look in all directions of gaze—up, down, right, and left. The normal conjunctiva is a thin membrane almost entirely transparent and appearing white, although a few patients may normally have hyperemic (red) eyes due to dilation of the many fine conjunctival vessels running throughout the membrane. In general, the examiner should be able to observe the white sclera through the transparent bulbar conjunctiva without difficulty, although occasionally deposits of pigment may be seen. On either side of the limbus a slightly raised yellow area (pinguecula) may normally be seen and may with age turn slightly yellow, due to benign degeneration of elastic tissue. Benign pigmented nevi may be present; these are flat and often translucent under magnification.

5. **The palpebral conjunctiva** is seen by lid eversion and varies in appearance with age. Above and below the tarsal plate it has many shallow folds; frequently, small bumps that represent follicles or lymphoid tissue formation are present. Follicles are normally absent in infants, prominent in children, and less notable in adults. Over the tarsal plate the conjunctiva is firmly bound to the fibrous plate and normally shows no follicles. The examiner may see faint yellow lines of the meibomian gland running vertically in the tarsal plate through the translucent overlying tissue. **Conjunctival lacerations or abrasions** are easily detected with a drop of sterile fluorescein solution or the application of a sterile fluorescein paper strip to the

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tear film. A white light will show the injured area as yellow-green. A cobalt blue light will show the area as bright green.

6. **Deep to the conjunctiva are the episcleral vessels**, which run in a *radial* direction from the cornea. Inflammation in these vessels is indicative of deeper disease than inflammation involving just the conjunctival tissues.
7. **The normal corneal surface** is so smooth that it is analogous to a convex reflecting surface. Any minor disruption in this surface will be readily apparent, particularly under magnification, as a break in a normally perfect light reflex. The size of each cornea should be noted and normally measures 13 mm horizontally and 12 mm vertically in an adult. A flashlight and loupe are extremely useful for examination in the absence of a slitlamp.
- Scars, old and active vessels, and deposits** in the stroma and on the back of the cornea are difficult to see with the unaided eye. **Small foreign bodies** may be missed without illumination and magnification. The application of a sterile **fluorescein or rose bengal dye strip** (wet with sterile saline) to the tear film is extremely important in detecting the presence of abrasions or foreign bodies on the corneal surface. Under white light, an abrasion will stain yellow-green and under cobalt blue light, bright green. Rose bengal stain will stain and outline the defect in red and is easily seen with a white light. A drop of local anesthetic will greatly aid the examination of a patient suffering lid spasm secondary to a corneal lesion.
 - Corneal sensitivity (esthesiometry)** should be ascertained prior to the instillation of topical anesthetics, particularly if the examiner is suspicious of herpetic viral disease. To determine corneal sensitivity, the cornea is lightly touched with a **wisp of cotton** drawn out to a few threads while the lids are held apart. The approach should be from the side so that the patient does not see the cotton tip coming toward him or her and reflexively close the eye. One eye should be compared with the other on a 0 to 10 scale and note made of reduced sensitivity. A more accurate measurement of corneal sensitivity may be made with the **Cochet-Bonnet anesthesiometer**. By adjusting the length of a retractable nylon thread, the examiner can measure in units the length at which the thread is first detected by each cornea and compare the readings.
8. **Anterior chamber** (see frontispiece). Detailed examination of the anterior chamber

is difficult without the use of a slitlamp biomicroscope, but a good light and the use of the naked eye or a magnifying loupe will allow the examiner to detect chamber depth, clearness or cloudiness of the aqueous fluid, and the presence of blood, either diffuse or settled out in hyphema layering. Hypopyon (the accumulation of pus in the anterior chamber) may also be detected in the inferior anterior chamber.

9. **Iris.** The color of each iris should be noted and differences in color, texture, and pattern recorded. Under magnification the examiner may detect the presence of nevi, abnormal areas of very dark pigmentation, new vessels, atrophy, tears, or surgical openings. Transillumination is useful here, because abnormalities will show up against the red pupillary–iris reflex (see sec. L.2., below).
10. **The pupils** should be inspected for size, shape, and reaction to direct and consensual (in the opposite pupil) light as well as the accommodation reflex. All of these reflexes involve decrease in pupil size on exposure to light or on attempted near focus.
 - a. **Normal pupils** are equal in size, although in blue-eyed patients there may be a 0.5-mm difference under normal conditions. The range of normal pupils is 3 to 5 mm in room light. Pupils smaller than 3 mm in diameter are miotic; pupils larger than 7 mm are mydriatic. Pupils may be miotic if the patient is taking certain drugs for glaucoma or is taking heroin. They may be abnormally large in cases of ocular contusion,

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systemic poisoning, and neurologic disease of the midbrain (see Chapter 13, sec. III.).
 - b. **The pupil is normally** round in shape. In the absence of surgical manipulation, irregularity is almost always pathologic. The shape may be affected by congenital abnormality, scarring down from iritis, syphilis, trauma, or the presence of surgically placed intraocular lenses (IOLs).
 - c. **The direct light reflex** is tested in a semidark room with a light brought in from the side. The pupil should contract to direct light as well as when light is shined in the pupil of the opposite side; this latter response is the **consensual** reaction to light. Reaction to accommodation is tested by holding a finger approximately 10 cm away from the eye being tested. The patient is asked to look at the finger and then at the far wall directly beyond it. The pupil normally constricts when looking at the near object and dilates when looking at the far object. Under normal conditions, if the pupil reacts to light, it will react to accommodation as well. The Argyll Robertson pupil is a condition due to CNS lues and occasionally to herpes zoster in which there is a failure of direct and consensual light response, but a normal reaction to accommodation. Adie tonic pupil responds to either stimulation, but does so abnormally slowly (see Chapter 13).
11. **The lens** may be observed under magnification for opacity using either a loupe or the plus lenses of an ophthalmoscope. This procedure is more easily done with the pupil dilated so that as much of the lens as possible can be seen. The examiner

should also note the central location of the lens and its stability in position (partially dislocated lenses are tremulous) as well as its translucency. Difficulty in viewing the fundus through the lens is indicative of a significant cataract or vitreous opacity. The hazier the view into the eye, the hazier the view out of it for the patient.

F. IOP measurements for glaucoma or hypotony

1. **Finger tension.** A rough estimate of IOP may be made by palpation of the eyeball through closed lids. The patient is asked to look down (but not close the eyes) and the examiner places two forefingers on the upper lid over the globe, exerting pressure alternately with each forefinger while the other rests on the globe. Pressure just sufficient to indent the globe slightly should be applied. In the absence of inflammation this is a painless procedure, but it should be avoided if rupture of the globe is suspected. After experience with palpating a number of normal eyeballs, the examiner will learn what normal resistance is and by comparison may determine whether an eyeball is either “too hard or too soft.”
2. **Tonometry.** Accurate IOP may be determined by use of tonometers. If the IOP is between 22 and 25 mm Hg or more, ocular hypertension or glaucoma must be considered. Visual field and ophthalmoscopic study of the nerve head should be performed. Tonometry readings may be repeated at different hours of the day to determine diurnal curve (see sec. II.F.3.). Pressures greater than 25 mm Hg are generally accepted as representative of ocular hypertension. In the presence of a visual field defect or asymmetric or marked cupping of the optic nerve head, the diagnosis of glaucoma can be definitely established.
 - a. **Technique of Schiötz tonometry.** After the instillation of local anesthesia, such as one drop of proparacaine or tetracaine, the patient is placed in a supine position and asked to look directly upward, fixing on some object such as his or her extended hand. The physician separates the lids to keep them from contacting the eyeball, taking care not to exert pressure on the globe (Fig. 1.2A). The instrument is placed gently in a vertical position directly over the cornea, and the plunger is allowed to exert its full weight. With the instrument held steady the pointer will stay fixed at a single scale, with slight oscillations 0.5 mm in either direction because of alterations in the internal pressure caused by the arterial pulse in the eye. If the reading with the 5.5-g weight is between

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 3 and 6 on the scale, this reading may be used. Readings below 3 are inaccurate with this instrument, and a 7.5-g weight should be added and the reading taken again. If the reading is still below 3, the 10-g weight should be used. If the patient squeezes his or her lids, this will raise the IOP; note should be made of this, because a falsely high pressure may be recorded. Schiötz tonometry tends to be less accurate in myopic patients or patients with thyroid ocular disease. Applanation tonometry is more accurate in these

patients.

Fig. 1.2. A: Technique of Schiötz tonometry. Digital pressure on the globe is avoided. **B:** Applanation tonometry. The applanation tonometer may be handheld or mounted on a slitlamp biomicroscope. (Adapted from Paton D, Craig J. *Glaucomas: diagnosis and management*. Clinical Symposia. Summit, NJ: Ciba Pharmaceutical Co., 1976.)

- b. **Applanation tonometry.** This very accurate method for measuring IOP may be performed with an applanation tonometer mounted on a routine slitlamp biomicroscope or with a handheld applanation tonometer (Fig. 1.2B). After local anesthesia is induced as with Schiötz tonometry, fluorescein paper strips are inserted into the lower cul-de-sac to place dye in the tear film. The tonometer scale is set at 0 and the head is then brought gently against the anterior corneal surface with the patient looking straight ahead. On contact and with the cobalt blue light in place, two fluorescein semicircles are seen through the microscope, one higher than the other; the top with the outer curve up and the bottom with the outer curve down. The semicircles should be equal in size and in the middle of the field of view. Their steady pulsation indicates that the instrument is in the correct position. Pressure on the eye is increased

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by turning the calibrated dial of the tonometer until the inner border of each semicircle just touches and overlaps with each pulsation. The pressure reading (in millimeters Hg) is determined directly by reading from the measuring drum. This machine is more accurate than Schiötz tonometry in patients with altered scleral rigidity (myopia, thyroid disease), but appears to be less accurate than the pneumotonometer or tonopen in post-laser-assisted in situ keratomileusis (LASIK) patients. The flow of volumetric displacement of 9.56 nm increases the IOPs by only 2.5%, as compared with the much greater volumetric displacement encountered with Schiötz tonometry.

- c. **The pneumotonometer** is an electronic tonometer that has its greatest use in patients with corneal scarring or altered corneal shape such that conventional Schiötz or applanation tonometers cannot be employed with any accuracy. The soft tip of a blunt pencil-like device connected by wire to an electronic recorder is momentarily touched to the anesthetized cornea. Pressure is calculated by the jump in scale readings from baseline noncontact curve to that of the momentary touch flattening the cornea or indicated directly on a digital screen. The **tonopen** is portable, battery operated, and similar in use to the pneumotonometer.
- d. **The air puff noncontact tonometer** is a reasonably accurate electronic tonometer that has the advantage of use without topical anesthetic. The patient sits with the head in a slitlamp-like device, and a 3-millisecond puff of air (a blink takes 10 milliseconds) is blown against the cornea. The indentation pattern is detected by the tonometer eye. The pressure is calculated by the

amount of corneal flattening by the fixed air puff pressure and displayed on digital readout. This machine can be used in mass glaucoma-screening programs.

3. **Tonography** is an electronic Schiötz measurement over 4 minutes to determine the rate of aqueous outflow from the anterior chamber. It is currently used infrequently. A coefficient of outflow factor less than 0 is suspicious of glaucoma.

G. Direct ophthalmoscopy

1. **Examination of the posterior segment of the eye** (vitreous, optic nerve head or disk, vessels, retina, choroid) is performed with the aid of an ophthalmoscope. A satisfactory examination of the posterior pole can usually be made through an undilated pupil, provided that the media (aqueous, lens, vitreous) are clear. However, a greater extent of the peripheral posterior segment can be examined through a dilated pupil. Ophthalmoscopy is best done in a darkened room.
2. **For optimum dilated fundus examination**, mydriatic agents in common use are cyclopentolate 0.5% or tropicamide 1%/phenylephrine 2.5%; the latter should be used with caution in any patient with a history of significant cardiovascular disease. No mydriatic agent should be instilled in an eye in which a shallow anterior chamber is suspected. An estimate of the anterior chamber depth can be made by illuminating it from the side with a penlight. **If the iris seems abnormally close to the cornea, dilation is contraindicated because of the risk of inducing acute angle-closure glaucoma** (see Chapter 10, sec. III.). A slitlamp beam depth of less than 3 to 4 corneal thicknesses centrally is also indicative of a possible shallow chamber and is a relative contraindication to dilation.
3. **Ophthalmoscopes.** There are many forms of ophthalmoscopes, the most commonly used being handheld **direct** ophthalmoscopes designed to provide a direct magnified (14×) view. The source of illumination is projected by means of a mirror or prism coinciding with the observer's line of vision through the aperture.
4. **Technique of ophthalmoscopy.** The ophthalmoscope is held close to the observer's eye and approximately 15 cm from the patient's eye in the observer's right hand to examine the patient's right eye and in the observer's left hand to examine the patient's left eye. The observer uses his or her

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right eye for the patient's right eye and his or her left eye for the patient's left eye. The patient should have no glasses on, have chin straight, and be fixating on a distant target with the eye as steady as possible. From time to time the patient may have to be reminded to refixate on a distant target to avoid accommodation from interfering with the observer's level of focus within the eye. The physician may have to adjust the ophthalmoscope power setting to accommodate for the patient's or his or her own refractive error—red-numbered minus lenses are used for nearsighted errors, black-numbered plus lenses are used for farsighted errors. Eyes that have

undergone cataract removal but no lens implantation (aphakia) should be examined with a +8 to +12 lens to obtain a view of the fundus. If both patient and examiner have normal eyes and the lens is set at 0, a red reflex will be seen and is considered normal. Moving the ophthalmoscope as close to the patient's eye as possible, the observer uses black or positive lenses. Lens settings of +4 to +8 will focus the ophthalmoscope on the anterior segment to reveal corneal opacities or changes in the iris and lens. The retina in a normal eye will focus at 0, provided that no refractive error is present. By decreasing the power of the lens from positive toward negative, the depth of focus will become greater so that the examiner may move from the anterior segment progressively through structures until the vitreous and retina are reached.

5. **Vitreous opacities** such as hemorrhages and floaters should be localized and noted, and changes in the posterior segment structures focused and studied.
6. **The optic nerve head** should be brought into focus and examined. This structure is generally circular to oval with vertical orientation and pink in color. The temporal side is usually lighter pink than the nasal side. The center of the disk may have some depression, which is referred to as the *physiologic cup*, the bottom of which may be fibrous in appearance and represents the fibers of the lamina cribrosa of the sclera. Normal cupping is round and may vary from absence to 80% involvement of the nerve head. In the presence of extensive, vertically elongated, or asymmetric cupping, glaucoma should be suspected. In optic atrophy the entire nerve head will be pale; in papilledema or papillitis it will be swollen and congested. The size of the normal nerve head may vary with the refractive error of the patient, being small in farsighted patients and large in myopic patients. The border of the nerve head is usually discretely demarcated from the retina, but may merge gradually into the surrounding tissue without any clear-cut edge. A white border representing a scleral ring or crescent is often present and formed by exposure of sclera between the choroidal vasculature and the opening for the optic nerve. There may be excessive choroidal pigment in this area.
7. **Fundus lesions** should be measured using the disk diameter (dd) as a reference size. For example, a retinal scar may be described as being 3 dd in size and located 5 dd nasal to the nerve head at 1 o'clock. Elevation of this lesion may also be measured by noting the difference between lens powers that clearly focus the top of the lesion and an adjacent normal area of the fundus. Elevation of 3 D lens change would be equivalent to approximately 1 mm in actual elevation. Multiples of this may be made according to the size and height of the lesion.
8. **Retinal arteries and veins (AV).** The arteries are red and smaller than the veins in about a 4:5 ratio. Because of a thicker wall, the arteries have a shiny central reflex stripe. The column of blood traversing these vessels may be seen through the transparent walls. Branching is variable. The examiner should evaluate the transparency of the vessels, the presence of pressure effects such as AV compression (nicking) where vessels cross each other, and presence of focal narrowing of arterioles, as well as increased tortuosity and widening of venules, hemorrhages, and exudates around the vessels. Round hemorrhages may occur in

patients with diabetes mellitus and are

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generally located between the posterior vitreous face and the retina. Flame-shaped hemorrhages are usually intraretinal and are commonly found in patients with high blood pressure and blood dyscrasias.

9. **The macular area** located about 2 dd temporal to the optic nerve head is darker than the surrounding retina and in a young person will have a lustrous central yellow point called the fovea centralis (see frontispiece). This appears as a small area of dark red with a tiny yellow light reflex at the center of the fovea. The foveal reflex dulls with age or certain drug-induced retinal toxicities.
10. **The periphery of the fundus** can be examined by the movement of the ophthalmoscope in various directions as well as by having the patient move the eye in various quadrants horizontally and vertically. Through a dilated pupil, the periphery can be seen directly with a direct ophthalmoscope up to 1.5 mm from the peripheral retinal attachment (ora serrata).
11. **Normal variations of the fundus.** With increased experience, the observer will become acquainted with a wide range of normal variations. Vasculature is particularly variable. Vessels may appear from the temporal half of the nerve head and run to the macular area. These cilioretinal vessels originate from the vascular circle of Zinn behind the nerve head in the sclera and are formed by branches from the short posterior ciliary arteries. They represent anastomosis between the choroidal (ciliary) and retinal circulation. Occasionally, a tuft of connective tissue arises from the nerve head on its nasal side and projects forward into the vitreous. This embryonic remnant of the hyaloid artery is located in the surrounding canal of Cloquet. If located near the edge of the nerve head, the disk margin may appear blurred or even elevated. Such persistent hyaloid remnants do not interfere with vision unless associated with other ocular defects.

Myelinated nerve fibers are another normal variation and may be seen as striking projections of white feathery tissue originating from the optic disk and extending for variable distances into the peripheral retina. Visual field defects may be present in the area of myelination of the nerve fibers running in this area. Drusen, small round hyaline excrescences formed on Bruch membrane, may create variations in elevation of the nerve head or scalloping of its border, or they may more commonly occur as scattered small yellow lesions in the peripheral fundus. They may occasionally produce pseudopapilledema of the nerve head, but no visual field defect will be present except for enlargement of the blind spot. **Macular drusen** may precede subretinal neovascularization. Fluorescein angiography may be indicated.

H. Indirect ophthalmoscopy

Indirect ophthalmoscopy is a technique generally used by specialists and involves the use of a head-mounted, prism-directed light source coupled with use of double aspheric (+14, +20, or +28) diopter condensing lenses to see the retinal image.

1. **Optics.** Several designs of indirect ophthalmoscopes are available, but all produce a stereoscopic image that is inverted, real, and capable of being seen on a semitransparent film held at the focal plane of the lens. Although most indirect ophthalmoscopes are designed for use through dilated pupils, some may be used through a miotic or undilated pupil; this is a great advantage in patients who cannot be dilated either because they do not respond to topical drugs, are at risk of angle-closure glaucoma, or have pupil scarred to the lens.
2. **The image** covers approximately ten times the area usually seen in the field of the direct ophthalmoscope, but is smaller than a direct ophthalmoscope (3×), although the larger field of view gives great perspective to the entire fundus and is helpful in locating multiple lesions or in evaluating retinal detachment. Another advantage is stronger illumination, which allows light to pass through opacities of the vitreous obstructive to a direct ophthalmoscope. See sec. D., above, for the use of lenses to obtain a magnified stereoscopic view of the posterior pole.

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I. Visual field testing

(see Chapter 13, sec. I.).

1. **The purpose** of visual field testing is to determine both the outer limits of visual perception by the peripheral retina and the varying qualities of vision within that area. Visual field interpretation is important for diagnosing disease, localizing it in the visual pathway between the retina and the occipital cortex in the brain, and noting its progress, stability, or remission. As a result, repeated tests of the visual field are important both diagnostically and in ascertaining the effects of therapy. Each eye is tested separately. With one eye fixing on a given distant test object, the sensitivity of various areas of the visual field may be tested with varying size and color of test objects moved throughout that field. The greatest sensitivity, of course, is at the fovea and represents the highest visual acuity of central fixation. This visual acuity decreases rapidly as the test objects are moved away from central fixation. Colored objects offer less stimulus to the retina than white objects of similar size. Therefore, an object may be too small to be detected by peripheral retinal receptors, but quite effective in mapping out central visual field within 10 to 15 degrees of foveal fixation.
2. **Techniques.** Visual fields are examined most frequently by four methods: Amsler grid, confrontation, perimetry, and tangent screen.
 - a. **Amsler charts** for qualitative vision evaluation make it possible to analyze the earliest maculopathies and their progression, as well as to detect any scotomatous defects encroaching on the central 10 degrees of vision.
 1. **Technique.** The small book of six charts contains diffusely dotted or lined square grids 10 cm on the side, the latter with smaller 5-mm squares within. With the chart held at 30 cm from the patient's eye, the

linear measurements correspond to visual angles of 20 degrees and 1 degree, respectively. The patient stares at the center of the squares one eye at a time. Alterations in perception of the regular patterns indicate various field defects.

2. **Purpose.** The examiner may find central scotomas (focal area of decreased or lost retinal sensitivity) as in macular scarring, cecocentral scotomas as in toxic amblyopias, paracentral scotomas as in chorioretinitis, and metamorphopsia (distortion of vision) as in very early maculopathies. The edge of a glaucomatous Bjerrum scotoma, a peripheral field defect secondary to CNS or peripheral retinal disease encroaching on the central 10 degrees of vision, will also be detected.
- b. **Confrontation.** No special instruments are required for this form of visual field testing, which provides a rough estimate of the patient's visual field by comparing it with the examiner's visual field. It is assumed that the examiner's visual field is normal.
1. **Technique.** The patient and examiner face each other at a distance of 1 m. With the left eye covered, the patient is instructed to look with the right eye at the left eye of the examiner, whose own right eye is covered. A small object such as a pencil or a larger one such as a wiggling finger may be used as a target. The examiner places his or her hand midway between the patient and him- or herself and initially beyond the limits of field of vision of either in a given meridian, e.g., far temporal to both patient and examiner. As the test object is moved slowly toward the line of vision between patient and examiner, the patient is asked to respond as soon as he or she is able to see the target. The physician compares this to the time when he or she is able to perceive the target. This is repeated at eight to ten equally spaced meridians at approximately 360 degrees. The visual field is considered normal if the patient sees the target 90 degrees temporally, 50 degrees nasally, 50 degrees upward, and 65 degrees downward. The test is then repeated on the other eye. With careful testing the blind spot and focal scotomas can be detected.

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2. **Purpose.** This test may also detect gross alterations in field defects due to ocular disease, such as chorioretinitis or advanced glaucoma, or to intracranial disease such as brain tumor or hemorrhage (see also Chapter 10, sec. II.E., Fig. 10.2 [glaucoma]; and Chapter 13, Fig. 13.3, Fig. 13.4 and Fig. 13.5 [neurophthalmic fields]).
- c. **Perimetry** is done to obtain accurate examination of the peripheral extent of the visual field. Perimetry may be done as manual *kinetic* (moving target from nonseeing to seeing areas of vision) or *static* (nonmoving target flashed at different locations in visual field) using a **Goldmann** type bowl perimeter, or by *automated static perimetry* using a bowl perimeter such as the **Humphrey**

visual field analyzer or the **Octopus**. In addition to varying target size, perimeters vary target brightness as well, presenting them at threshold (the dimmest spot detected during testing) or suprathreshold levels. Size I is 0.25 mm² and size V is 64 mm² with gradations in between. Luminance varies from 32 to 1,000 apostilbs with ten gradations in between. Most automated perimeters provide normal values and compare the patient to normal in the printout of the results. The Humphrey analyzer will also give a probability that any test location is not normal dependent on patient age and location in the visual field. The standard glaucoma field is 30-2, with follow-up fields either 30-2 or 24-2. In addition to automated static perimetry, there is now **short-wavelength automated perimetry (SWAP)** which appears to detect visual field defects earlier than automated static perimetry, and **frequency doubling perimetry**, which is a 1-minute screening test that is very good in detecting moderate to advanced glaucoma.

The Octopus detects threshold sensitivity to a light stimulus at 72 points in the visual field. The intensity of the stimulus is carried to below threshold and worked up to suprathreshold. Its advantages are that the Octopus picks up the earliest, most subtle field defects, the results are reproducible, and progression of subtle or gross defects can easily be documented. The disadvantages of all automated perimeters are subjective patient fatigue, the expense of the machines, and the need for trained personnel to run them.

Visual field examination is indicated when the physician detects or suspects a disorder that has constricted the side, paracentral, or central vision. In uncooperative patients, the results of this test are unreliable.

1. **Technique.** The patient is seated at the perimeter with one eye covered and the chin on the chin rest. The patient must fix his or her vision on the central target of the perimeter and a test target, static or kinetic as just described, is presented at some location in the field. The patient is asked to signal immediately when he or she sees the target, indicate when it disappears, and indicate again when it reappears. By the end of the test, the entire 360 degrees of field have been mapped.
 2. **Purpose.** The examiner may accurately map defects in the peripheral vision all the way from the far extent of the field into central or foveal fixation. The smaller the test target used, the greater the possibility of discovering scotomas in the field.
- d. **Tangent screen.** Up to 90% of all visual field defects in the central 30 degrees may be picked up using this method of kinetic perimetry (a suprathreshold stimulus moving from nonseeing to seeing areas of vision). It is not as sensitive in picking up early defects as the Goldmann and automated perimeters.
1. **Technique.** The patient is seated 1 m from a 2-m² black screen with a direct line of fixation on the central object in the tangent screen. One eye is tested at a time. A 3- to 50-mm white test object is brought in

from the periphery, exploring 8 to 10 meridians from periphery to central fixation, as in perimetry. The patient indicates immediately when the object appears and disappears so that the examiner can

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map areas of decreased or absent vision. The blind spot should be outlined carefully and early in the examination to show the patient the nature of scotoma mapping. The findings, including the size and color of the test object and the distance from the screen, are charted. *Color fields* with red and blue test objects are most useful in the central 10 to 15 degrees of vision and may be the test that picks up early toxic retinopathy soonest.

J. Tear film adequacy: clinical tests

The testing of tear film adequacy can be divided into three separate areas: (a) tear quantity, (b) tear quality, and (c) tear film stability. Each is of importance in determining the role of the tear film in the symptomatology and pathologic changes noted in dry eye syndromes.

1. **Tear quantity test.** Tear secretion may be divided into basal and reflex secretion. Basal secretion is maintained by the accessory conjunctival lacrimal glands of Krause and Wolfring. Reflex secretion is a product of the main lacrimal gland. Accurate interpretation of tests requires assessment of the role that reflex tearing played during the test. The average basal tear volume is from 5 to 9 μL with a flow rate of 0.5 to 2.2 μL per minute. Unlike reflex tearing, this parameter is not age dependent, and basal volume or flow rate does not normally decrease in elderly persons. The majority of clinical complications of tear volume, however, result from hyposecretion. The epithelium, cornea, and conjunctiva are extremely sensitive to decreased tear volume, especially in the exposed interpalpebral area. The early effects of dryness are degeneration and death of epithelial cells, which may progress in severe cases to keratinization of the cornea and conjunctiva.
 - a. **Schirmer test.** The purpose of this test is the measurement of the **total (reflex and basal) tear secretion**. To minimize reflex tearing, the eyes should not be manipulated before starting this test. There is no contraindication to this test. The materials used are commercially available Whatman no. 41 filter paper strips 5 mm wide \times 30 mm in length, known as Schirmer tear test filter strips. The patient is seated in a dimly lit room, and the filter paper strips are folded 5 mm from the end. The folded end is placed gently over the lower palpebral conjunctiva at its lateral one-third. The patient keeps the eyes open and looks upward. Blinking is permissible. After 5 minutes the strips are removed and the amount of wetting is measured from the folded end. If the strips are completely wetted before 5 minutes, they may be removed prematurely. A normal patient will wet from 10 to 30 mm in 5 minutes; this is age dependent and decreases after the age of 60 years, but is rarely less than

10 mm in 5 minutes. Measurements greater than 30 mm at 5 minutes indicate that reflex tearing is intact but not controlled and, therefore, are of little diagnostic value. Between 10 and 30 mm of tear secretion may be normal, or basal secretion may be low but compensated for by reflex secretion. Values less than 5 mm on repeated testing indicate hyposalivation of basic tearing. There is a 15% chance of diagnostic error in this test.

- b. **Basic secretion test.** The purpose of this most commonly used test is to measure the basal secretion by eliminating reflex tearing. Topical anesthetic is instilled into the conjunctiva and a few minutes allowed to pass until reactive hyperemia has subsided. The room is darkened and the procedure is the same as in the Schirmer test I. Interpretation of the results is also similar. The difference between the results of this test and those of the Schirmer test I is a measurement of reflex secretion contraindications and any contraindication to the local anesthetic. Materials used are the Schirmer strip and proparacaine 0.5%.
- c. **Tear film breakup time (TFBUT).** The TFBUT is the time between a complete blink and appearance of the first random corneal dry spot, and indicates relative tear film stability. It should be performed *before any drops* are instilled. Saline-wetted fluorescein strip is touched to the

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lower tear meniscus to enhance visibility of dry spots. A shortened TFBUT of 1 to 2 seconds suggests mucin deficiency or other ocular surface abnormalities. Normal TFBUT is 10 to 15 seconds.

- d. **Rose bengal staining.** The purpose of this test is to ascertain indirectly the presence of reduced tear volume through **detection of damaged epithelial cells**. The eye is anesthetized topically with proparacaine 0.5%. Tetracaine or cocaine may give false-positive tests because of their softening effect on corneal epithelium. One drop of 1% rose bengal solution or a drop from a **saline-wetted** rose bengal strip is instilled in each conjunctival sac. Rose bengal is a vital stain taken up by dead and degenerating cells that have been damaged by the reduced tear volume, particularly in the exposed interpalpebral area. This test is particularly useful in early stages of conjunctivitis sicca and keratoconjunctivitis sicca syndrome. A positive test will show triangular stipple staining of the nasal and temporal bulbar conjunctiva in the interpalpebral area and possible punctate staining of the cornea, especially in the lower two-thirds. False-positive staining may occur in conditions such as chronic conjunctivitis, acute chemical conjunctivitis secondary to hair spray use and drugs such as tetracaine and cocaine, exposure keratitis, superficial punctate keratitis secondary to toxic or idiopathic phenomena, and foreign bodies in the conjunctiva. The stain will also color mucus and epithelial debris, which may mask the results. Certain patients who are normal will show some positive staining to rose bengal on the cornea. Because of this, conjunctival as well as corneal staining should be present before the diagnosis of keratoconjunctivitis sicca is made.

2. **Tear quality test** involves tests for the presence of mucus, protein, and tear film stability. Mucin lowers the surface tension of the tears and converts the hydrophobic corneal epithelial surface to a wettable hydrophilic surface. Mucin is produced by conjunctival goblet cells and spread by the action of the lids over the corneal epithelium. Mucin-deficient diseases such as Stevens-Johnson syndrome and pemphigus result in corneal desiccation despite normal tear volume, due to the lack of mucus as a wetting agent.
 - a. **A conjunctival biopsy** may be done to ascertain the presence or absence of mucin-producing goblet cells. Four percent cocaine solution on a cotton-tipped swab is applied directly to the lower nasal fornix, an area containing the highest population of goblet cells. After 60 seconds, a Vannas scissors and a jeweler's forceps are used to excise a conjunctival sample 5 mm long × 2 mm deep. The tissue is spread gently on a 2 × 2 cm cardboard, epithelial side up until it is flat. The cardboard is placed in 95% alcohol and sent to the pathology laboratory with a request for periodic acid–Schiff (PAS) stain. Histologically, the normal lower nasal fornix contains from 10 to 14 goblet cells per field at 200×. In a mucin-deficient state, this population is markedly diminished or absent. This procedure is extremely simple and painless. The conjunctiva heals rapidly over a 24- to 48-hour period. Local antibiotic ointment such as erythromycin or bacitracin should be instilled.
 - b. **A qualitative mucous assay** may be performed to determine the presence of mucus. Cotton strips 3 × 10 mm are placed in the inferior cul-de-sac of the unanesthetized eye for 5 minutes. Each strip is then placed on a glass slide and stained with PAS reagent. Color change is noted 1 minute later and compared with a sample from a known normal subject. If adequate mucus is present the strip will show a positive PAS reaction, turning dark purple. In the absence of mucus the reaction is negative. This test may be meaningful only in those eyes containing at least some tear film.

K. Tear secretion tests

Tests of tear secretion are important in ascertaining the **etiology of chronic tearing (epiphora)**. The causes of epiphora can be divided into (a) partial or complete obstruction of the excretory canal, (b) increased lacrimal secretion (see sec. II.J.1., above), and (c) decreased basal

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lacrimal secretion with secondary reflex tearing (see sec. II.J.1., above). Tear excretion involves the pumping action of the lids and good anatomic apposition of the patent punctal openings against the globe. Any lid abnormality such as entropion, ectropion, or punctal occlusion may be associated with chronic tearing. Examination of the eyelids prior to the test may reveal an anatomic etiology for chronic tearing, rather than a deficiency of the deeper nasolacrimal canal drainage system.

1. **Regurgitation test** is the test of the excretory patency medial to the lacrimal sac

(canalicular canals running in the lid margin). The examiner gently compresses the skin over and around the medial canthal ligament while observing the punctum under magnification. Obstruction medial to the lacrimal sac, i.e., in the canal, results in regurgitation of fluid, often mucoid or purulent, through the punctum when pressure is applied over the lacrimal sac. This obstruction is almost always complete and is usually associated with inflammation in the sac (dacryocystitis).

2. **The primary dye test** is used to test the patency of the entire excretory system (the nasolacrimal drainage system into the back of the nose). Fluorescein is instilled into the lower cul-de-sac. A small wisp of cotton on the end of a wire cotton applicator or a sterile cotton tip is placed 3.8 cm into the nose under the inferior meatus. (This is along the floor of the nasal canal.) After 2 minutes the cotton is removed and examined. If the cotton is fluorescein-stained, the test is positive and the system is patent and functioning. If there is no dye on the cotton, either the cotton was misplaced or the excretory mechanism is obstructed. There is no localizing value regarding the site of obstruction within the nasolacrimal canal.
3. **The secondary dye test** (lacrimal irrigation test) is another test of the excretory patency and is used if the primary dye test is negative. A 2-mL syringe is filled with saline and a lacrimal cannula attached to it. This cannula is placed in the lower canaliculus, entering through the lower punctum, and the saline is injected. The patient leans forward and the naris on the ipsilateral side is observed. If the patient tastes the saline in his or her throat or if fluorescein fluid comes from the naris, the test is positive. If the primary dye test is negative and the secondary dye test positive, the system is partially blocked. If both tests are negative, the excretory system is totally blocked. There is no localizing value to this test for lesions within the nasolacrimal system. Because the pressure of the injection may open a partially obstructed system, lacrimal irrigation without performing the primary dye test may be misleading.
4. **Canaliculus testing** is a test for the patency of the canaliculi or canals running in the lid margin. Clear saline is injected through the punctum of one canaliculus using a 2-mL syringe and lacrimal cannula. The opposite punctum on the same eye is observed. If saline returns through the other canaliculus, both are patent and the obstruction is in or beyond the common canaliculus beyond the medial canthus. If no fluid comes from the opposite punctum, at least one of the canaliculi is obstructed. This test is contraindicated in the presence of acute inflammation of the lacrimal sac.
5. **Dacryocystography** for localization of obstruction site is discussed under radiographic techniques (see sec. III.1.8., below).

L. Corneal sensation

Corneal sensation is tested prior to topical anesthetics by gently touching the cornea with a wisp of cotton (drawn out from the end of a cotton-tip applicator) and comparing each eye against the other on a 0 to 10 scale of increasing sensitivity. A more precise reading may be achieved using the Cochet-Bonnet anesthesiometer, which gives a scale reading relative

to the length of a retractable nylon filament extended from the end of the handle.

M. Transillumination

1. **Intraocular tumors** may often be detected by transillumination of the globe. Intense light, such as that from a small handheld flashlight, placed on the sclera in successive quadrants behind the ciliary body will be transmitted inside the eye, where it produces a red reflex in the pupil. Intraocular

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masses, such as malignant melanoma containing pigment, will block the light when it is placed over the tumor, thus diminishing or preventing the red reflex. The presence of tumor under a retinal detachment (detachments are commonly caused by intraocular tumors) may be detected in this manner; the test is also useful for distinguishing a retinal detachment resulting from causes other than tumor. Normally, retinal detachment will not interfere with the normal red reflex so produced.

2. **Atrophy of the iris pigment layer** or ciliary body may also be revealed by transillumination. Such atrophy is frequently seen in patients with chronic intraocular inflammation. This test should be performed in a completely darkened room, with the examiner dark adapted and the instrument placed 8 mm posterior to the limbus to avoid the ciliary body, which would normally cut off light entering the eye.

N. Exophthalmometry

The exophthalmometer (**Hertel**) is used to determine the degree of anterior projection or prominence of the eyes. This instrument is helpful in diagnosing and in following the course of exophthalmos.

1. **Technique.** The patient holds the head straight and looks directly at the examiner's eyes. Two small concave attachments of the exophthalmometer are placed against the lateral orbital margins, and the distance between these two points is recorded from the central bar. This distance must be constant for all successive examinations in order to judge accurately the status of ocular protrusion. The examiner views the cornea of the patient's right eye in the mirror while the patient fixes the right eye on the examiner's left eye. Simultaneously, the cornea is lined up in the mirror with the scale, which reads directly in millimeters. A similar reading is then taken from the left eye with the patient fixing on the examiner's right eye. The bar reading and the degree of exophthalmos are then recorded in millimeters; e.g., a bar reading of 100 might have right eye 17 mm, left eye 18 mm.
2. **Interpretation.** The normal range of exophthalmometry readings is 12 to 20 mm. The readings are normally within 2 mm of each other and indicate the anterior distances from the corneas to the lateral orbital margins. Exophthalmos is present if the reading is greater than 20 mm in one eye and may indicate a search for an underlying cause such as thyroid ocular disease or orbital tumor. A disparity of 3 mm

or greater between readings taken from each eye during a test is also an indication for further investigation, even though both readings may fall within the normal range.

O. Placido disk and Klein keratoscope

These simple instruments are useful in the qualitative diagnosis of corneal reflex regularity and irregular astigmatism. The presence of a pathologic state, such as subtle or gross scarring or early keratoconus, will cause the normally regular concentric circles viewed through the keratoscope or disk to be asymmetric or frankly distorted and irregular. The examiner holds the disk or keratoscope to his or her eye and observes the illuminated cornea of the patient through the aperture. Distortion or roughening of the rings may account for a marked decrease in vision through a cornea that may appear normal on initial examination. A focally indented area in the rings indicates a shortening of that meridian such as from a tight suture that may need to be cut to relieve astigmatism.

P. Keratometry

The keratometer is an instrument generally used for measuring corneal astigmatism in two main meridians. It is particularly useful in the fitting of corneal contact lenses, but may also be used to detect irregular astigmatism and early pathologic states such as keratoconus. Successive readings several months apart will indicate progression or stability of corneal disease. The device is similar to a slitlamp in use. The corneal reflex is evaluated for regularity and measured at 90-degree axes in the two meridians of greatest difference, i.e., the flattest and steepest planes.

Q. Gonioscopy

The visually inaccessible **anterior chamber angle** may be viewed directly with gonioscopic techniques that involve the use of a contact lens, focal illumination, and magnification. The contact lens eliminates the

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corneal curve and allows light to be reflected from the angle so that its structures may be seen in detail.

1. **Technique.** This procedure may be performed with topical anesthetic drops at the slitlamp and such lenses as the Alan-Thorpe, Goldmann, or Zeiss lenses, all of which have periscopic mirrors by which the angle is examined with reflected light. The patient may also undergo gonioscopy without the slitlamp while in the supine position when the Koeppel contact lens is used. The angle is viewed through a handheld microscope with the Barkan light held in the other hand giving bright focal illumination. Greater magnification is achieved with the Koeppel lens than with lenses on the slitlamp, thereby allowing greater magnification of details of the angle, but this technique is used less frequently because of relative inconvenience compared to lenses applied with the patient at the slitlamp.
2. **Purpose.** This technique is most useful in determining various *forms of glaucoma*,

such as open-angle, narrow-angle, angle-closure, and secondary angle-closure glaucoma, by allowing evaluation of the angle width (distance of the iris root from the trabecular meshwork) and study of the tissues in the angle of the glaucomatous eyes at various stages (see Chapter 10). Gonioscopy is also of great use in examining *other problems* within the anterior chambers, such as retained intraocular foreign bodies hidden in the recess of the angle. It is useful in the study of iris tumors and cysts as well as in the evaluation of trauma to the tissues in the area of the angle. With wide pupillary dilation the area behind the iris (posterior chamber), including ciliary processes, zonules, lens, and equator, may be seen in many patients.

III. Hospital or highly specialized office techniques

A. Corneal topography

Corneal topography is done with computerized machines which use video capture of concentric circle Placido disk images to produce videokeratographs in the form of color-coded dioptric contour maps which show even subtle variations in power distribution plots, and can calculate the power and location of the steepest and flattest meridians, similar to values given by a keratometer. Cool colors are lower in power than warm colors, e.g., blue = flat, red = steep, green = normal. The corneal modeling system uses 32 rings with 256 points analyzed on each ring with a power change resolution of 0.25 d. The EyeSys uses 16 rings with a fast-imaging processing time. Corneal *diagnosis and changes* may be monitored by sequential topography and include disorders such as keratoconus, contact lens warping of the cornea, postoperative healing patterns (keratoplasty, cataract, tight sutures, radial keratotomy, excimer laser photorefractive keratectomy), marginal degenerations, and keratoglobus.

B. Corneal pachymetry

Pachymeters measure corneal thickness (normal 0.50 to 0.65 mm, thicker peripherally) and are good indicators of endothelial function as well as being useful in calculating blade set for radial keratotomy. Optical pachymeters attach to the slitlamp and are quite reliable, but are subject to reader variation. Ultrasonic pachymeters can record readings at multiple corneal sites with a vertical applanating tip, thus minimizing errors caused by tilting, but also making peripheral readings more difficult.

C. Specular photomicroscopy

This camera-mounted, slitlamp-like instrument allows visualization and photography of the corneal endothelial mosaic. Wide-field microscopy encompasses 200 cells per frame and can be done at multiple corneal sites. Normal endothelial density averages 2,400 cells per mm² (1,500 to 3,500 range) and decreases with age. Cell shape is normally hexagonal. Microscopy will detect pleomorphism (cells deviating from normal shape), cell dropout as in Fuchs dystrophy, and polymegethism (abnormal cell size variation). All may contribute to endothelial dysfunction and corneal edema and may be seen in diabetes; following anterior segment surgery; in inflammation, glaucoma, and contact lens wear; and following

intracameral drug administration.

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D. Confocal scanning slit microscopy

Confocal scanning slit microscopy allows a direct, highly magnified, high-resolution viewing of corneal cells, structures, and organisms in patients. The instrument focuses on a single plane in the cornea while eliminating light from all other planes. The field of view is expanded via the scanning system and has a magnification of 200× and resolution of 9 μm. Confocal microscopy is used to follow healing after laser or traditional surgery and to help identify infectious organisms such as fungi and bacteria.

E. Fluorescein and indocyanine green (ICG) angiography of the fundus

1. **Purpose.** **Fluorescein** angiography (FA) has proved to be a valuable tool in the diagnosis and management of a large number of retinal disorders that affect either the retinal vascular system or the choriocapillaris, Bruch membrane, or the pigment epithelial layers. Disease states particularly amenable to evaluation by angiography include diabetic retinopathy, ocular histoplasmosis, macular edema, idiopathic preretinal macular fibrosis, retrolental fibroplasia, vascular occlusive disease, flecked retina syndrome, sickle cell retinopathy, viral retinopathy, retinal telangiectasis, von Hippel-Lindau disease, Eales disease, choroidal tumor, both primary melanoma and metastatic carcinoma, and benign hemangioma. **ICG** methodology is similar to FA. Compared to FA, ICG produces better choroidal vessel resolution but lesser resolution of retinal vessels. ICG is mainly used to detect occult choroidal neovascular membranes or their recurrence posttreatment, and for suspected retinal epithelial detachment. The fundic FA may provide three kinds of information:
 - a. **Documentation of the fine anatomic detail** of the fundus.
 - b. **Physiologic information** pertinent to the index of flow of blood to the eye and flow through the retinal circulation.
 - c. **Documentation of fundic pathology** when dye is seen passing vascular barriers that are ordinarily impermeable.
2. **Technique.** After the patient's pupils have been dilated, he or she is seated at a slitlamp mounted with a fundus camera and equipped with both exciter and barrier interference filters. These filters will allow only green light from the fluorescent dye passing through the vessels to be recorded on the film, thus exclusively outlining the vascular pattern and pathologic structures contained therein. Five milliliters of sodium fluorescein 10%, a harmless and painless dye, is injected into the antecubital vein. Photographs of one eye are taken at 5 seconds and then every second thereafter for 15 more seconds. Photographs will then be taken for up to 1 minute at 3- to 5-second intervals and then repeated at 20 minutes in both eyes. Occasionally, in patients with sensory epithelial detachments or diffuse retinal edema, photographs

will be taken at 1 hour or more.

3. **Side effects.** Normally, the patient will have some afterimage effect and a yellowish discoloration of the skin, both of which will disappear within a matter of a few hours. The urine will also be discolored for approximately 1 day. Transient episodes of nausea may occur, and rarely there may be transient vomiting. Fainting is uncommon but may be seen, particularly in young male patients. Such patients should be held in the office for 1 hour to ascertain that there is no more severe reaction following. Severe allergic reactions such as anaphylaxis or cardiorespiratory problems are extremely rare and should be handled by a competent medical team.
4. **Stages of the normal angiogram.** Dye is visible in the choroidal circulation approximately 1 second before its appearance in the retinal arterioles (arterial phase). It lasts until the retinal arteries are completely filled. The AV phase of the transit involves complete filling of both retinal arteries and capillaries and the early stages of laminar flow in the veins. The venous phase of the dye transit includes initial laminar flow along the walls of the veins and then complete venous filling. The transit time in the macula is the most rapid, and the retinal capillary bed is best resolved in the macula because of increased pigmentation in the retinal pigment epithelium (RPE), which will block out underlying choroidal fluorescence.

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5. **In interpreting the angiogram** the examiner may refer to a few terms that need definition.
 - a. **Pseudofluorescence** results from fluorescein leakage into the vitreous and is a reflected illumination from this body.
 - b. **Autofluorescence** pertains to true fluorescence of structures in the retinal area, such as drusen of the optic nerve head.
 - c. **A window defect** is a localized deficiency of pigment granules in the RPE through which choroidal fluorescence is seen.
 - d. **Pooling** is an accumulation of dye in a tissue space such as that between the RPE and Bruch membrane.
 - e. **Staining** is an increased accumulation of dye within tissue substance, such as the sensory retinal capillary bed.
 - f. **Blocked fluorescence** is interference with visualization of the normal underlying choroidal fluorescence, as in increased RPE thickness, increased choroidal pigmentation as in a nevus, or the presence of retinal hemorrhages or exudates in the sensory retina beneath the pigment epithelium.
 - g. **A filling defect** is an area of decreased fluorescence where circulation is occluded. It occurs in either the choroidal or retinal vascular bed. The rate of filling, emptying, and configuration assists the examiner in diagnosis and evaluation of various disease states of the fundus such as ischemic diabetic retinopathy.

F. FA of the iris

FA of the iris is performed to document abnormal vascular patterns, tumors, ischemia, and inflammatory patterns. Unfortunately, the iris pigment often absorbs emitted fluorescein enough to make this test worthwhile only in light- to medium-(hazel) pigmented eyes. It may be performed on the fundus fluorescein camera by dialing a plus lens into the optical system, pulling the camera farther back, and focusing on the iris. Photography is delayed a few seconds longer than in retinal angiography because of the longer arm-to-iris circulation time for the injected fluorescein.

G. ERG

1. **Purpose.** The ERG is an important instrument in the detection and evaluation of hereditary and constitutional disorders of the retina. These disorders include: partial and total color blindness, night blindness, retinal degeneration such as retinitis pigmentosa, chorioretinal degenerations or inflammations including choroideremia, Spielmeier-Vogt disease, leucic chorioretinitis, Leber congenital amaurosis, retinal ischemia secondary to arteriosclerosis, giant-cell arteritis, central retinal artery or vein occlusion, and carotid artery insufficiency. Toxicity secondary to administration of drugs such as hydroxychloroquine, chloroquine, and quinine may be detected and quantitated by the ERG. Siderosis, whether from local iron deposit or systemic disease, will also produce abnormal changes in the recording. Frequently, the ERG will not distinguish among these, but will indicate the presence of diffuse abnormalities. Retinal detachment will reduce the recording levels of the ERG, although ultrasonography is probably a better way to detect such detachment in the presence of an opacity of the ocular media. Systemic diseases associated with low-voltage ERG include hypovitaminosis A, mucopolysaccharidosis, hypothyroidism, and anemia. The ERG may also be used to rule out the retina as the level of blindness in certain conditions such as cortical blindness, dyslexia, and hysteria.
2. **ERG is a technique** of placing an ocular fitted contact lens electrode on the patient's eye so that recordings of electrical responses from various parts of the retina to external stimulation by light of varying intensity may be made. The A and B waves originate in the outer retinal layers, the A wave being produced by the photoreceptor cells and the B wave by the interconnecting Müller cells.
3. **Disadvantages.** The ganglion cells do not contribute to the ERG because their electrical signals are in the former spike, which cannot be recorded

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externally. Therefore, a normal ERG may be recorded in the absence of ganglion cells and in the presence of total optic nerve atrophy or advanced retinal diseases, such as Tay-Sachs disease, in which the metabolic defect is located in the ganglion cells. In addition, because the ERG is a mass response from the retina, diseases of the macula that represent only a small part of the retina will not be recorded on the ERG.

H. EOG

EOG is an electrical recording based on the standing potential of the eye.

1. **Use in retinal disease.** The EOG is useful in situations in which the ERG is not sufficiently sensitive to detect macular degeneration. This includes Best's disease (vitelliform macular degeneration), in which the ERG is abnormal even in carriers, and early toxic retinopathies such as those caused by chloroquine or other antimalarial drugs. Supranormal EOGs have been found in albinism and aniridia, in which chronic excessive light exposure appears to have resulted in attendant peripheral retinal damage. The EOG records metabolic changes in RPE as well as in the neuroretina. Therefore, it serves as a test that is supplemental and complementary to the ERG and, in certain disease states, more sensitive than the ERG.
2. **Use in eye movements.** By placing the skin electrodes around the eye and using the cornea as the positive electrode with respect to the retina, eye movements of both eyes can be recorded either separately or together, using bitemporal electrodes. This technique is most useful in recording various forms of nystagmus, and is particularly useful for clinicians who desire objective recordings of spontaneous and caloric-induced nystagmus. The technique is highly specialized, and the information produced therefrom is of use to only a fairly small number of clinicians.

I. Ultrasonography

Ultrasonography (echography). Diagnostic ocular ultrasonography has made possible the detection of intraocular abnormalities not visualized clinically because of opacification of the cornea, anterior chamber, lens, or vitreous, as well as pathologic processes involving the periorbital tissues. It provides much the same information as a computed tomography (CT) scan. Ultrasonography is analogous in many ways to soft tissue x-ray and consists of the propagation of high-frequency sound waves through soft tissue, with the differential reflection of these waves from objects in the beam pathway. The reflected waves create echoes that are displayed on an oscilloscope screen as in sonar or radar systems, producing a picture that is amenable to clinical interpretation. This technique has an advantage over x-rays or CT scans because it is a dynamic examination allowing innumerable views including studies of the moving globe. The main disadvantage is the need for direct contact with the globe or lid. Because of the highly sophisticated and expensive equipment involved and the necessity of dynamic interpretation of data, this technique is performed only by specialists within the field.

1. **Forms of ultrasonic testing** commonly used are A-mode, B-mode, high-frequency ultrasound; optical coherence tomography (OCT); and confocal scanning laser ophthalmoscopy.
 - a. **A-mode** is a one-dimensional time-amplitude representation of echoes

received along the beam path. The distance between the echo spikes recorded on the oscilloscope screen provides an indirect measurement of tissue such as globe length or lens thickness. The height of the spike is indicative of the strength of the tissue sending back the echo; e.g., cornea, lens, retina, or sclera produce very high amplitude spikes, and vitreous membranes or hemorrhage produces lower spikes. In B-mode ultrasound the same echoes produced in A-mode may be presented as dots instead of spikes. By the use of a scanning technique, these dots can be integrated to produce an echo representation of a two-dimensional (2-D) section of the eye rather than the one dimension seen with A-mode. The location, size, and configuration of structures are rapidly apparent with this technique. The combination of both A-mode and B-mode techniques simultaneously produces the most successful results in ultrasonic testing.

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- b. **Routine B-scan ultrasound** is performed using 10 MHz or less and is useful in detecting retinal detachments, swollen cataracts, hyphemas, and ciliary body detachment in hypotonous eyes.
 - c. **High-frequency ultrasound** is a newer, more sensitive technique using up to 50 to 60 MHz and detecting anterior segment pathology in great detail. It requires a water bath because depth of penetration is less than the 10 MHz ultrasound, reaching to 4 to 5 mm behind the cornea to iris, lens, and ciliary body. It detects ciliary body detachment, plateau iris, anterior chamber angle outline, adhesions, trabecular membranes, and small foreign bodies in the angle. **Tridimensional high-frequency scanning** also is being used to image the posterior segment and localize lesions and detachments in a 3-D image. Very high frequency scans are being developed, up to 150 MHz, particularly for corneal evaluation, e.g., for use with excimer laser surgery.
 - d. **OCT** complements all of the ultrasound techniques described in this section in posterior segment evaluation. It is a noncontact, noninvasive cross-sectional imaging technique that does not require immersion of the eye and can detect and measure changes in tissue thickness with micron-scale sensitivity to produce high-resolution measurements and images of the eye. Imaging of the anatomic layers within the retina and quantitation of the *optic nerve fiber layer* is quite accurate and correlates well with *glaucoma status*. The **confocal scanning laser ophthalmoscope** is a further complement to ultrasound in creating 3-D images of the optic nerve head using a series of tomographic optical sections of the structure being imaged. Such parameters as cup area and volume, cup/disk ratio, rim volume, and peripapillary nerve fiber layer (NFL) thickness may be calculated in the computer data system.
2. **Technique.** Both A and B types of ultrasound may be performed by either contact or immersion methods, both with the patient lying on a table.
 - a. **In the contact method**, a transducer probe shaped like a pencil is held in direct contact with the eye or closed lid, using a topical anesthetic with a

viscous coupling agent. In A-mode ultrasound, the examiner moves the probe around the eyes systematically until abnormal areas are found. These abnormal echoes are then tested with electronic variables to characterize them in terms of location, density, thickness, and shape. Because this equipment is portable, the examination may be done at the patient's bedside or in the operating room. In uncooperative young children the contact method may be the only practicable method. The major drawback is obscuration of the first few millimeters of the anterior segment and ciliary body.

B-scan contact techniques are similar to those employed with A-mode instruments. Without immersion, echo characterization is limited to determining tissue configuration and density, and resolution suffers somewhat due to the continuous rapid display on the oscilloscope. The anterior segment and adjacent areas are obscured by electronic artifact, as with the A-mode. B-scan using the contact method is satisfactory for detecting most kinds of intraocular pathologies, but is of limited value in the orbit.

- b. **Immersion.** The most successful use of ultrasound is with immersion methods, where the eye is in direct contact with a water bath, with the transducer tip held just beneath the water surface but not against the eye. Anterior segment examination as well as examination of the deeper ocular and orbital structures is very successful under these conditions. Although untoward experience is unlikely, immersion techniques are not used on recently traumatized or postoperative eyes unless the information derived will influence treatment.
3. **Interpretation.** Ultrasonic techniques may be used to ascertain the size, shape, and integrity of the wall of the globe and are frequently useful in detecting hidden anterior as well as posterior penetrating wounds. Collapse

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of the globe would be obvious on ultrasound, as is phthisis bulbi (end-stage shrinkage of the globe).

- a. **Anterior segment examination** reveals chamber depth and configuration as well as debris. Cataractous changes and subluxation of the lens may be identified most easily by B-scan techniques. Iris abnormalities such as iris bombé, recession of the root, cysts, and tumors may be shown if they are sufficiently large. Ultrasonography does not determine the functional status of the angle relative to outflow of aqueous in glaucoma, only its physical status.
- b. **Examination of the posterior segment** by either A- or B-scan ultrasound may pick up subtle vitreous changes such as asteroid hyalosis or synchysis scintillans. Membrane opacities such as retinal detachment, choroidal detachment, vitreous membranes, diffuse debris, and organized tissue are also easily detected. In cases of penetrating injury, the path followed by a foreign body may be detected on ultrasound as a track of moderate-amplitude echoes from hemorrhage or debris. An echo track may indicate the location of a foreign body exiting from the eye posteriorly. Intraocular tumors may be located, and configuration and degree of choroidal excavation may be helpful

clues to differentiating melanomas from metastatic tumors and benign hemangiomas; however, these criteria are not highly reliable with present techniques. Other masses such as subretinal hemorrhage and diskiform chorioretinopathy may simulate the tumor pattern. Vitreous membranes, retinal detachments, and choroidal detachments all produce distinctive pictures that may differentiate one from the other.

- c. **The localization of foreign bodies** is most accurately detected and located by a combination of A- and B-scan ultrasound. Radiographic techniques, however, have long been in use and also provide very accurate information about the localization and nature of most intraocular foreign bodies. Radiologically there is no way to differentiate among iron, copper, stone, or leaded glass fragments. Foreign bodies such as vegetable matter, nonleaded glass, or plastic, however, may not be sufficiently radiopaque to show up on film, whereas they would show up on ultrasound. Not only may the foreign body be located within the globe, but the amount and density of tissue damage or tissue reactions surrounding it may also be determined. Ultrasound is superior to CT scan if the foreign body is localized near the ocular wall, because a foreign body CT artifact may obscure whether the object is inside or outside of the eye. The magnetic character of a foreign body may be ascertained by pulsing a weak magnet over the eye and observing the behavior of the foreign body echo on the oscilloscope. Orbital foreign bodies, unlike intraocular ones, are much more difficult to locate with ultrasound because of the high reflection from the surrounding fat, muscle, and associated bony structures. Although in theory there is no limit to the size of foreign bodies that may be detected, practically speaking, small foreign bodies may be missed because the examiner may search randomly with the probe, not passing the beam through the exact area of the foreign body. Consequently, a negative report does not exclude foreign body in the eye, whereas the positive finding of foreign body is usually quite definite and highly localizing.
- d. **Orbital ultrasonography** is most useful in evaluation of soft tissue lesions causing exophthalmos. Pseudoproptosis due to a large globe or a shallow orbit may be detected, and cystic, solid, angiomatous, and infiltrative mass lesions may be differentiated from each other. Inflammatory disease such as pseudotumor oculi, Graves' disease, neuritis, and cellulitis are also amenable to localization and differentiation, as is retrobulbar hemorrhage. Fractures of orbital walls are not amenable to ultrasonic evaluation; radiographic study should be used in such situations.

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- e. **Surgical implications.** Ultrasonography has been an invaluable technique for determining the potential functional status of an eye in which the ocular media has made impossible ordinary clinical examination. ERG is frequently unreliable in the presence of opaque media; under such circumstances ultrasound may be the sole means of determining the integrity of intraocular contents. Ascertaining of normal posterior segment will allow a surgeon to

proceed with keratoplasty or cataract extraction with greater confidence of good results than when forced to operate on an eye with no knowledge of the status of the posterior segment. This technique is a noninvasive, well-tolerated, safe procedure with no known toxicity.

- f. **Intraocular lenses (IOLs).** A very frequent use of ultrasonography is the determination of certain ocular measurements such as anterior chamber depth and global length. This, coupled with keratometry readings, will allow a surgeon to determine which implant power will make a cataract patient emmetropic, hyperopic, or myopic postoperatively (see Chapter 7, sec. VII.B.).

J. Scanning laser polarimetry (SLP)

Scanning laser polarimetry (SLP) evaluation of retinal nerve fiber layer (NFL). The NFL is composed of the axons of the 1 to 2×10^6 retinal ganglion cells. The nerve fiber analyzer and the GDx combine polarimetry with the scanning laser ophthalmoscope. With the aid of digital enhancement, scanning laser ophthalmoscopes can show the NFL with high lateral resolution and contrast even through a small pupil and unclear media. SLP is done using a scanning laser ophthalmoscope coupled with a polarization modulator, which detects the birefringent properties of the retinal NFL resulting from its microtubule substructure. Data obtained are *relative*, not absolute, NFL thickness. The focal NFL defects are more sensitive indicators of **glaucomatous optic atrophy** than changes in cup size. Abnormally shaped disks, e.g., tilted or myopic, can also be evaluated more accurately for neurological loss.

K. Radiologic studies of the eye and orbit

Radiologic examination of the eye and orbit is useful in evaluating trauma, foreign bodies, and tumors.

1. **Anatomy.** Each orbit is a four-sided pyramidal cavity with the apex aimed posteromedially and the base opening onto the face. It is made up of seven bones and divided into the roof, lateral wall, medial wall, and the floor. Detailed anatomy is described in Chapter 4.
2. **Routine radiologic views,** in many cases, will reveal as much information as a CT scan and are indispensable in cases in which a patient cannot cooperate for the longer scanning procedure. They are of little use in soft tissue injuries of the eye. X-ray studies of the orbits are more difficult than x-rays of other sites of the body because of the superimposition of other bones of the skull. The patient is placed on the radiographic table, usually in the prone position. The head may be adequately adjusted and immobilized by a clamp device, headband, or sandbags. Several variations of position may be used as well as tomographic techniques to localize at a particular depth.
 - a. **Caldwell view** is a posterior–anterior (PA) projection of the orbit. The patient is in prone position with the forehead and nose resting on the table. This

position offers the following **advantages**: (a) the petrous ridges are projected downward and there is a clear visualization of the **orbital rim and roof**, (b) the **greater wing of the sphenoid** is easily detected as it forms the large part of the lateral wall, (c) the **orbital section of the lesser wing of the sphenoid** is projected close to the medial wall, (d) the **superior orbital fissure** is clearly seen between the greater and lesser wings of the sphenoid, and (e) the **foramen rotundum** is projected under the inferior rim of the orbit.

- b. **Waters view.** This PA film allows additional visualization of the orbital and periorbital structures. The patient is again prone with the head extended so that the chin lies on the table and the tip of the nose is approximately 4 cm above the table. The Waters view allows a clear **view of**

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the maxillary antrum separate from the superimposed petrous bones; the petrous ridges are projected downward, whereas the antral contours are complete and not deformed. Visualization of the maxillary antrum is of use in revealing orbital pathology. The **inferior orbital rim, the lateral wall, the zygomatic arch, and frontal and ethmoidal sinuses** are all demonstrated in this view.

- c. **The oblique view** is used for visualization of the outer wall of the orbit and should be taken from both sides. The patient rests with cheek, nose, and brow of the side of interest resting on the table. The x-rays are projected through the occiput and exit through the center of the orbit. This technique obtains better visualization of the **outer rim of the orbit** and is of particular interest if orbital rim fracture is suspected.
- d. **The Rhese position** is useful for demonstration of the **optic canal**. The patient is prone with head adjusted so that the zygoma, nose, and chin rest on the table. The structures that are visualized are the optic canal (appearing in the lateral quadrant of the orbit), the ethmoid cells, the lesser wing of the sphenoid, and the superior orbital fissure. If the patient is unable to lie prone, this film may be taken in the supine position as well.
- e. **The lateral view** is useful for localization of **foreign bodies**. The patient lies on the side, and the outer canthus of the orbit of interest is placed against the film. The x-rays are directed vertically through the canthus.
3. **Orbital tomography.** Body section radiography (**polytomography**) is a method whereby the examiner may blur the superimposed surrounding structures and clearly visualize a given spot at a given depth. During exposure the x-ray tube is moved in one direction above the object and the film is moved in the opposite direction with the tube adjusted so that the fulcrum point is at the level of anatomic interest. This plane will then be shot focused against the blurred anatomic structures around it. Tomography is of use particularly in **localizing small fractures** as well as in determining the **extent of linear fractures** and the presence of **orbital tumors**. In conjunction with specialized routine views, polytomograms are believed by most radiologists to be as informative as a CT scan.

4. **CT scan.** The CT scan's ability to delineate tissues of varying density make it an invaluable diagnostic tool. Routine CT scans are usually multiple axial or transverse "cuts," 8, 2, or even 1 mm apart, depending on the lesions being evaluated, starting at the skull vertex and going to the skull base. As such, the orbital walls, eye, and extraocular muscles are sectioned longitudinally in the horizontal plane. Orbital and extraocular examinations are enhanced by coronal and sagittal sections. Radiopaque medium may be injected during the scan to demonstrate vascular abnormalities. The CT is the study of choice in soft tissue inquiries. Spatial resolution of better than $1 \times 1 \times 1.5 \text{ mm}^3$ provides fine detail. Cuts 1 to 2 mm should be used especially for injuries such as potential optic nerve damage or localization of ocular or orbital foreign bodies of varying composition and density. Blow-out fractures with muscle incarceration are best seen with coronal sections through the orbital floor and maxillary antrum. Incarceration of muscle may be distinguished from that of fat. Other diagnoses possible with CT scanning include tumors or hematomas of the lids, extraocular muscles, orbit, or optic sheath, transected muscle or optic nerve, incarcerated muscle, ruptured globe, dislocated lens, vitreous hemorrhage, choroidal or retinal detachment, fractures of the optic canal, fracture of any wall, and secondary sinus involvement. The main disadvantages of CT scanning are poor contrast between some different soft tissues, possible radiation hazards (orbital CT scan = 2 to 3 rad, similar to an orbital series of skull x-rays), beam-hardening artifacts created by metallic objects or cortical bone, and lack of direct scanning in the sagittal plane. Indicated uses of CT versus magnetic resonance imaging (MRI) are discussed in sec. III.K.5., below. CT

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is not sensitive enough to be the sole diagnostic factor for open globe injury, but must only complement other clinical findings.

5. **MRI** is the procedure of choice for soft tissue anatomy and pathology and vascularized lesions of global, orbital, and neuroophthalmic structures from the orbit through the brain.
- a. **Advantages and disadvantages.** The patient is in a magnetic field and not exposed to ionizing radiation. Application of a radiofrequency pulse to various tissue protons causes a change in the intrinsic spin and magnetic vector in many nuclei. The superior soft-tissue contrast is a result of differing T1 (longitudinal or spin-lattice relaxation time) and T2 (transverse or spin-spin relaxation time). Simply said, long T1 values yield a dark (hypointense) signal and long T2 values yield a bright (hyperintense) signal. The technique is therefore extremely safe as long as the area examined is *free of foreign magnetic metal* and the patient has *no cardiac pacemaker*, which may be turned off or on by the MRI.
- Other advantages of MRI are that the technique is not hampered by bone, which, because of low molecular mobility, is relatively invisible on the images. Soft tissues are thus seen in an unobstructed fashion; anatomic delineation of normal and abnormal structures as well as a metabolic profile of those structures is obtained. Better resolution is obtained with 3-D isotropic images

where thinner slices (2 mm) are taken, and better contrast is obtained on 2-D images with thicker slices (3 to 5 mm), which give greater signal to noise ratios. Lesions smaller than 2 mm are best seen on 3-D images, because they do not blend into their surrounding tissues, whereas larger lesions can be demonstrated on either 2-D or 3-D imaging. MRI is capable of differentiating hemorrhages, ischemia, multiple sclerosis, and tumors of the brain as well as virtually all ocular and orbital structures.

- b. **Ocular indications** for use of MRI (usually 3-D) and/or CT include ocular trauma, tumors within opaque media when ultrasound is equivocal, and suspected intraocular foreign bodies. *MRI should not be used* if the intraocular foreign body is thought to be ferromagnetic (e.g., BBs, iron, unknown composition), however, and CT and ultrasound should be used for such evaluations. IOL haptics of titanium or platinum are not a contraindication to MRI. MRI can distinguish retinoblastoma (low-intensity mass) from hemorrhage or exudate, which appears brighter, and from Coats's disease or toxocariasis because of the latter two having bright T2-based signals. MRI will distinguish choroidal melanotic melanomas from nonpigmented tumors and effusions, but not from fat.
- c. **Orbital indications** for CT and/or MRI are proptosis, papilledema, and orbital inflammatory, infectious, or neoplastic disease. Two-dimensional imaging is commonly used. Excellent contrast is provided between fine cortical bone, orbital fat, extraocular muscles, optic nerve, the globe, and the numerous disease processes that may involve these structures. Dye-contrasted CT and MRI resolve vascular lesions with excellent delineation, e.g., hemangiomas, carotid–cavernous sinus fistulas, and thrombosed ophthalmic veins.
- d. **Neuroophthalmic indications** for CT and/or MRI include the above orbital disorders, if unexplained after orbital evaluation, plus unexplained optic and cranial neuropathies, eye movement disorders, visual field defects, or any other signs or symptoms of intracranial disease. MRI images are generally superior to CT in delineating vascular or solid lesions in the sella turcica, cavernous sinus, optic chiasm, posterior fossa, and brain stem. MRI also shows multiple sclerosis plaques and hemorrhages better than CT, but CT is superior if a calcified lesion is under evaluation. The election of CT, MRI, or both must be based on clinical suspicion of the nature of the disease, but with faster scan time, finer resolution use of paramagnetic contrast agents, increased availability,

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lack of radiation exposure, and decreasing cost taken into consideration. MRI may progressively become the procedure of first choice over CT scanning.

- 6. **Magnetic resonance angiography** is a noninvasive method for imaging the carotid arteries and major cerebral blood vessels. The technique is based on phase shift in the velocity of blood flow through the vasculature and can detect atherosclerotic plaques, aneurysms, and dissections. Intraarterial angiography is still superior for

detecting aneurysms.

7. **Other noninvasive tests for carotid disease** include oculoplethysmography and pneumoplethysmography, transcranial or external Doppler, and carotid ultrasonography with duplex scanning.
8. **Dacryocystography** is the radiographic evaluation of the excretory system in an attempt to localize the precise **site of obstruction**. The procedure will vary with the radiologist. Water-soluble contrast medium such as cyanographin or salpix is used. The lacrimal irrigation test (secondary dye test) with the patient at an x-ray machine is performed and 1 mL of contrast solution is injected through the lower canaliculus. AP Waters and lateral projections are taken of the excretory system. If both sides are injected simultaneously, a back view should be taken in case the lateral views overlap. The results of radiographic examination will reveal the site of obstruction. This is of particular value in partial or intermittent obstruction, obstruction secondary to trauma, or obstruction associated with diverticulum or fistula. **Contraindications** to the test are radiologic contraindications as determined by the radiologist, acute dacryocystitis, and allergy to iodide.

L. Anterior chamber aspiration (keratocentesis)

1. **Indications.** Diagnostic aspiration of aqueous from the anterior chamber is indicated for (a) specific identification of intraocular microbes, (b) identification of inflammatory cell types indicative of disease type, and (c) determination of specific antibodies in the aqueous and comparison of these to serum antibodies against the same antigen in an attempt to localize antigens to the eye.
2. **Technique.** Keratocentesis may be carried out on an outpatient basis in the minor surgery room. A lid speculum is applied and, after a single proparacaine drop is instilled, a cotton-tipped applicator moistened with cocaine 4% is applied for approximately 15 seconds to an area of conjunctiva near the inferior limbus. This area is thereby anesthetized so that it may be grasped firmly with a toothed forceps. A 30-gauge disposable needle attached to a disposable tuberculin syringe is then inserted into the cornea near the forceps with minimum pressure while the examiner slowly turns the syringe barrel back and forth in his or her finger. As the bevel of the needle enters the anterior chamber, the examiner's assistant withdraws the plunger, thereby aspirating 0.1 to 0.2 mL of aqueous. The needle tip is kept over the iris at all times to avoid hitting deeper ocular structures. If the chamber shallows so that the anterior surface of the iris approaches the site of needle penetration, the bevel should be withdrawn and the procedure halted regardless of the amount of fluid withdrawn. At the end of the procedure, antibiotic ointment and cycloplegic drops should be applied, and a light patch put over the eye for a few hours. Keratocentesis is basically painless, although hyphema may develop in patients with neovascularization of the iris; it is, therefore, not recommended in such a clinical situation. There may be a transient increase in IOP for 12 hours after paracentesis, particularly in patients with Behçet syndrome. The etiology of this pressure increase

is unknown.

3. **Diagnostic tests.** The aqueous fluid so withdrawn is very limited in quantity; consequently, the clinician should have a clear idea of which tests are desired at the time of the tap so that no fluid is wasted. Tests include bacterial cultures, parasitic or cytologic examination using conventional stains, or fluorescent antibody stains for viruses and dark-field examination for treponemas. Aqueous can be concentrated on a filter disk (Millipore,

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Bedford, MA) for electron microscopic examination or prepared by wet fixation for Papanicolaou testing for malignancy. Serologic examination of the aqueous humor is of value if specific antibody is present in the aqueous in higher concentration than in the circulating serum. This finding is indicative of the presence of antigen within the eye; such antigen is most likely the cause of a given disease state, e.g., toxoplasma. Serologic examination must be done in a hospital university research laboratory or by the state laboratory. In case of **endophthalmitis**, aqueous cultures and smears are of **limited use**. Vitrectomy is the diagnostic procedure of choice (see Chapter 9).

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