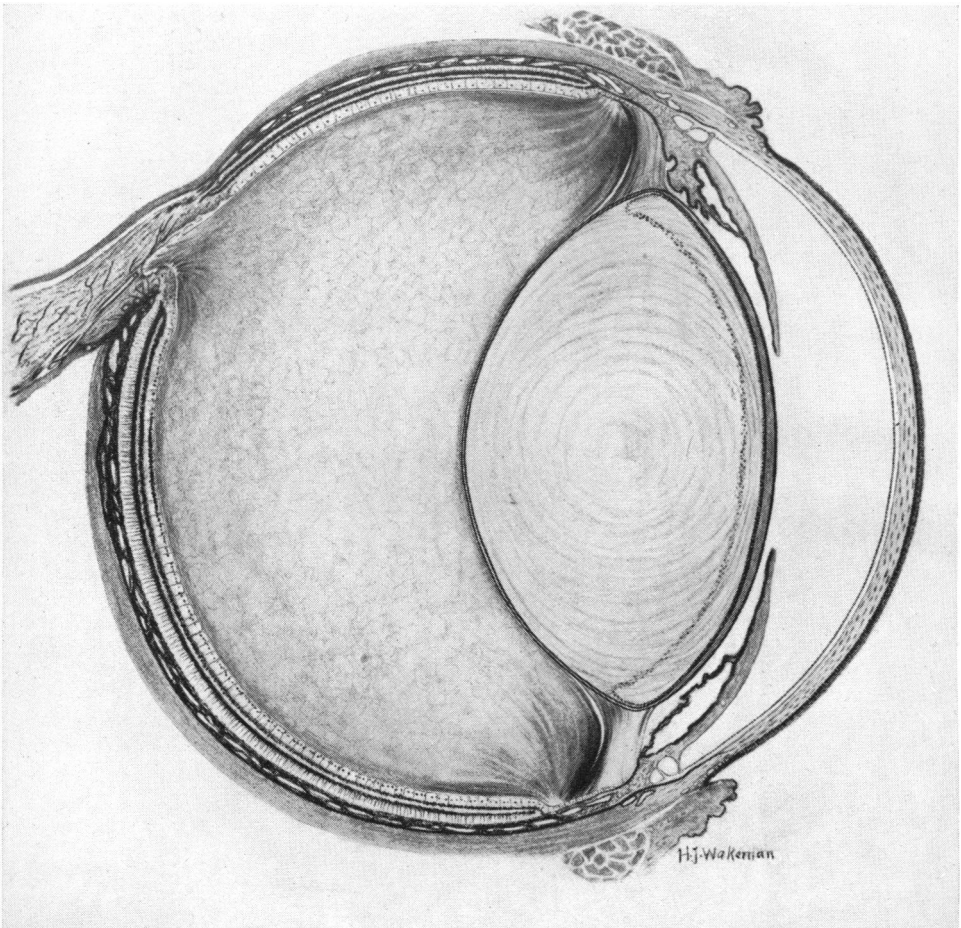

Semi-schematic drawing of a vertical axial section of the rabbit eye. The drawing is based chiefly on two sections: one, an almost ideal histologic section, which was used for general outlines and for details of the retina, choroid, and optic nerve; the other, from a specimen in which the vitreous had been injected with India ink, and was used for details of vitreous and zonule. The chief axis of the eye is represented a little too long in proportion to the transverse. Retina, choroid, and lens capsule are too thick, but have been purposely drawn to better bring out their structures.

16. Senckpiehl: Inaugural dissertation, Berlin, 1887.
17. Müller: Deutsch. Klinik, 1869, xxi, p. 321; 1870, xxii, p. 27.
18. Kerner: In appendix; Weiss, Die neuesten Vergiftungen durch verdorbene Würste, beobachtet an neun und zwanzig Menschen in und um Murrhardt im Königreich Würtemberg, nebst der Versuche einer physiologisch-pathologischen Darstellung der Einwirkung dieses Giftes auf den Menschen, Karlsruhe, 1824.
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20. de Saint-Martin: Bull. et mém. Soc. méd. d. hôp. de Paris, 1920, xliv, p. 52.
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THE ANATOMY AND HISTOLOGY OF THE EYE AND ORBIT OF THE RABBIT*

FREDERICK ALLISON DAVIS, M.D.
Madison, Wis.

FOREWORD

The material on which this study is based has been collected and studied from time to time during the past few years. The work was done chiefly in an effort to acquire a better knowledge of the histology of the rabbit's eye to be used as a basis for interpretation of a large collection of pathologic eyes.

Presentation of this study has seemed worth while since considerable experimental work is now being done on the rabbit's eye, and no general survey of the subject is available. Krause, Gerhardt, and Bensley have some material concerning the rabbit's eye. The first two of these texts are in German, and the last mentioned is primarily a dissecting manual; consequently, they are only of limited service, though excellent in many particulars. There are errors and omissions in them which seriously handicap one at critical points.

Numerous monographs and papers have been written dealing usually with some specialized phase of the subject, and

* From the Department of Ophthalmology, University of Wisconsin. Candidate's thesis for membership accepted by the Committee on Theses.

some of these have been used in the preparation of this paper when the writer's deductions seemed convincing. These are largely in foreign languages, however, and so are lost to the average American reader. These papers are listed in the bibliography.

With the time limit required for the presentation of this paper it has been impossible to give an exhaustive study of every detail of the gross and microscopic anatomy of the rabbit's eye. It is my hope to elaborate and complete this study at some future date. At present, the paper should be considered as a general survey of the gross and microscopic anatomy of the orbit and globe of the rabbit. Certain newer observations are stressed, namely, the absence of Bowman's membrane of the cornea; more specific nature of the sensitive streak of the retina; the relations of the sheaths of the optic nerve as they join the sclera; the direct communication between the intervaginal spaces of the nerve and the perichoroidea of the choroid and sclera; the practical absence of a lamina cribrosa in the rabbit; more specific descriptions of the filtration angle; and more exact information regarding the venous drainage of the orbit. One of the most striking observations concerns the venous drainage of the orbit. Dissections routinely reveal a large venous sinus which hugs the globe and Harder's gland, practically surrounding the entire muscle cone. No mention has been found anywhere in the literature of this large structure which is always encountered on enucleation and in dissection. For want of a better name we have called it the orbital sinus.

This study is based on original dissections and solely on our own histologic material.

PREPARATION OF MATERIAL

Gross dissections have been made on fresh specimens and also on material fixed in 10 per cent. formalin. Special study of the vascular supply has been aided by injection of the

arteries and veins, using gelatin and gelatin starch masses with different pigments. The veins, especially the orbital sinus, are shown equally well with ordinary formalin fixation without special injection of the vessels. The orbital contents are best studied by complete removal of the bony walls of the orbit. The various structures can thus be easily dissected without injury.

The material for histologic study has been prepared in different ways. Formalin, Zenker's, and Bouin's solutions have been used. Zenker's or Bouin's is much more satisfactory, as a rule, since there is less shrinking of the tissues, particularly of the choroid and retina.

Sections of the whole eye were cut in celloidin, using the dry celloidin (cedar oil) method as published by Friedenwald, and first suggested to the writer by Finnoff. Paraffin sections have been used for the study of special parts of the eye and the surrounding tissues.

Most specimens have been stained in hematoxylin and eosin, although van Gieson's stain has been found very useful in studying certain parts of the eye.

THE ANATOMY AND HISTOLOGY OF THE EYE AND ORBIT OF THE RABBIT

ORBIT

The orbits of the rabbit are situated in either side of the skull and their openings are directed almost at right angles to the transverse plane of the head, the exact angle being eighty-five degrees. The visual axes are directed laterally and slightly upward. The rabbit thus furnishes an example of purely monocular vision. The orbits of the rabbit are much more complete than those of many of the lower mammals, though not so well developed as those of the human. The orbital walls are well developed in both height and length, but the depth is shallow; the latter, however, is considerably

increased by dense fibrous projections from the rim. The apex of the orbit is the inner wall, which fuses with that of the fellow-eye to form a single bony partition in the region of the optic foramen.

The orbital cavity (fig. 2) may be said to have six walls, of which four are bony. The inferior is muscular, and the external wall is the orbital orifice. The superior wall is made up largely of the frontal bone, which curves over to form a crest known as the supra-orbital process. The latter shows two projections from its body, one anterior and one posterior. Between these and the body of the frontal bone are located the anterior and posterior supra-orbital incisures. These are transformed by ligaments into foramina, of which the anterior transmits the frontal artery and nerve, as well as the angular vein; the posterior serving for the passage of the supra-orbital artery and nerve.

The inferior wall is largely muscular, though in the anterior portion there is a bony projection of the maxilla which supports the last three molar teeth. The upper surface of the pterygoid process of the sphenoid furnishes a small bony shelf. The remainder of the inferior wall, however, is made up of the muscles of mastication.

Krause and other writers frequently refer to the floor of the orbit as membranous and have given the impression that a membrane, namely, the membrana orbitalis, separates this from the maxillary fossa. This membrane in dissections, however, proves to be nothing more than the delicate connective tissue or membranous sheath which surrounds the soft parts of the entire orbit.

The anterior wall is formed by the lacrimal bone, the ethmoidal portion of the orbito-sphenoid, and the supra-orbital process of the maxilla. The posterior wall is formed by the temporal bone, the greater wing of the alisphenoid, and the posterior wing of the orbito-sphenoid.

The internal wall is concave, and is formed by the inferior

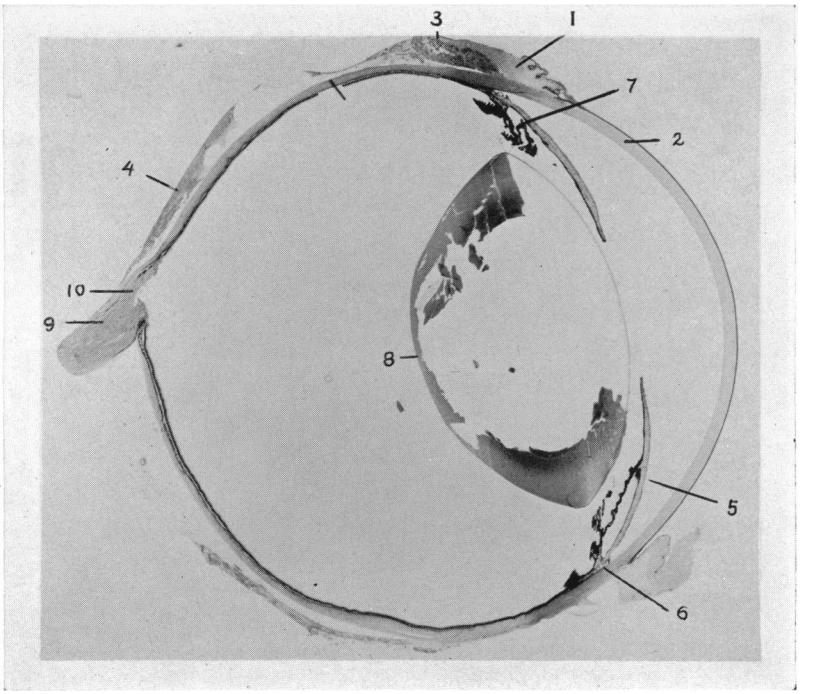

Fig. 1.—Median sagittal section of normal rabbit eye: 1. Conjunctiva. 2. Cornea. 3. Insertion of superior rectus. 4. Insertion of retractor bulbi. 5. Iris. 6. Ciliary body. 7. Ciliary processes. 8. Lens. 9. Optic nerve. 10. Papilla (hematoxylin-eosin).

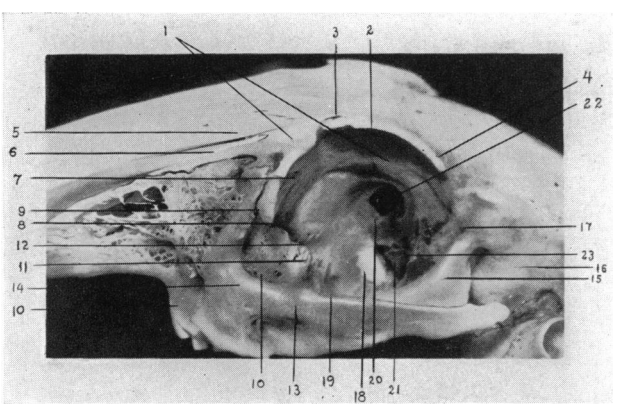

Fig. 2.—Lateral view of the rabbit skull to show the orbit: 1. Frontal. 2. Supra-orbital process of frontal. 3. Anterior supra-orbital incisure. 4. Posterior supra-orbital incisure. 5. Nasal. 6. Premaxilla. 7. Lacrimal. 8. Subcutaneous process of lacrimal. 9. Nasolacrimal canal opening. 10. Maxilla. 11. Alveoli of cheek teeth. 12. Infra-orbital canal. 13. Zygomatic arch. 14. Maxillary root of zygomatic arch. 15. Zygomatic process of squamosal. 16. Squamosal. 17. Temporal foramen. 18. Alisphenoid. 19. Palatine. 20. Orbito-sphenoid. 21. Basisphenoid showing through a break in the paper-like wall of the alisphenoid. 22. Optic foramen. 23. Superior orbital fissure (× 1.7).

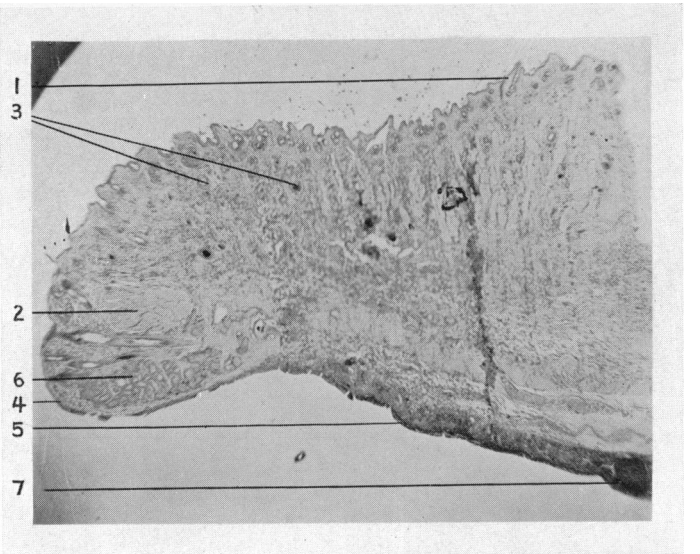

Fig. 3.—Vertical section of lower lid: 1. Skin. 2. Orbicularis muscle fibers. 3. Hair-follicles. 4. Transition of skin into conjunctiva. 5. Conjunctiva, with lymph-follicles. 6. Meibomian gland. 7. Krause's gland (accessory tear gland) (hematoxylin-eosin, × 15).

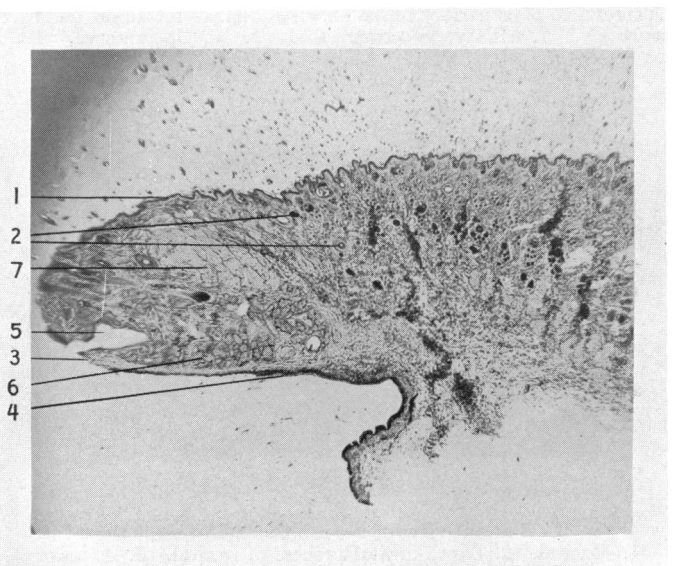

Fig. 4.—Vertical section of upper lid: 1. Skin. 2. Hair-follicles. 3. Transition of skin into conjunctiva. 4. Conjunctiva. 5. Opening of Meibomian gland. 6. Meibomian gland. 7. Orbicularis fibers (hematoxylin-eosin, × 15).

portion of the orbital process of the frontal, the wing of the sphenoid, and the maxilla below. This wall does not have the cone-shaped contour of the human orbit, but is more saucer-shaped. The optic foramen perforates it, the right and the left foramina uniting directly into a single canal, and this, in turn, opens directly into the cranium by a single orifice. The foramen is about 4 mm. in diameter. Its position differs from that of the human in that it is in the upper and posterior portion of the socket.

The external wall is represented by the orbital orifice. The inferior portion of it, however, is bordered by the zygomatic arch.

The bony margin of the orbit appears roughly quadrilateral, though it is circular before the removal of the soft parts. It is 20 mm. in diameter, measured from the supraorbital crest of the frontal bone to the zygomatic arch, and 21 mm. measured from the subcutaneous process of the lacrimal bone to the zygomatic process of the squamous portion of the temporal. The circular margin is broken at two places, namely, at the temporal fossa and at the anterior root of the zygomatic arch. In life (or fresh specimens) the temporal fossa is bridged by a ligament and the anterior angle is filled by the inferior portion of the lacrimal gland, thus making the effective orbital margin practically circular. A second ligament from the posterior process of the supraorbital crest to the crest of the zygomatic process of the squamosa encloses the temporal fossa.

The depth of the orbit measured from the plane of the orbital rim to the inferior border of the optic foramen is 19 mm. The vertical diameter of the orbital rim makes an angle of approximately thirty degrees with the sagittal plane of the head. Since the eye is directed laterally, this means that a considerable portion of the superior surface of the eyeball is not covered by bone. This exposed portion of the globe projects about 12 mm. beyond the rim of the supra-

orbital crest, while the middle of the cornea projects only 5 mm. beyond the edge of the zygomatic arch.

The protrusion of the eye from the socket and the very large cornea obviously provides a wide range of vision; at the same time the globe is more exposed to trauma.

LIDS

The average width of the palpebral fissure is 10 mm. and its length 16 mm. The upper lid is shorter and thicker than the lower. The distance from the upper palpebral margin to the upper fornix of the conjunctival sac is 8 mm., while the same distance for the lower lid is 13 mm. At rest (open), both lid margins are near the corneal borders, the lower being somewhat more advanced than the upper. The cilia are long on the posterior half of the upper lid and short on the anterior half, while on the lower lid they are longer in front and shorter behind. On each lid the transition from long cilia to short is abrupt and extreme, the short cilia being scarcely distinguishable. On the upper lid the cilia are larger and more numerous than on the lower and they are directed backward. On the lower lid they stand out much straighter. It appears that this arrangement of cilia combines maximum protection for the eyes with maximum range of vision. There is but one lacrimal punctum and this is located on the inner surface of the lower lid, 3 to 4 mm. from its border, close to the nasal angle, and at the lower end of the caruncle. The inner surface of the lower lid also bears an elongated mass of lymph-follicles.

The tarsal border of the lids is pigmented (figs. 3 and 4). The transition between the epithelium of the skin and of the conjunctiva occurs beyond the inner tarsal margin, thus more on the inner surface of the lid than in the human. The Meibomian glands, forty to fifty in number on each lid, are slightly smaller than in the human. The tarsal border of the lid is thinner in relation to the other portions of the lid than

in the human. In other words, it does not present the same sharp contour but is more pointed. The lids are united by the temporal and nasal ligaments, the nasal being the stronger. These canthal ligaments are not so well developed as in man. The histologic structure of the lids is similar to that of man, namely, skin, orbicularis muscle, tarsus, and conjunctiva. The bundles of the orbicularis muscle fibers are fairly well developed.

The palpebra tertia (plica semilunaris) or third eyelid is a fold of conjunctiva reflected from the inner canthus and enclosing a saucer-shaped plaque of cartilage which exactly conforms to the curvature of the globe (figs. 5 and 6). The cartilage makes up about one-eighth of the thickness of the entire structure, the remaining portion being produced by glands, fat, and loose areolar tissue (fig. 7). The gland of the third eyelid is thin and flat and covers much of the external surface of the cartilage. Its ducts, several in number, pierce the cartilage and open on the inner surface. This lid measures about 10 mm. from base to apex. It is 12 mm. wide and 1.2 mm. to 2.2 mm. thick in the cartilaginous portion, tapering to a point at the free margin, which is pigmented. There is a row of fine papillæ on the outer surface near the margin. Krause states that the glandular tissue in the third eyelid is a part of Harder's gland, but our histologic study of this structure does not substantiate this statement. The gland is made up of small acini, the cells of which contain numerous secretion granules (fig. 8). It has the appearance of a typical serous gland. Löwenthal has described this gland in great detail. (For the structure of Harder's gland see below.)

The third eyelid contains no muscles, though a slip from the levator is attached to its base at the upper margin. It can advance more than two-thirds of the distance across the eye, almost covering the cornea. This action can best be studied while the lids are held open with a speculum. Irrita-

tion of the eye results in prompt withdrawal of the eye into the socket and the "closing" of the third eyelid. The retraction of the globe is brought about chiefly by the action of the retractor bulbi muscle, and probably also by the recti muscles. (This will be described later.) The retractor bulbi muscle pulls the eyeball backward, pressing it against Harder's gland and the orbital sinus, which, in turn, are pressed against the wall of the orbit. The gland is loosely attached to the surrounding tissues by delicate areolar tissue and so slips forward and is partly extruded from the orbit and thus presses the third eyelid, to which it is firmly attached, outward across the eye. Since it conforms to the contour of the globe and adheres by suction to it, its motion is lateral across the surface of the eyeball. Relaxation of the retractor bulbi allows Harder's gland to slip back into its normal position, and the third eyelid is thus drawn with it. It appears that the levator muscle contributes to this action through a slip described later as the retractor palpebræ tertia. A small, semilunar shelf of cartilage projects back under Harder's gland for about 2 mm. The outer edge of the gland thus rests on and is firmly attached to the cartilage. The mechanism described above is much more readily understood when one considers that the orbital contents are made up largely of the extra-ocular muscles, the above-mentioned Harder's gland, and the venous sinus surrounding it. The absence of a large mass of fat behind the globe, such as we find in the human, is striking. In fact, there is little fat in the orbit except for small, isolated masses which are found here and there, attached to the glands and muscles.

The third eyelid is surmounted by a small, triangular area of skin, the caruncle, which blends with the upper and lower lids at the inner canthus (fig. 6). The base of the caruncle is about 5 mm. broad, and its depth from base to apex is about 2 mm.

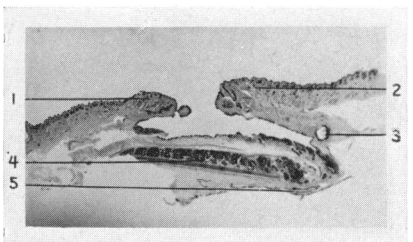

Fig. 5.—Vertical section through lids and palpebra tertia near the nasal angle: 1. Upper lid. 2. Lower lid. 3. Lacrimal duct near the punctum. 4. Palpebra tertia (showing cartilage and glands). 5. Opening of duct from Harder's gland (hematoxylin-eosin, × 4.6).

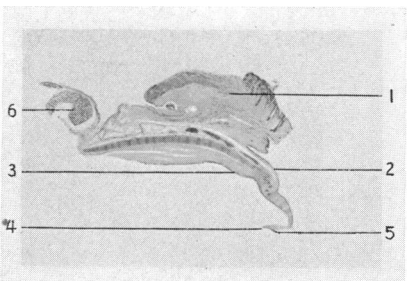

Fig. 6.—Palpebra tertia and caruncle, longitudinal section: 1. Caruncle. 2. External surface. 3. Internal surface. 4. Free margin of palpebra tertia. 5. Papilla on outer surface near margin. 6. Small piece of Harder's gland. The irregularity in shape of the internal surface is artefact: it should be smooth (hematoxylin-eosin, × 6.5).

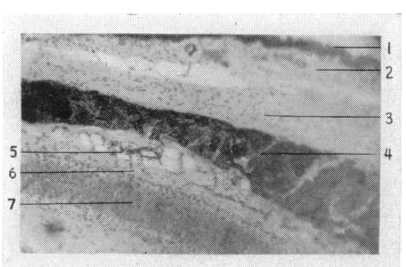

Fig. 7.—Detail of palpebra tertia: 1. External epithelium. 2. Subepithelial fibrous tissue. 3. Denser fibrous tissue, sheath of gland. 4. Glandula palpebræ tertiæ. 5. Fat. 6. Perichondrium. 7. Cartilage (hematoxylin-eosin, × 67).

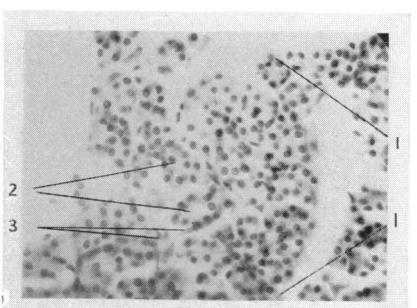

Fig. 8.—Glandula palpebræ tertiæ: 1. Portion of a lobule. 2. Individual acini. 3. Fibrous tissue nuclei (hematoxylin-eosin, × 500).

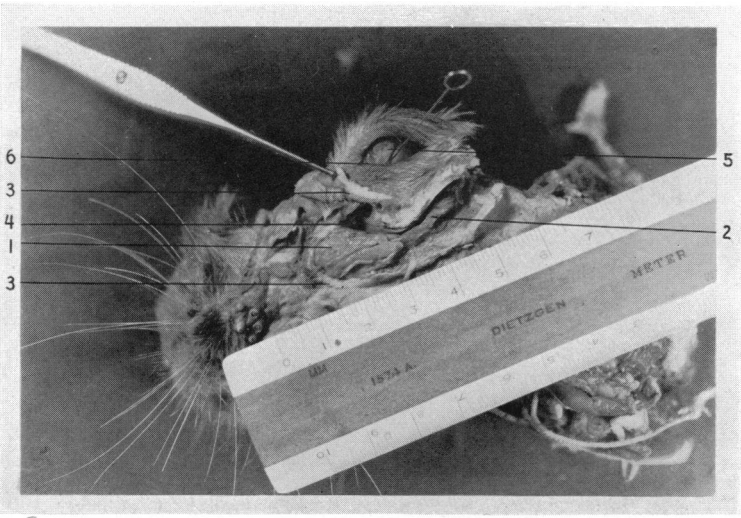

Fig. 9.—Dissection of infra-orbital portion of lacrimal gland: 1. The large lower end of the gland. 2. The narrow posterior portion, which has here been displaced from behind the zygomatic arch. 3. Fascia, which has been cut to expose the gland. 4. Lacrimal duct. The probe is inserted in this duct through the lacrimal punctum. 5. Palpebra tertia. 6. Caruncle.

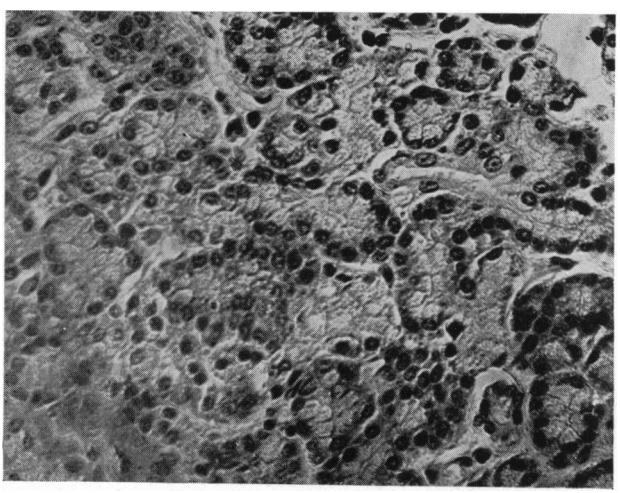

Fig. 10.—Lacrimal gland. The section shows typical structure of lacrimal gland (hematoxylin-eosin, × 400).

GLANDS OF ORBIT

In addition to the Meibomian glands and the special glands on the third eyelid, already mentioned, there are three glands in the orbit, namely, the lacrimal gland, the infra-orbital gland, and Harder's gland.

The lacrimal gland of the rabbit was first accurately described by Cuvier in 1845. His description was overlooked by subsequent writers, and many of these, notably Krause and Löwenthal, misinterpreted the lower portion of the gland, mistaking it for an infra-orbital salivary gland. Lor, in a very complete study of the lacrimal gland, describes it accurately as we have found it and points out the errors made by other writers, particularly Krause.

The gland is unusually large and extends above and below the eye. The upper portion is the smaller and rests under the supra-orbital ridge and in the posterior incisure. In well-nourished animals it protrudes through the incisure so that it can be seen under the fascia on the external surface of the skull. The gland is soft, flat, and approximately circular in outline, being about 5 mm. in diameter. The duct courses under the supra-orbital ridge and through a groove in the supra-orbital and palpebral ligaments to open into the conjunctiva of the upper lid near the temporal angle. Lor states that there are several secondary lobes in the course of the duct, which may open separately in the conjunctiva.

The lower portion of the gland is much larger, being about 4 cm. in length (fig. 9). It is irregular in shape, the posterior portion being long and thin, the anterior thick and bulky. The inner surface of the narrow portion rests against Harder's gland and the globe, being separated from them by the so-called orbital membrane. Its outer surface is in contact with the zygomatic arch. It is easily exposed by cutting through the fascia attached to the margin of the zygomatic arch in its posterior half. It gradually thins out into a narrow duct which opens into the lower lid near the temporal angle. This

duct is extremely small and scarcely visible to the naked eye. It bears some accessory lobules which do not have separate openings.

The anterior end of the lower portion of the lacrimal gland extends out over the anterior half of the zygomatic arch and rests on the side of the face, filling the nasal angle of the bony orbit. It is covered by deep fascia which extends across the gland without attaching to the zygomatic arch under it, whereas the same fascia is attached to the arch farther back in the region of the narrow portion of the gland. Pressure on the eye in the fresh specimen will cause protrusion of the upper gland through the supra-orbital incisure, and bulging of the large nasal end of the lower gland. It is easy to locate the glands in this manner. Microscopically the upper and lower portions of the gland are identical, being essentially the same as in the human (fig. 10).

The drainage of tears from the eye is not through two marginal puncta, as in man, but by a single slit-like opening in the conjunctiva of the lower lid, 3 to 4 mm. from its border, near the nasal angle and at the lower end of the caruncle. The punctum is visible to the naked eye and has a raised rim. Krause states that this rim contains cartilage, but none was found in our sections. The duct does not lead into a definite lacrimal sac, but gradually expands into an elongated dilatation which passes forward to enter the naso-lacrimal canal. The nasolacrimal duct is 3 to 4 cm. long and passes forward to open under the anterior end of the inferior turbinate.

The infra-orbital gland is described by Lor as a small triangular mass resting in the angle between the zygomatic arch and the cheek teeth. It lies in direct contact with the anterior portion of the lower lacrimal gland, being separated from it only by loose areolar tissue. Lor states that it is a buccal mucous gland, but our sections reveal nothing but fat.

Harder's gland has no counterpart in the human. It is

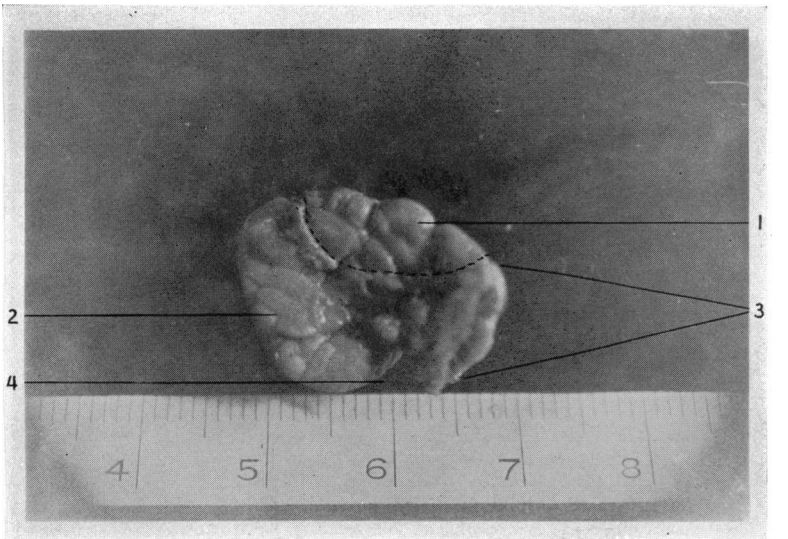

Fig. 11.—Harder's gland, internal surface. The dotted line approximately separates whitish from reddish lobe: 1. Whitish lobe. 2. Reddish lobe. 3. Zone of attachment of palpebra tertia. 4. Notch through which the inferior oblique passes.

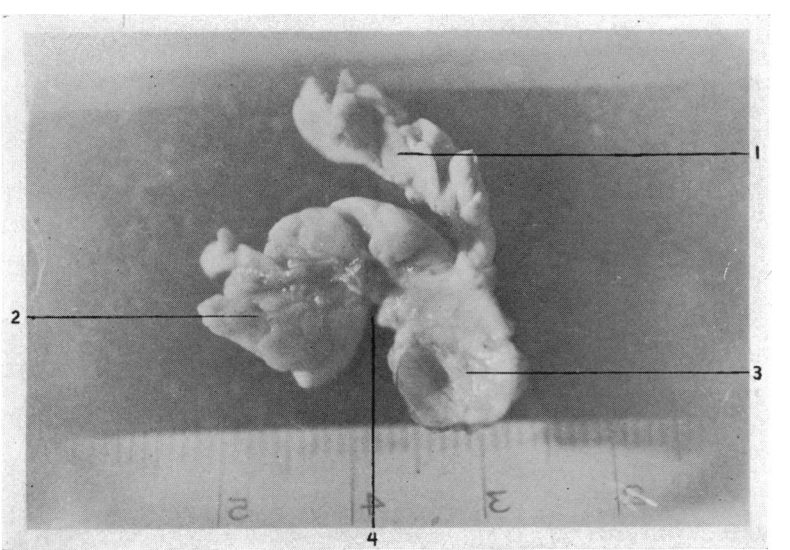

Fig. 12.—Harder's gland, internal surface, with the two lobes dissected apart: 1. Whitish lobe. 2. Reddish lobe. 3. Palpebra tertia. 4. Notch for inferior oblique.

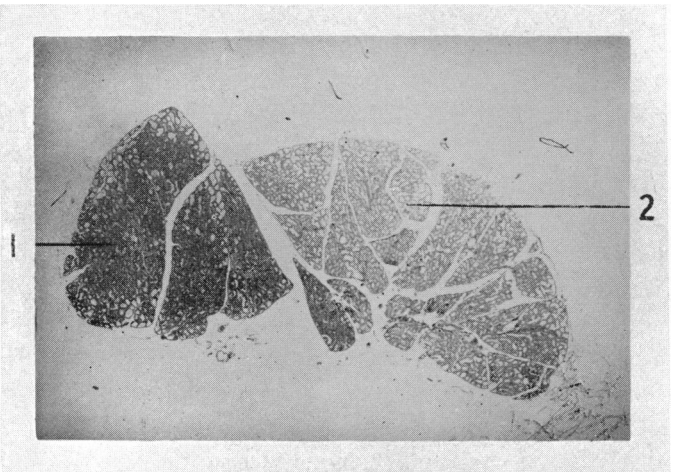

Fig. 13.—Harder's gland, transverse section. The whitish portion, 1, and the reddish portion, 2, are slightly separated artificially (hematoxylin-eosin, × 5.5).

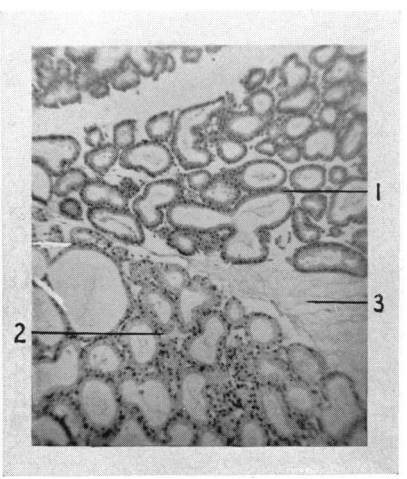

Fig. 14a.—Section of Harder's gland from which the fat has been washed by passage through alcohol and xylol: 1. Whitish portion. 2. Reddish portion. 3. Loose fibrous tissue uniting the two lobes (hematoxylin-eosin, × 100).

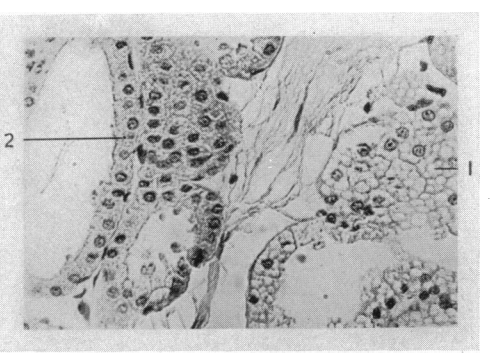

Fig. 14b.—Detail of fig. 14a. Note the low cuboidal epithelium, the vacuoles from which fat has been dissolved in the red part (1), and the finely granular appearance of the white part (2) (× 500).

found in those animals which have a well-developed third eyelid. It is a large, complex gland filling the lower anterior portion of the orbit. It is in direct contact with the globe and is attached to the base of the third eyelid. It is surrounded by a delicate capsule and outside of this is almost completely enclosed by a venous sinus, which will be described later.

Grossly, the gland is irregularly kidney-shaped (fig. 11). It is convex on the outer side and concave on the inner, to conform to the shape of the globe. It is about 20 mm. long, 15 mm. wide, and 4 mm. thick. There is a deep notch on its inferior anterior border, in which the inferior oblique muscle rests, and a shallow depression on its convex surface into which the summit of the alveolar ridge of the maxilla fits. The gland consists of two lobes: the upper is whitish, the lower pinkish in color. The lower lobe is about twice the size of the upper, although the ratio is variable. The two lobes are loosely connected by delicate areolar tissue and may be easily separated by gross dissection, so that they suggest two glands rather than one (figs. 12 and 13). Lor states that white and reddish lobules may be found mixed, but we have not found this in our sections.

Microscopically, both lobes are made up of large acini lined with cuboidal epithelium (fig. 14, a and b). The protoplasm of the cells of the reddish lobe is made up of a coarse reticulum the spaces of which are filled with fat globules. Most of the lumina of these acini are also filled with fat. The protoplasm of the cells of the white lobe is made up of a very fine reticulum which is likewise filled with fat granules. The lumina of these acini contain fat in fine dispersion. Apparently, then, the difference in appearance between the two lobes is based on the fine dispersion of the fat in the whitish lobe. The fat in the gland does not stain with osmic acid, but does stain intensely with Sudan III. Taddei has produced butyric, caproic, and caprylic acids from fats iso-

lated from this gland, and apparently the fats from the two lobes are identical chemically. Krause states that the material in the white gland is probably colloidal and not fat, but Taddei's work and our own stains refute this statement.

Löwenthal describes additional accessory serous glands connected with the duct, as well as goblet cells in the wall of the duct. Taddei describes protrusions of the gland cells, apparently secreting another substance than fat. We have also seen these protrusions. They do not contain fat granules. Thus it appears that the final secretion of the gland is a complex mixture, in which fat predominates. It is alkaline, and probably serves to lubricate the third eyelid. The secretion is discharged by a single duct opening on the concave surface of the palpebra tertia, well back and near its inferior border. This opening can be seen with the naked eye.

MUSCLES

The muscles of the rabbit's eye have been described by Krause and Motais. We have used these descriptions as a guide for our own dissections, but have found them to be inaccurate in some details. Therefore, the description which follows is based entirely on our own dissections.

The extra-ocular muscles are nine in number, namely, the orbicularis, the levator palpebræ superioris, the depressor palpebræ inferioris, the four recti, the two obliques, and the retractor bulbi. The orbicularis is a thin muscle with bundles of delicate fibers separated by connective tissue. The levator palpebræ superioris has its origin on the dorsal wall of the orbit above the optic foramen, and is inserted in the margin of the upper lid for its entire length. It is thin and so involved in the orbital fascia that it is very difficult to isolate. A strong slip of this muscle is inserted on the upper margin of the palpebra tertia, serving as a retractor for this structure. This is, indeed, more than a slip and should be described as a separate muscle, the retractor palpebræ tertia.

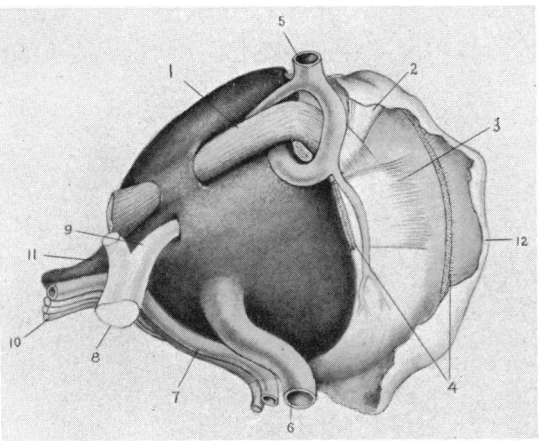

Fig. 15.—Dissection of orbital contents (superior view): 1. Superior oblique. 2. Retractor palpebræ tertia. 3. Superior rectus. 4. Cut ends of levator palpebræ superioris. 5. Supra-orbital vein. 6. Posterior ophthalmic vein. 7. Lacrimal artery and nerve. 8. Optic chiasm. 9. Optic nerve. 10. Branch of fifth nerve to lower lid. 11. Internal ophthalmic vein. 12. Cut margin of conjunctiva and Tenon's capsule. Entire dark area is orbital venous sinus.

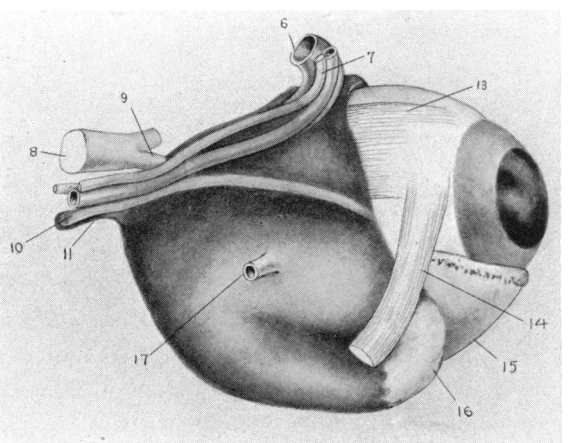

Fig. 16.—Dissection of orbital contents (inferior view): 6, 7, 8, 9, 10, 11 are the same as in fig. 15. 1, 2, 3, 4, 5, 12 do not show in this drawing. 13. External rectus. 14. Inferior oblique. 15. Palpebra tertia. 16. Harder's gland. 17. Inferior ophthalmic vein. Dark area is orbital venous sinus.

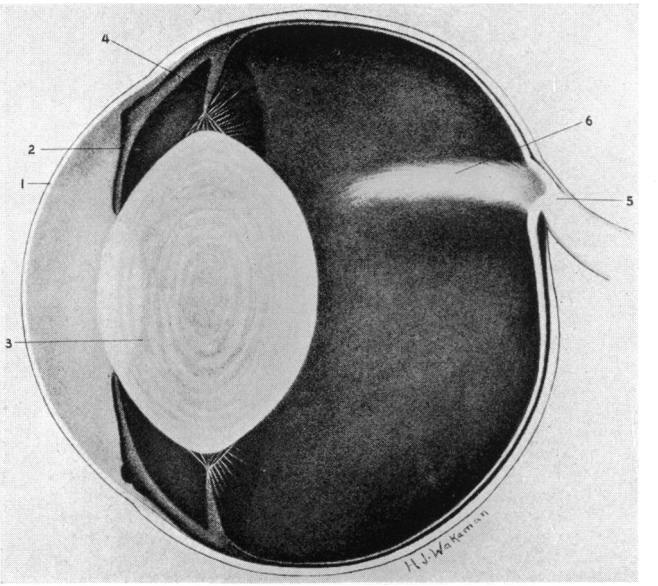

Fig. 17.—Normal pigmented rabbit's eye. Drawing from gross specimen mounted in jelly: 1. Cornea. 2. Iris. 3. Lens. 4. Ciliary processes and zonule. 5. Optic nerve. 6. Medullated nerve-fibers.

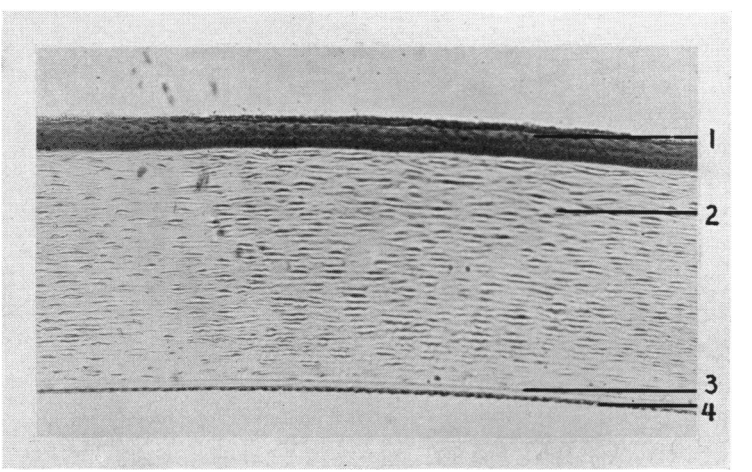

Fig. 18.—Cornea: 1. Epithelium. 2. Stroma. 3. Descemet's membrane. 4. Endothelium (hematoxylin-eosin, ×110).

It has its origin in common with the levator, above the upper rim of the optic foramen, and separates from it at about the level of the oblique pulley. It runs under the reflected portion of the superior oblique, while the levator spreads out, fan-like, over it. Its course is obliquely forward and outward to its insertion, passing over the superior anterior border of Harder's gland. The muscle is about 3 mm. across and about 20 mm. in length, measured from its junction with the levator to its insertion (fig. 15). The depressor palpebræ inferioris is somewhat heavier than the levator muscle, according to Motais, who gives its origin on the rim of the zygomatic arch and its insertion in the anterior third of the lower lid.

The origin of the superior rectus is on the inner wall of the orbit, above and behind the optic foramen. It passes diagonally forward and is inserted on the sclera in the mid-dorsal line near the limbus by a broad, fleshy tendon 6 to 8 mm. wide. The insertion is oblique, the anterior border being 2 mm. from the limbus, the posterior 3 mm. The muscle passes over the tendon of the superior oblique, which inserts immediately under it (fig. 15).

The inferior rectus originates under the optic foramen, just below the origin of the internal rectus. It inserts into the sclera about 2 mm. from the limbus by a broad, fleshy tendon. The tendon is 6 to 8 mm. wide.

The external rectus originates from the posterior inferior rim of the optic foramen, below the origin of the superior rectus. It has a long, delicate tendon which is about 6 mm. wide and inserts into the sclera about 4 mm. from the limbus (fig. 16).

The internal rectus originates on the inner wall of the orbit in front of the optic foramen. It is inserted into the sclera about 8 mm. behind the limbus. The tendon is extremely delicate and is about 4 mm. wide. Its insertion is slightly oblique, the superior extremity being near the cornea.

The superior oblique arises from the inner wall of the orbit above the optic foramen and just above the internal rectus. It extends obliquely outward and nasally to reach the pulley, and from here passes diagonally outward and temporally to insert in the sclera 6 mm. from the limbus, under the superior rectus (fig. 15). In removing the orbital contents *in toto* the diagonal course of this muscle is very striking, since it occupies the uppermost position in the soft parts of the orbit. It is surrounded on either side by portions of the large venous sinus, in which it appears to be embedded. The superior oblique pulley is 3 mm. long and is situated under the anterior end of the supra-orbital crest just medial to the anterior supra-orbital foramen.

The inferior oblique is a thick, fleshy muscle which arises from the lower posterior angle of the lacrimal bone and extends obliquely outward and backward across Harder's gland to be inserted in the sclera. The insertion is oblique, its anterior border being 1 mm. from the limbus and the posterior border 2 mm. The tendon is about 4 mm. wide at its point of insertion. The muscle crosses the inferior rectus and inserts in the narrow space between the external rectus and the corneal border (fig. 16). Portions of the tendons of these two muscles appear to blend with each other upon insertion. The course and insertion of the two oblique muscles suggest that their function is primarily rotatory, the superior oblique rotating the eye forward, the inferior rotating it backward on the vertical axis.

The retractor bulbi (choanoid muscle) is very short. It is thick in its posterior portion but thins out and becomes much more delicate as one approaches its insertion. Its origin is inside the origins of the recti on the margin of the optic foramen except for its upper quadrant. In the lower part of the optic foramen the muscle seems to join the fellow muscle of the other side. It extends outward below the optic nerve in a cone-shaped manner, to be inserted on the sclera well

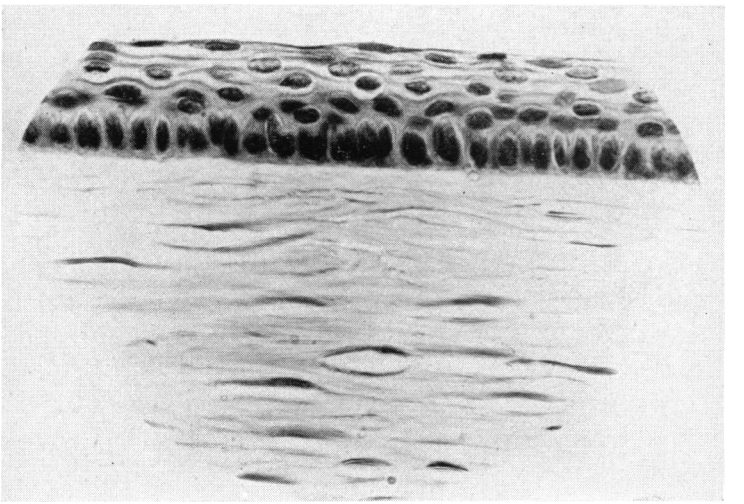

Fig. 19.—Detail of anterior surface of cornea. Note that the epithelium lies directly on the stroma, without the intervention of a hyaline membrane (× 500).

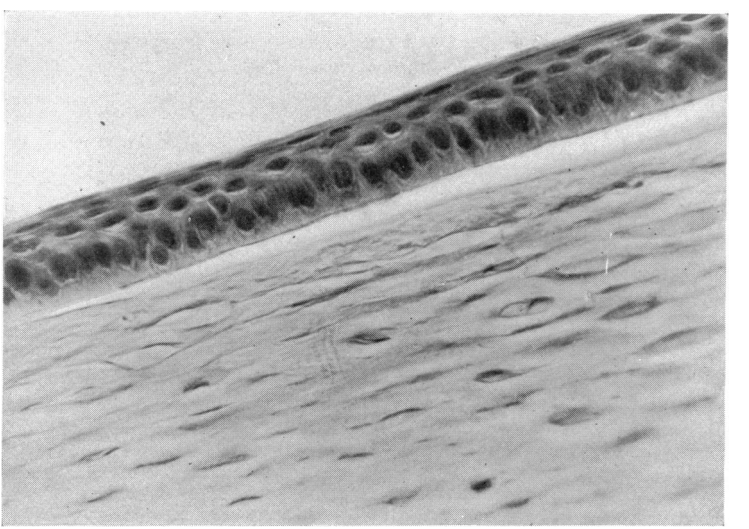

Fig. 20.—Cornea. Same as Fig. 19. The epithelium is slightly raised from the stroma, so that the fibrous structure of the latter can be seen up to its anterior border (hematoxylin-eosin, × 600).

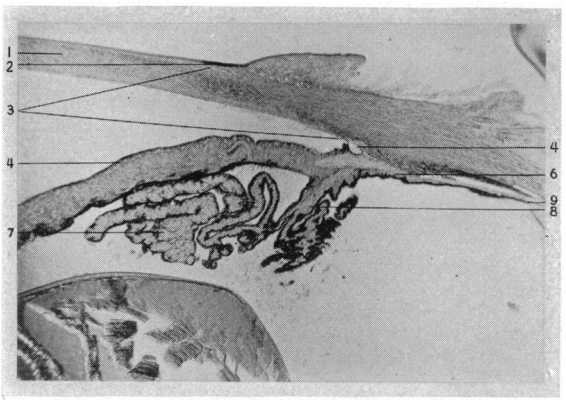

Fig. 21.—General view of region of limbus: 1. Cornea. 2. Pigmented ring. 3. Approximate limits of limbus. 4. Filtration angle. 5. Iris. 6. Ciliary body. 7. Ciliary processes. 8. Ciliary shelf, or "Sims." 9. Ora serrata (van Gieson, × 25).

Fig. 22.—Filtration angle of an albino rabbit: 1. Cornea. 2. Sclera. 3. Descemet's membrane. 4. Descemet's endothelium. 5. Schlemm's canal. 6. Corneoscleral trabeculum. 7. Uveal meshwork. 8. Iris pillars. 9. Descemet's membrane splitting to partially clothe a pillar. 10. Iris. 11. Veins (van Gieson, × 108).

behind the equator. The insertion is an irregularly wavy line, extending farther forward in the spaces between the recti. At these points it reaches to 8 to 9 mm. from the limbus, while the portions under the recti are farther back.

One striking feature of the extra-ocular muscles of the rabbit eye is the manner in which they hug the posterior portion of the globe closely with little intervening space inside the cone.

CIRCULATION OF ORBIT AND GLOBE

The external ophthalmic artery is the chief arterial supply to the orbital contents, including the bulbus (with the exception of the retina). It is a branch of the internal maxillary artery, given off shortly after the entrance of the latter into the orbit through the anterior sphenoidal foramen. The internal maxillary artery is a branch of the external carotid. It accompanies the maxillary branch of the fifth nerve through the orbit to exit through the infra-orbital foramen. The external ophthalmic artery passes upward behind the optic nerve and curves over it to anastomose with a branch of the internal ophthalmic artery. It supplies branches to all the eye muscles and to Harder's gland. It gives off the long ciliary arteries, nasal and temporal (the former being augmented by a branch from the internal ophthalmic), and finally divides into the lacrimal and frontal arteries which leave the orbit through the posterior and anterior supra-orbital foramina, respectively. The short ciliary arteries are, in part, branches of the long ciliary arteries and, in part, direct branches of the external ophthalmic. The long ciliary arteries may be seen in their course through the sclera until they disappear just behind the limbus. Their course is slightly below the horizontal plane. The arteries actually become buried in the substance of the sclera about 2 mm. behind the equator.

The internal ophthalmic artery is a very fine branch of the

internal carotid. It enters the orbit through the optic foramen, passes under the optic nerve, and enters its substance near its union with the globe. As stated above, it also takes part in the formation of the long nasal ciliary artery.

The nomenclature of the main arteries of the orbit is confused, since various authors have adopted different names for the same vessels. Thus, Krause calls the external ophthalmic the "inferior ophthalmic," and the internal ophthalmic the "superior ophthalmic." Fuchs uses the terms "bulbo-orbitalis" and "internal ophthalmic," Bensley employs "inferior ophthalmic" and "ophthalmic," and Leber uses the same terminology we have adopted, namely, "external ophthalmic" and "internal ophthalmic." We feel these are the more descriptive terms.

The confusion regarding the venous outflow from the orbit is even more complete than that of the arterial supply. This outflow centers in a large sinus which occupies much of the deeper part of the orbit (figs. 15 and 16). In all the literature available to us this structure seems to have been either disregarded or not recognized.* The sinus is so bulky that it is almost impossible to enucleate the rabbit's eye without cutting into it and obtaining severe hemorrhage. The sinus completely surrounds the muscle cone except for the superior oblique, which forms a groove in the external surface of the sinus. It also completely covers Harder's gland except for its lower anterior pole. The sinus is much more voluminous in the inferior anterior part of the orbit, forming a half-moon-shaped mass which surrounds the bulging red part of Harder's gland. The anterior limits of the orbital sinus are irregularly curved and in most places project slightly in front of the equator. Posteriorly it tapers to a narrow

* Since this paper was completed the author's attention has been directed to an article by Ulbrich in which the orbital venous sinus has been described. The description is accompanied by two excellent illustrations. Time has not permitted an opportunity for an analysis of his findings, so the above description is based solely on my own dissections. (F. A. D.)

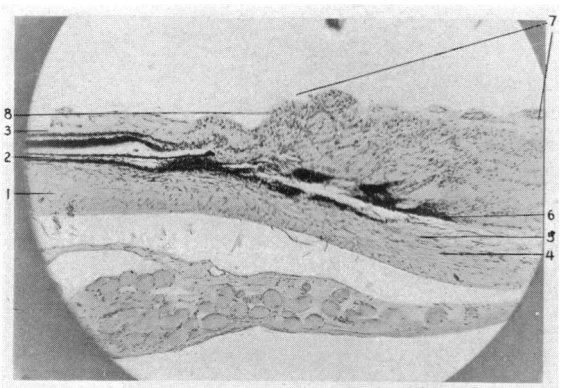

Fig. 23.—Region of dorsal margin of papilla: 1. Sclera. 2. Choroid. 3. Retina. 4. Dura. 5. Arachnoid. 6. Pia. 7. Papilla. 8. Border of same. 9. Fibers suggesting lamina cribrosa (hematoxylin-eosin, × 100).

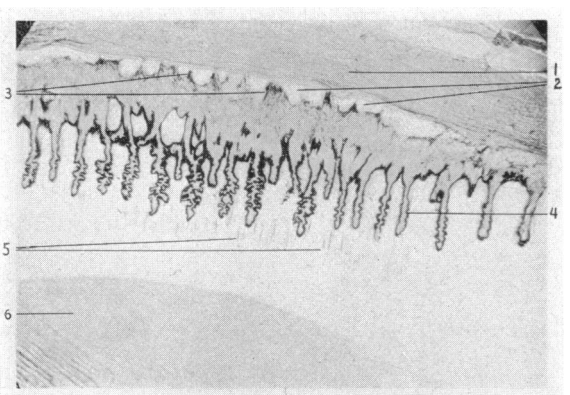

Fig. 24.—Frontal section in the region of the iris angle: 1. Sclera. 2. Spaces of Fontana. 3. Iris pillars. 4. Ciliary processes. 5. Fibers of suspensory ligament. 6. Lens (hematoxylin-eosin, × 33).

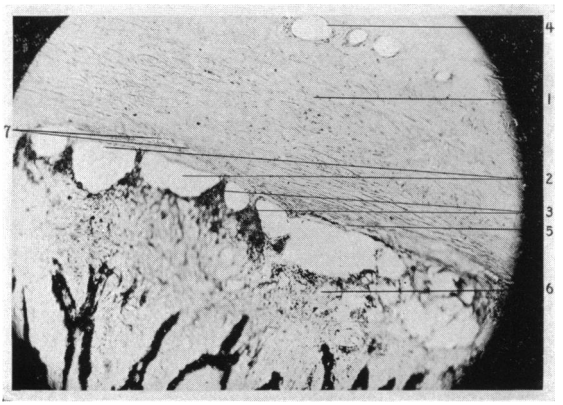

Fig. 25.—Detail of a section similar to that of fig. 24: 1, 2, 3 are the same as in fig. 24. 4. Veins of the episcleral tissue. 5. Corneoscleral trabeculum. 6. Uveal framework. 7. Divisions of Schlemm's canal (hematoxylin-eosin, × 100).

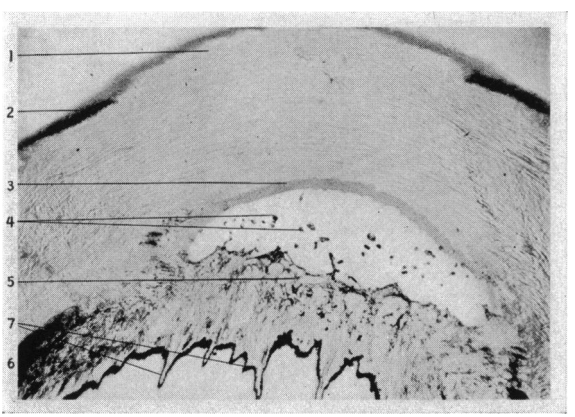

Fig. 26.—Tangential section through the region of the iris angle: 1. Cornea. 2. Pigment ring in epithelium. 3. Descemet's endothelium. 4. Iris pillars cut across. 5. Uveal framework. 6. Ciliary processes cut across near their posterior ends. 7. Ciliary body (hematoxylin-eosin, × 33).

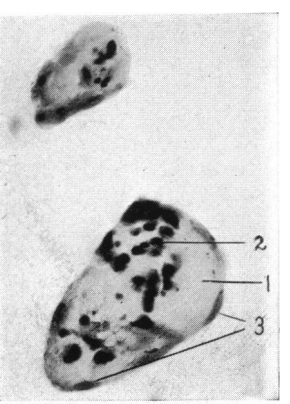

Fig. 27.—Transverse sections of iris pillars—detail of fig. 26: 1. Collagenous tissue. 2. Pigment cells. 3. Endothelial cells (× 600).

vessel which leaves the orbit through the superior orbital foramen.

The orbital sinus receives all the blood from the eye and the contents of the orbit. The four venæ vorticosæ enter it in two pairs, an upper and a lower. The upper veins leave the sclera on either side of the superior rectus, converging slightly to enter the sinus separately. The inferior veins leave the sclera on either side of the inferior rectus, also converge slightly, and enter the sinus separately. The vortex veins emerge from the sclera near the equator and continue backward over it as the ciliary veins, to discharge separately into the orbital sinus.

The blood leaves the orbital sinus through several channels: 1. The posterior ophthalmic vein arises from the external border of the sinus, curves up on the temporal wall of the orbit, and leaves the orbit through the temporal foramen. It drains into the posterior facial vein. 2. The supra-orbital vein arises from the sinus dorsally by two branches, one on either side of the superior oblique muscle just posterior to its pulley, and leaves the orbit through the anterior supra-orbital foramen, accompanied by the frontal artery and nerve. Outside the orbit it is known as the angular vein, which curves around the anterior orbital margin and unites with the two labial veins to form the external maxillary vein, which is the chief branch of the anterior facial. 3. The inferior ophthalmic vein arises from the sinus just lateral to the posterior cheek tooth, and immediately leaves the orbit through the masseter muscle. Its continuation outside the orbit is known as the deep facial vein, which enters the external maxillary vein just below the anterior angle of the lower jaw. 4. A small branch to the internal maxillary vein leaves the orbit through the anterior sphenoid foramen in company with the internal maxillary artery. The internal maxillary vein unites with the external maxillary vein to form the anterior facial vein under the lower border of the

mandible. 5. The internal ophthalmic vein is the direct medial continuation of the orbital sinus. It is a small vein which leaves the orbit through the superior orbital fissure to enter the vertebral vein.

It will be noted from the above description that practically all the blood from the eye and orbit is returned to the extracranial venous system. Parsons states that this is also true in the dog. He describes the arterial supply of the rabbit's orbit, but omits any description of the venous system.

In dissections of the orbit the best results can be obtained by first removing its bony walls with rongeurs. The soft parts, and particularly the sinus, are thus preserved intact. The walls of the sinus are easily torn unless approached in this manner.

NERVES

The nerves, with the exception of the optic, enter the orbit through the superior orbital fissure. The third, fourth, sixth, and the ophthalmic and maxillary branches of the fifth nerve lie in close contact. Their distribution is similar to that of the human eye with some exceptions. The sixth nerve supplies the retractor bulbi in addition to the external rectus. The delicate ciliary ganglion lies close to the optic nerve. The trochlear nerve divides into two branches near the superior oblique, one branch entering the posterior and the other the anterior portion of this muscle.

GLOBE

The rabbit's eye is relatively large compared to the size of the animal. The shape differs materially from that of the human eye. It appears compressed in its anteroposterior dimension. According to Krause, the optic axis measures 16 mm., the vertical diameter 18 mm., and the horizontal diameter 17 mm. Our measurements show considerable variations with the size of the animal, averaging about 16

mm. in the chief axis, 17 mm. vertically, and 18 mm. horizontally (fig. 17).

The cornea is unusually prominent and wide (fig. 1). The sclera is thin and varies considerably in thickness in different parts of the eye. The optic nerve entrance is above the posterior pole, in a horizontal plane which cuts the vertical axis of the eye at about the junction between its upper and middle thirds; thus the disc is seen with the ophthalmoscope far above the posterior pole. The anterior chamber appears deep in the center, but is unusually shallow at the periphery due to the extreme bowing forward of the iris. The posterior chamber is narrow and the ciliary processes encroach far forward on the posterior surface of the iris. The lens is large and more spherical than that of the human, particularly on its posterior surface. The contour of the cornea follows the same curvature as that of the sclera, there being no scleral furrow. Its radius of curvature is about 7.3 mm. Its shape is roughly elliptical, with the longer axis horizontal. The horizontal diameter averages about 15.6 mm., the vertical about 13.8 mm. The thickness of the cornea is fairly uniform, being slightly greater at the limbus. It averages 0.37 mm. at the center and 0.45 mm. near the limbus.

In the microscopic examination of the cornea the striking feature is the absence of Bowman's membrane. In an examination of several hundred eyes we have never found a definite anterior elastic layer. Occasionally one encounters some condensation of the stroma just under the epithelium, but detailed examination shows that this area consists of definite bundles of fibrous tissue, just as does the rest of the stroma. Thus the corneal epithelium rests directly on the stroma. The accompanying illustrations (figs. 18 and 19) show this feature, as does also figure 20, in which the epithelium is raised. In the literature we have found no reference to an absence of Bowman's membrane in the rabbit. Zietschmann says: "Nach meinen Präparaten zeigen alle Haus-

säuger etwa gleichmässig einen deutlichen Faserbau bis unter das Epithel der Hornhaut." In his treatise he does not mention the rabbit eye, and one is left in doubt as to whether the above observation is intended to apply to this animal. However, the statement that the structure is absent in other domestic animals is significant. Zietschmann publishes a figure of the donkey's cornea, which is similar to that of the rabbit. The absence of Bowman's membrane should have an important bearing on the production of experimental lesions of the rabbit cornea. Interesting in this connection is the ease with which herpes virus invades the rabbit cornea, and the rather destructive lesion which follows it, as recorded by Friedenwald. W. S. and P. M. Duke-Elder show some interesting figures of the rabbit's cornea in a recent study of the effect of ultraviolet light on the cornea. The drawings are excellent and accurate, though they make no mention of the absence of Bowman's membrane.

The cornea is covered by a stratified squamous epithelium of about six layers. The deepest layer, which lies in contact with the stroma, consists of cylindric cells. Detailed histologic structure is quite similar to that of the human. In pigmented rabbits the basal cells of the epithelium near the limbus contain pigment (fig. 21). There is also some scattering of pigment in the outer cells. In gross specimens this pigment is seen as a definite dark ring encircling the cornea and serving as its anatomic border.

The structure of the corneal stroma is essentially the same as in man and presents no details of peculiar interest. Eloui has described corneal nerves of the rabbit. Some of the earlier work on corneal corpuscles was done on the rabbit (Altmann).

Descemet's membrane is a tough "glass membrane." It is much thicker than in man and varies in thickness with the age of the animal, being thicker in the older animals. Its thickness averages 14μ at the center, with variations

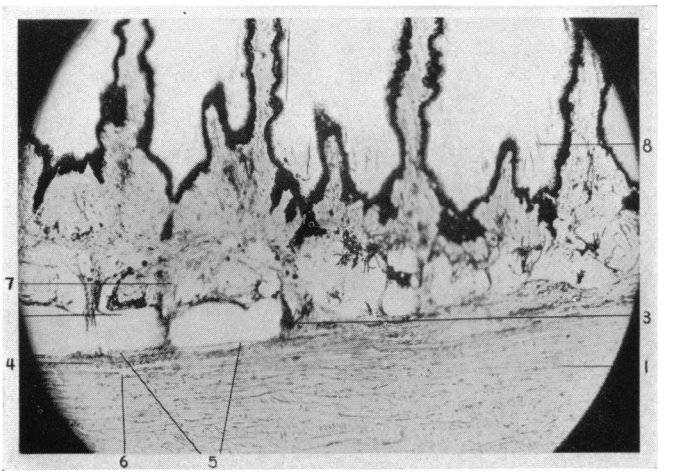

Fig. 28.—Frontal section of region of iris angle: 1. Sclera. 2. Spaces of Fontana. 3. Iris pillars. 4. Corneoscleral trabeculum. 5. Terminal portions of Descemet's membrane. 6. Schlemm's canal. 7. Uveal framework. 8. Zonule fibers arising from ciliary processes (hematoxylin-eosin, × 100).

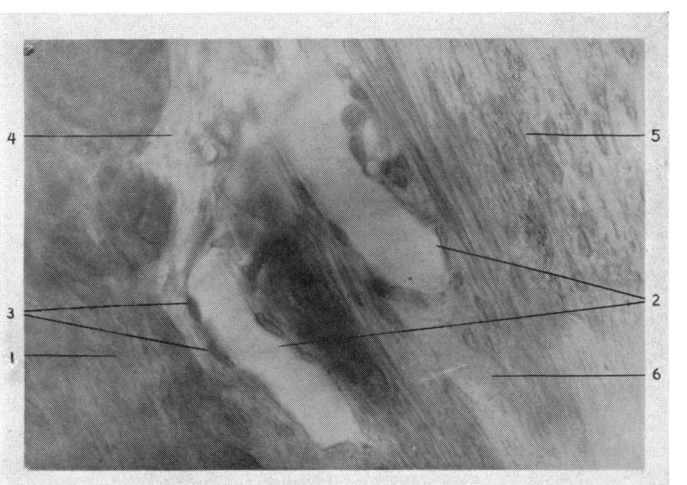

Fig. 29.—Schlemm's canal—detail of the canals seen in fig. 22: 1. Scleral tissue. 2. Schlemm's canals. 3. Endothelium lining same. 4. Loose fibrous tissue surrounding canals. 5. Trabecular tissue. 6. A smaller canal which connects with the main one (van Gieson, × 1000).

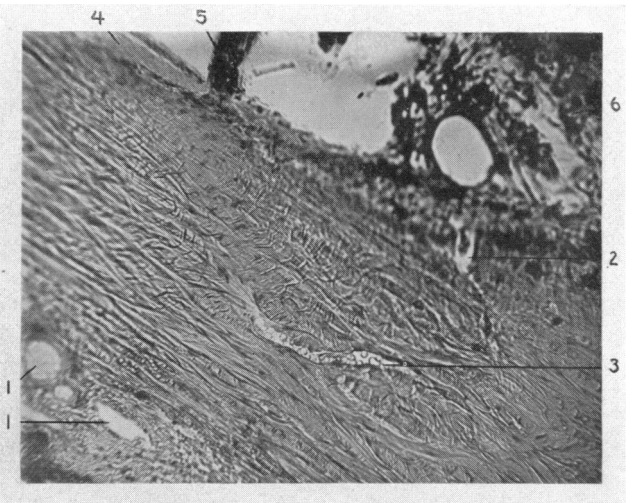

Fig. 30.—Detail of sclera near filtration angle: 1. Veins of episcleral tissue. 2. Schlemm's canal. 3. A vein in the midst of the sclera. Study of the series of sections to which this specimen belongs reveals that 3 connects with both 2 and 1. 4. Descemet's membrane. 5. Iris pillar. 6. Filtration angle (hematoxylin-eosin, × 600).

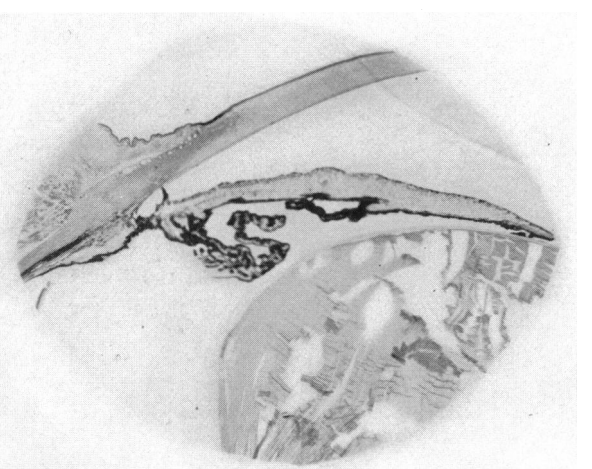

Fig. 31.—Anterior segment showing shape of the iris and attachment of ciliary processes (labels as in fig. 21) (× 15).

from 7μ to 22μ. Near the periphery it is thicker and more variable, with a maximum of 45μ and a minimum of 10μ in different animals. It has very sharp contours and differs from the corneal stroma in staining reaction, taking a lighter red with van Gieson's stain and with eosin. It becomes irregular in thickness near the filtration angle. Here it splits (fig. 22), portions extending backward to clothe some of the iris pillars, the terminal portion thinning out and partly bordering the inner surface of the pectinate ligament. It tapers to a thin edge, which ends abruptly; there are no fine continuations into the pectinate ligament. Its outer border forms a very irregular line, in places extending far onto the pectinate ligament, in others extending but a short distance onto this structure. Wart-like thickenings, which are prominent in the periphery of the human Descemet, are usually not to be found in the rabbit. The inner surface of the membrane is covered by a single layer of flat endothelial cells.

The limbus corneæ (fig. 21) is a broad zone limited anteriorly by the pigment ring, posteriorly by the anterior end of the pectinate ligament. The corneoscleral junction is thus a very oblique line, which extends diagonally between these two points. The anterior end of this junction cannot be determined as the place where Bowman's membrane ends, as in man, since this membrane is absent in the rabbit.

The basal cells of the corneal epithelium become smaller and poorer in cytoplasm in the pigmented zone, so this zone may also be recognized in the albino rabbit. Beyond the pigmented zone the basal cells become lower and the layers of the epithelium become fewer, thus changing over gradually into the condition of the conjunctiva scleræ, on which the epithelium is relatively thin and is made up of a row of large goblet cells, under flattened surface cells, while in most places a row of flattened basal cells is made out. The fibrous tissue of the conjunctiva is continuous with the more anterior of the corneal lamellæ.

The outer corneal layers lose their regularity at the region under the pigmented zone. This irregularity becomes deeper and more pronounced as one approaches nearer the posterior limits of the limbus. There is a striking absence of the scleral furrow, either external or internal. There is practically no depression on the internal surface in the region in which the cornea goes over into the sclera. Further details of this region will be found in the description of the filtration angle.

The sclera varies considerably in thickness in different portions of the globe. It is thickest in the region of the ciliary body and gradually becomes thinner toward the optic nerve. The average of measurements of six eyes cut in the vertical axial plane shows that the thickness of the sclera just behind the limbus, above, is about 0.5 mm., below, 0.4 mm. At the equator the averages are 0.25 mm. above and 0.19 mm. below (the section reproduced in figure 1 is an exception in this particular). At the posterior pole the average is 0.18 mm. At the nerve it tapers to a much thinner structure, appearing below to completely end shortly before the union of nerve and globe. Above it also becomes much thinner, but unites with the dural sheath of the nerve in an unbroken line (fig. 23). The region of the optic nerve entrance is described later.

The layers of the sclera may be divided into episcleral tissue and sclera proper. The former is made up of loose, delicate bundles of fibrous tissue which are more tortuous than the fibers of the sclera. This tissue begins at the limbus and extends over the insertions of the recti. It is characterized by numerous blood-vessels which are the ones involved chiefly in circumcorneal injection. Behind the muscles the episcleral tissue is very thin. The appearance is quite different in horizontal and in vertical sections because of the difference in location of the insertions of the respective recti. In the sclera proper the fibers are much more dense

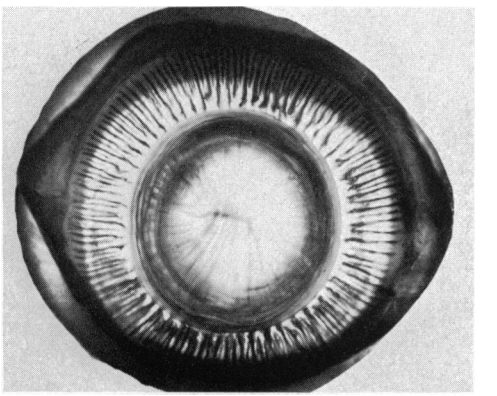

Fig. 32.—Front half of an injected albino eye, viewed from behind, showing ciliary processes and the posterior lens suture.

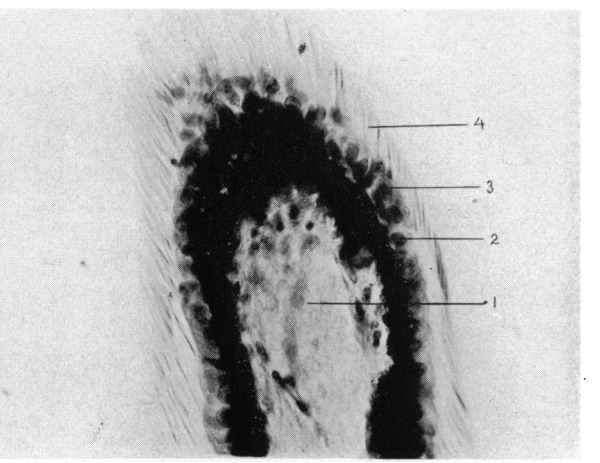

Fig. 33.—Detail of a ciliary process: 1. Stroma, with a large vein. 2. Pigment epithelium. 3. Unpigmented epithelium. 4. Zonule fibers (hematoxylin-eosin, × 600).

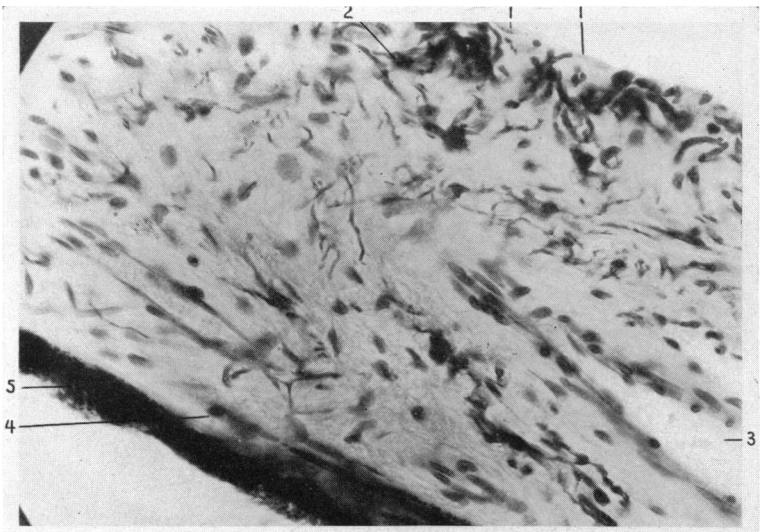

Fig. 34.—Detail of iris: 1. Endothelial nuclei on the anterior surface. 2. Pigment cells in stroma. These are more numerous near the anterior surface. 3. Circulus arteriosus iridis major. 4. Dilator pupillæ. 5. Epithelium on posterior surface (hematoxylin-eosin, × 600).

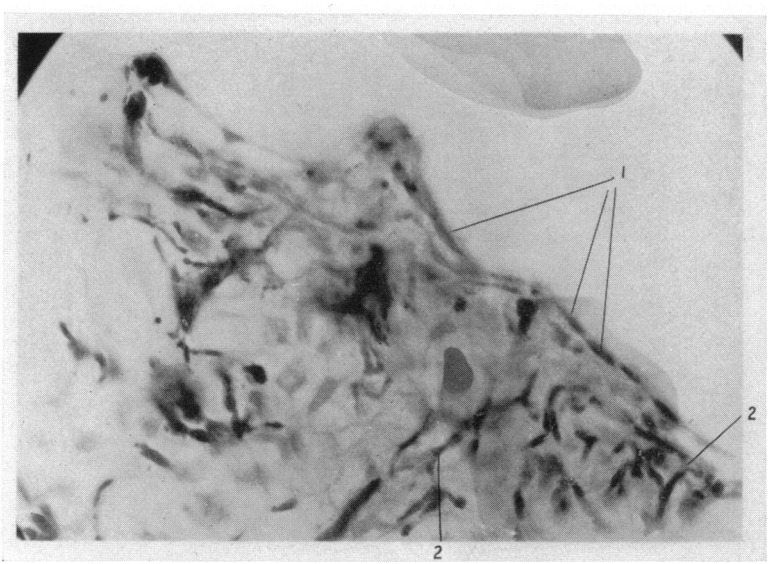

Fig. 35.—Detail of anterior portion of iris in filtration angle: 1. Endothelial nuclei. 2. Chromatophores (hematoxylin-eosin, × 600).

and appear in definite bundles which do not run parallel to each other. It is poor in blood-vessels, except for the vessels which it transmits to other structures. We have not completed studies of Tenon's capsule.

FILTRATION ANGLE

The iris angle differs materially from that of the human eye (figs. 21 and 22). As mentioned above, the scleral furrow is practically absent. The meshwork of the angle is much more highly developed, including special processes of the iris substance which insert through Descemet's membrane into the sclerocornea—the iris pillars. This meshwork may be divided into two parts, scleral and uveal. The uveal framework is very weakly developed in man, while in the rabbit it reaches a high grade of development. Its anterior portion consists of numerous thin, finger-like processes arising from the iris stroma by broad bases and tapering to thin apices as they pass through Descemet's membrane to be inserted in the anterior portion of the sclerocorneal trabeculum. These pillars suggest a circle of peaks rising from the iris and burying their tops in Descemet's membrane (figs. 24, 25, 26, and 27). The arrangement of these processes aids in anchoring the base of the long, narrow iris to the relatively rigid cornea. Such an anchoring is made more necessary by the bulky ciliary processes and the large lens, which are for the most part attached to the iris near its base. These pillars are not present in the new-born rabbit. They begin to develop as rather weak and short processes at about six weeks of age and are fairly well formed at two months. As the iris angle widens spaces develop in the meshwork. Thus, these pillars are not outgrowths from the base of the iris, but develop as a result of the spacing out of the tissue about them. It is possible that, in development, the large ciliary processes and heavy lens have pulled the base of the iris away from the cornea, thus deepening the iris angle.

The great development of uveal meshwork, including pillars, would naturally follow, to serve as a mechanical support for the iris. It also appears probable that a large iris angle is necessary to allow filtration from the huge anterior chamber of the rabbit.

Many writers have described iris pillars in different animals. Zietschmann describes the iris angle of several domestic animals, with two good figures of this region in the horse, showing a condition similar to that of the rabbit. Bentzen, in reporting some experimental work on the production of glaucoma, publishes, without description or comment, a very good colored plate of the region of the iris angle in the rabbit. Dostoiewsky describes the filtration angle in a number of different mammals. An interesting deduction from his figures, although he does not mention it himself, is that the size and complexity of the iris pillars seem to be related to the size of the ciliary processes and the extent to which they encroach on the posterior surface of the iris. Tanber has a very good description of the filtration angle of several rodents, including the rabbit. We have found it to be essentially accurate, although not clear in some points. For example, he leaves us in doubt as to whether endothelium clothes the individual fiber bundles of the trabeculum or merely covers the entire trabeculum. He also mentions the Schlemm's canal system as a venous plexus, without noting that it usually does not contain blood.

Deeper in the iris angle the uveal framework becomes much more delicate, consisting of fine processes which run in various directions to enclose narrow spaces (figs. 22 and 28). These spaces become larger the nearer one approaches the anterior chamber and they are direct continuations of the anterior chamber. The uveal framework is bordered externally by the more dense sclerocorneal trabeculum, toward the inner side by the root of the iris and the ciliary body, and toward the front by the anterior chamber. It is a triangular

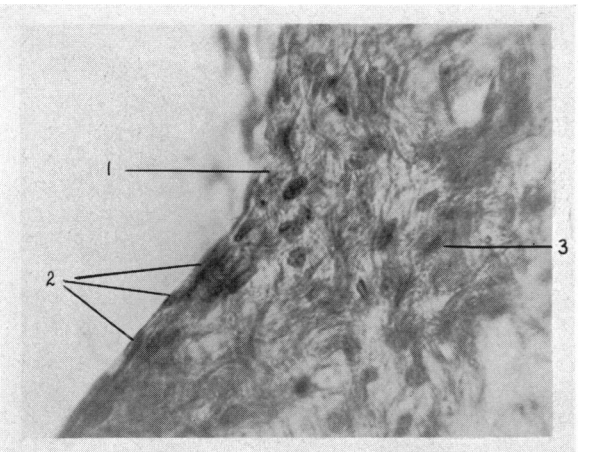

Fig. 36.—Detail of anterior surface of iris of an albino rabbit: 1. Crypt. 2. Endothelial nuclei. 3. Iris stroma (van Gieson, × 600)

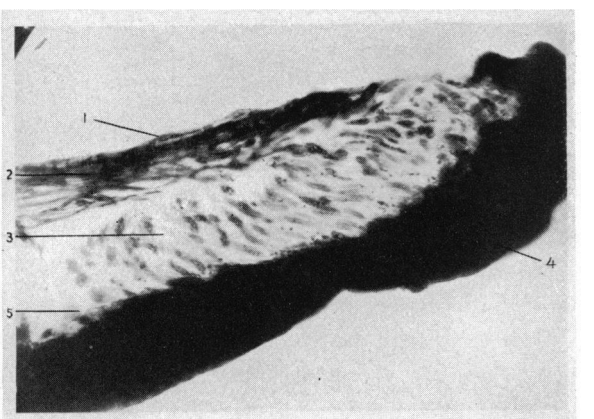

Fig. 37.—The pupillary portion of the iris: 1. Endothelial nuclei. 2. Stroma containing densely packed chromatophores. 3. Sphincter pupillæ. 4. Epithelium. 5. Dilator fibers (hematoxylin-eosin, × 600).

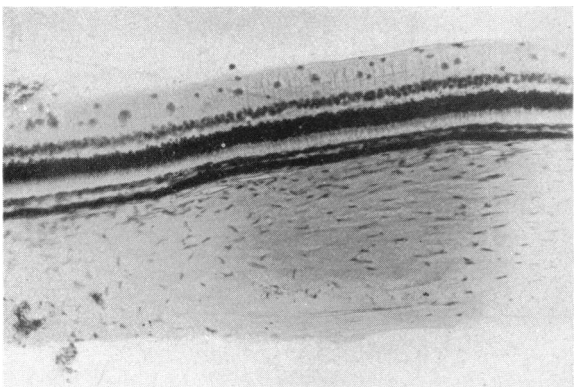

Fig. 38.—Wall of eyeball a short distance above nerve. Compare with fig. 39 (hematoxylin-eosin, × 225).

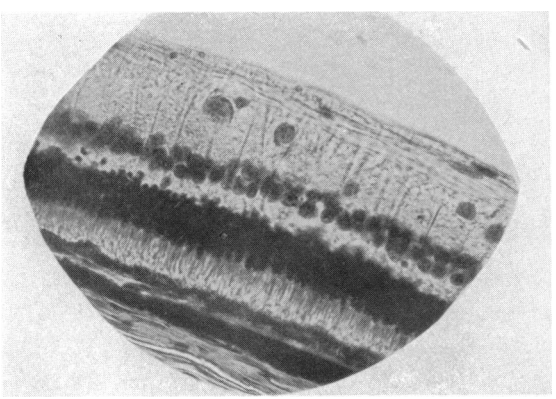

Fig. 38a.—Retina and choroid a short distance above the nerve. For names of structures shown see fig. 47 (hematoxylin-eosin, × 500).

area in meridional section, and is about 0.35 mm. wide in front (height of iris processes), and about 0.8 mm. deep.

Study of the finer structure of the uveal meshwork shows that the spaces are lined with endothelial cells which are continuous with Descemet's endothelium. The pillars are white, fibrous tissue with pigment cells, covered by an endothelial layer (fig. 27). The more posterior parts of the meshwork have both elastic and collagenous fibers. There are no blood-vessels in this meshwork, but there is a rich vascular supply in the iris, especially near the bases of the pillars. Terminal portions of Descemet's membrane are found on some of the iris pillars and partly lining the larger spaces. We have been unable to find delicate prolongations of Descemet's membrane bordering the fiber bundles of the iris angle, such as described by Salzmann for man.

The sclerocorneal trabeculum is a much more dense mass of fibrous tissue in which elastic fibers predominate. It is bordered on the external surface by the corneosclera and by Schlemm's canal, and internally by the uveal meshwork. Its anterior end tapers and is inserted between Descemet's membrane and the cornea. Posteriorly it is continuous with the fibrous tissue of the ciliary body. It is rich in nuclei, most of which appear to be endothelial cell nuclei, but the detailed structure which Salzmann describes for man could not be made out in our study. Specifically the collagenous fibers are much finer in the rabbit, and we cannot see that they are bordered on either side by elastic fibers, glass membrane, and endothelium, as in man. Rather, the collagenous and elastic fibers seem to run through the trabeculum as isolated fibers. There are some isolated bundles of fibrous tissue running opposite to the course of the main fibers, parallel to the corneal border. Possibly further studies with careful histologic methods may throw further light on this region.

Schlemm's canal is found lying external to the sclerocorneal trabeculum, slightly behind the end of Descemet's

membrane (fig. 22), and in some sections appears to be separated from the spaces of the trabeculum only by its own endothelium. It is located in a depression of the sclera; the portion immediately behind it would, in the human, be called the scleral spur. Owing to the lack of pull of the ciliary muscle, the latter is not so well developed as in man. In meridional sections a single canal may be seen or it may show several divisions, thus suggesting that the canal is really a plexus of vessels. In our sections the spaces are practically always empty. The lining membrane consists of a single layer of endothelial cells (fig. 29). Surrounding this is usually some loose fibrous tissue which is directly continuous with the trabeculum, though occasionally vessels are found which are surrounded only by scleral tissue. Lauber refers to this canal system as a vascular plexus which drains out through the cornea into the veins of the anterior episcleral tissue. We have been able to follow these connecting vessels (fig. 30). In most cases they are fine, tortuous veins which reach the scleral surface about opposite Schlemm's canal and not, as Lauber describes them, larger trunks which run obliquely forward to reach the surface. We do not find so extensive a plexus of scleral veins in this region as has been described for man.

CILIARY BODY AND IRIS

The ciliary body is very poorly developed in the rabbit (figs. 21 and 31). It appears as a flat structure, due to the absence of any definite ciliary muscle. Its length, from the ora serrata to the root of the iris, is about 1.5 mm., its thickness, just back of the iris root, about 0.3 mm. Krause describes the ciliary muscle as a flat structure with separated bundles. Lauber says that the muscle is weak and contains pigment cells which lie between the fibers. We cannot be certain that there is a ciliary muscle. Van Gieson stains show that the location of the muscle is occupied by dense

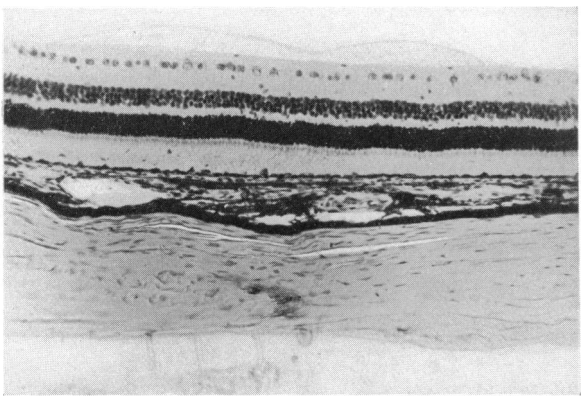

Fig. 39.—Wall of eyeball in region of visual streak. Same section as used in fig. 38. Note greater thickness of retinal layers and of choroid (× 225).

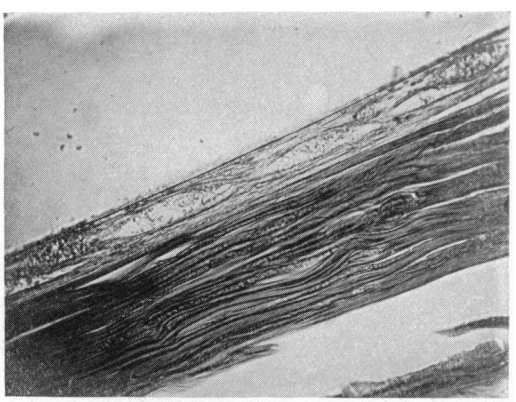

Fig. 40.—Choroid and sclera of an albino rabbit. For details see fig. 41 (van Gieson, × 255).

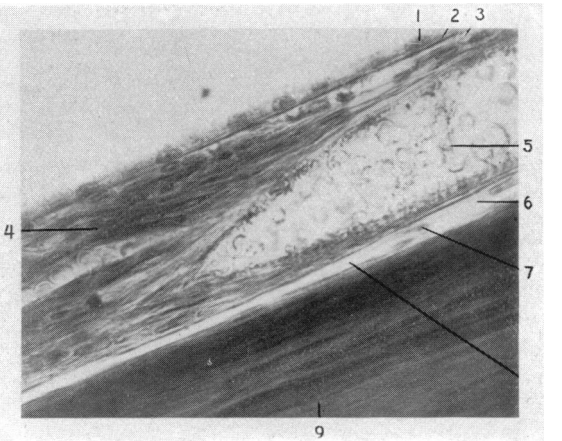

Fig. 41.—Detail of choroid shown in fig. 40: 1. Pigment epithelium. 2. Lamina vitrea. 3. Choriocapillaris. 4. Stroma of choroid. 5. Large vein. 6. Suprachoroidea. 7. Endothelial nuclei. 8. Suprachoroidal spaces. 9. Sclera (van Gieson, × 600).

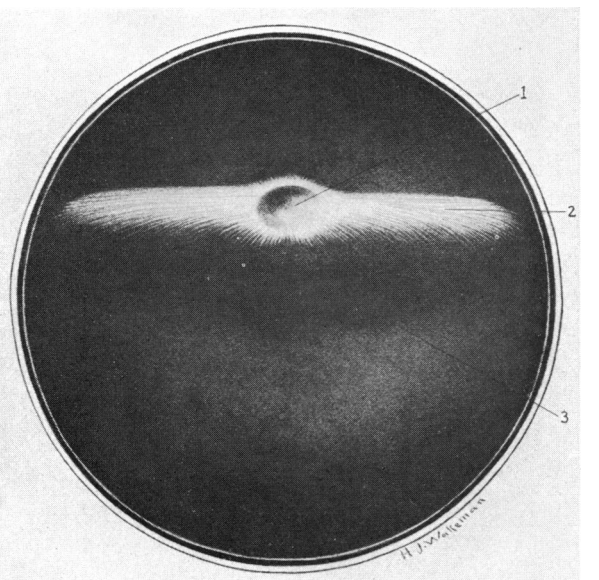

Fig. 42.—Fundus pigmented rabbit (drawing from gross specimen): 1. Optic disc; oval deep cup. 2. Medullated nerve fibers. 3. Pigmented streak (macula?).

fibrous tissue with considerable pigment. A few thin bands of yellow-staining tissue are found among these dense fibers, but, even if these are muscle fibers, they are so few as to have no practical effect. The ciliary processes arise from the anterior part of the ciliary body and continue onto the posterior surface of the iris. Opposite the iris pillars these processes have a very strong attachment to the base of the iris, the so-called "ciliary shelf" (fig. 21). The ciliary processes are unusually well developed. Their attachment may extend well beyond the middle of the iris. The processes vary considerably in length; their arrangement, however, is fairly symmetrical, alternating as long, medium, and short (fig. 32). The ciliary epithelium is composed of two layers: the deeper is pigmented, the surface layer non-pigmented. The non-pigmented portion of the inner epithelium covers the orbiculus and the posterior portions of the ciliary processes. The zonule fibers appear to be derived from the non-pigmented epithelium, as far back as the ora serrata. They originate from the entire surface of the epithelium, on the summits of the ciliary ridges as well as in the valleys, and as far forward as the epithelium is unpigmented (figs. 24, 28, and 33). This arrangement suggests that the posterior portion of the processes serves for the suspension of the lens, while that portion anterior to the shelf is more concerned with the production of aqueous. Virchow has written an exhaustive description of the gross structure of the ciliary processes, to which the reader may refer for further details.

The gross appearance of the iris coloration varies considerably with the degree of pigmentation of the animal, but is usually some shade of brown. The pupil is centrally located and is very slightly oval vertically. The markings are less distinct than those of the human iris, the surface appears smoother, the radial striæ are finer, the crypts are not so deep. The iris is slightly more pigmented near the

pupillary border but there is normally no ectropion of the uvea.

Meridional sections show that the iris is broad and relatively thin, gently arched, and arises from the ciliary body by a narrow root (fig. 31). It is bowed forward due to the large, thick lens. It is thin near the root, thicker near its middle, and tapers to a thin edge at the pupillary border.

The stroma, making up the body of the iris (fig. 34), consists of loose connective-tissue fibers, in which are embedded blood-vessels and nerves. The pigment is in branching chromatophores which are scattered diffusely throughout the stroma, being more concentrated at the anterior surface, especially near the pupillary margin. Hauschild has described the pigment distribution in the rabbit iris. The iris pillars, which represent projections of the stroma, have already been described. In sections we constantly encounter a large artery near the center of the iris. This is the circulus arteriosus iridis major described by Leber. The long ciliary arteries enter the iris nasally and temporally and divide, each sending a branch above and below to form the circle. From this circle all the arteries of the iris and ciliary processes are given off.

The blood-vessels of the iris have thick adventitia. Near the bases of the iris pillars there are numerous, fairly large veins (fig. 22) which possess large perivascular lymph-spaces. It does not seem unreasonable to assume that some of the aqueous may filter out into these lymph spaces, and that this represents a mechanism accessory to Schlemm's canal for the filtration of aqueous from the large anterior chamber of the rabbit. A similar exit of aqueous through the lace-like uveal meshwork of the iris angle and thence into the veins of the ciliary body seems possible.

The anterior surface of the iris is relatively smooth but there are shallow depressions (figs. 35 and 36). The deeper of these, near the iris root, probably represent true crypts.

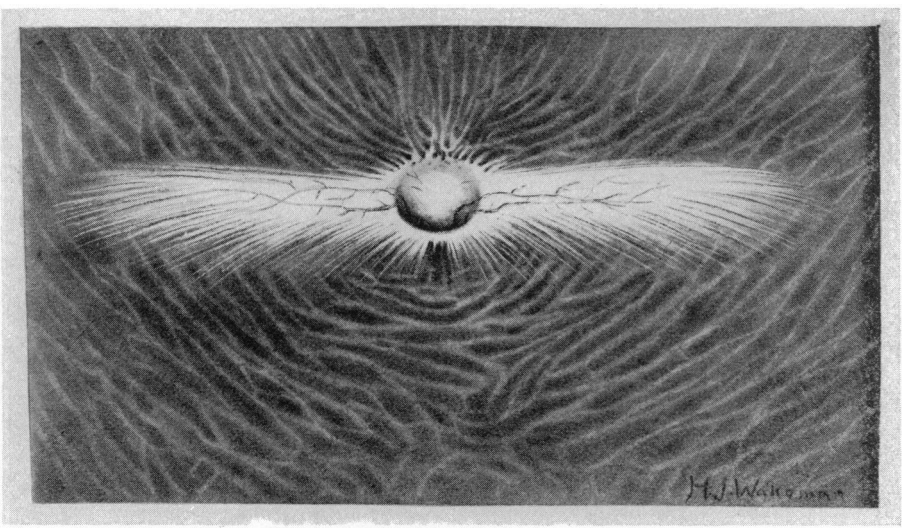

Fig. 43.—Normal fundus of rabbit—gray.

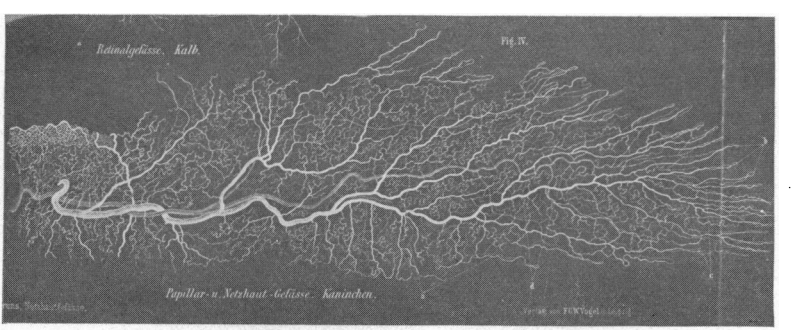

Fig. 44.—Reproduction of Bruns' figure of the retinal vessels of the rabbit. The fine network at the left is the blood-vessel system of the papilla.

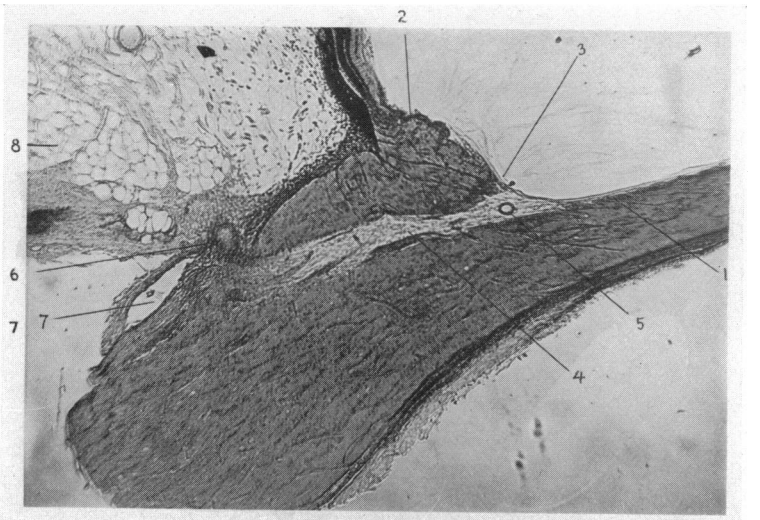

Fig. 45.—Longitudinal section of the optic nerve entrance: 1. Dorsal portion of papilla. 2. Its ventral portion. 3. Center of optic cup. 4. Strand of fibrous tissue which accompanies the blood-vessels through the nerve. 5. One of branches of central retinal artery, cut across. 6. Position of entrance of vessels into nerve. 7. Dilated intervaginal space behind this entrance. 8. Fat (hematoxylin-eosin, × 50).

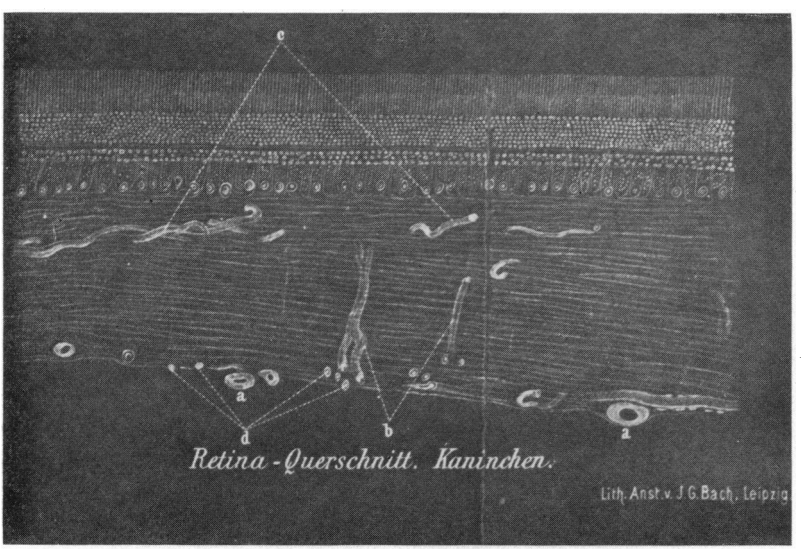

Fig. 46.—Reproduction of a figure by Bruns, showing the blood-vessels of the medullary-ray area of the retina.

The surface is covered by a single layer of thin endothelial cells which are not, as Krause states, laid over one another as shingles, but form a continuous surface with no overlapping. The continuity of this endothelium appears to be broken occasionally at the bottom of the deeper depressions. Wolfrum, discussing the endothelial covering of the iris in rodents, states that these cells are very similar to fibroblasts, that connections between them and the iris stroma can be demonstrated, and thinks that a true endothelium in these animals is doubtful. We do not know whether or not his statements refer specifically to the rabbit, but on the basis of our preparations we feel that the cells probably do represent a true endothelium.

The posterior surface of the iris is rough and irregular, due to the attachments of the ciliary processes. It is covered by a layer of densely pigmented epithelium which is especially thick near the pupil. It is the direct continuation of the surface epithelium of the ciliary body. The deeper layer of ciliary epithelium is continued onto the iris as the dilator pupillæ (fig. 34), a thin, flat muscle, made up of modified epithelial cells. It is pigmented except for some of the more distal fibers and extends the entire length of the iris. The sphincter muscle is well developed and appears in sections as a fairly dense mass of fibers in the stroma of the iris at the pupillary border, lying between the pigment epithelium on the one side and the deeply pigmented stroma of the anterior surface on the other (fig. 37).

CHOROID

The choroid is a well-developed coat in the rabbit. Its anterior limits are continuous with the stroma of the orbiculus, and there is no change in the appearance of this coat at the ora serrata. There is considerable variation in the manner in which it joins the optic nerve. Above the nerve there appears to be a direct continuation of the spaces of the supra-

choroidea with the subdural and subarachnoid spaces. Below the nerve the connection of spaces is less evident, but the substance of the choroid is continuous with that of the pia and arachnoid. Laterally the conditions show a transition between those below and above the nerve (fig. 52). Experiments by Wagenfarth, injecting the subarachnoid space of the brain, indicates that this space is continuous with the perichoroidal space through the optic nerve. Dr. J. N. Evans, of New York, has kindly sent us a slide of a section of the eye of a rabbit, in which the subarachnoid space of the brain had been injected with India ink. The perichoroidal spaces were filled with ink. Further details on the relation of the choroid to the optic nerve will be taken up under the discussion of the optic nerve entrance.

There are striking variations in the thickness of the choroid in different parts of the eye. For example, in the region just above the nerve it averages about 45μ (fig. 38), while below, in the region of the visual streak, it measures about 120μ (fig. 39), and under the medullary rays it becomes very thin. In general, it becomes thinner as one approaches the ora serrata, and is thickest at the posterior pole. This transition is not uniform, however; for the most part it is thicker in the lower part of the globe than in the upper.

The histologic structure is essentially the same as that of the human choroid (figs. 40 and 41). One can easily identify the suprachoroidea, the layer of large vessels, the choriocapillaris, and the glass membrane. The suprachoroidea is made up of delicate lamellæ containing elastic fibers clothed with endothelium. Between these lamellæ are spaces which are easily spread into wide clefts by the shrinkage usually encountered in histologic preparations. We think that these are lymph spaces (see above). The suprachoroidea contains abundant pigment cells, so that it is almost solid black in a pigmented eye. Its structure is best studied in albino eyes.

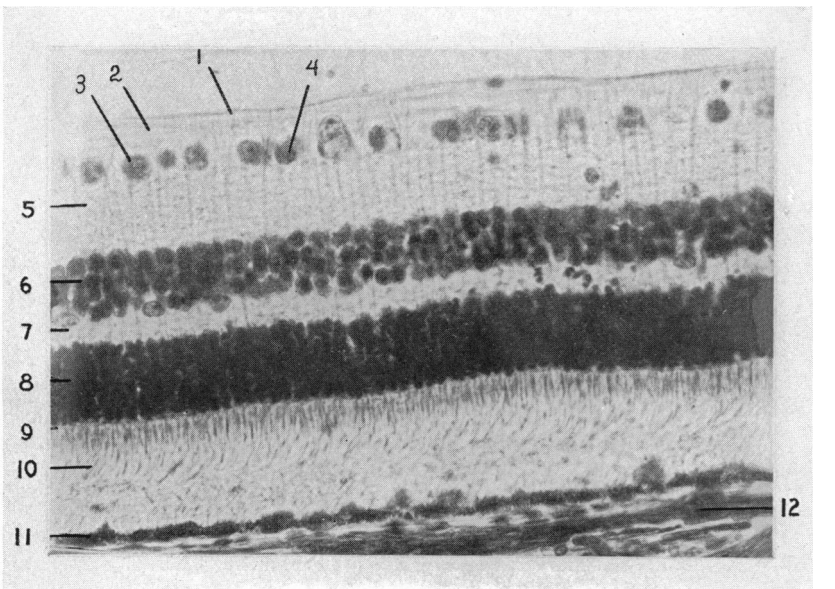

Fig. 47.—Detail of retina in visual streak: 1. Limitans interna. 2. Nerve-fiber layer. 3. Ganglion cell. 4. Glia cell. 5. Internal plexiform layer. 6. Internal nuclear layer. 7. External plexiform layer. 8. External nuclear layer. 9. Limitans externa. 10. Rods and cones. 11. Pigment epithelium. 12. Stroma of choroid (hematoxylin-eosin, × 500).

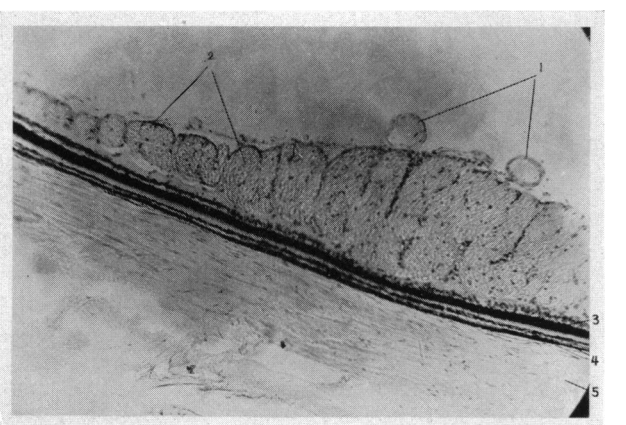

Fig. 48.—Section of wall of eye through medullary rays: 1. Retinal vessels. 2. Bundles of medullated nerve fibers. 3. Layers of retina. 4. Choroid. 5. Sclera (hematoxylin-eosin, × 135).

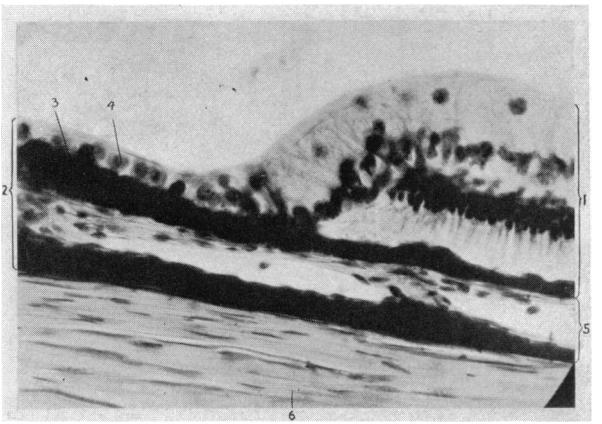

Fig. 49.—Detail of ora serrata. The layers of the retina may be recognized, with the exception of a nerve-fiber layer: 1. Retina. 2. Orbiculus ciliaris. 3. Pigment epithelium. 4. Ciliary epithelium, non-pigmented. 5. Choroid. 6. Sclera (hematoxylin-eosin, × 600).

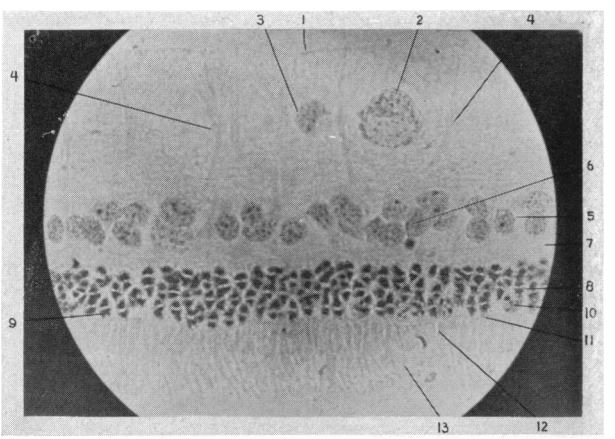

Fig. 50.—Thin section of retina to show detail: 1. Limitans interna. 2. Ganglion cell. 3. Glia cell. 4. Mueller's fibers. 5. Internal nuclear layer. 6. Nuclei of Mueller's fibers. 7. External plexiform layer. 8. External nuclear layer. 9. Rod granules. 10. Cone granules. 11. Limitans externa. 12. Internal segments of rods and cones. 13. External segments of rods and cones (hematoxylin-eosin, × 1000).

There are no blood-vessels in this portion of the choroid except those which course through it.

A layer of large vessels makes up the bulk of the choroid, and are chiefly veins. They are contained in a stroma rich in collagenous fibers. This stroma is somewhat more dense than in the human choroid.

The choriocapillaris forms a single layer of fine capillaries separated from the former layer by stroma, which in this region becomes parallel to the surface and contains an abundance of elastic fibers. Immediately internal to the choriocapillaris the lamina vitrea appears as a thin, homogeneous, unbroken, glass-like membrane which gives the internal surface a smooth, sharp contour. The pigment epithelium is almost always found in contact with this membrane in preparations, although the retina may have been detached.

We wish to direct especial attention to the pigmented streak of the choroid which has not received the attention it deserves from other writers (fig. 39). Krause refers to the visual streak as being marked out in life by its greater content of visual purple, saying nothing about the condition of the choroid in this region. Chievitz mentions the sensitive area of the retina as a light streak. As a matter of fact, the choroid is thicker than elsewhere under the visual streak, so that transillumination of the enucleated globe (or, better, of the posterior half of the globe, mounted in glycerin jelly) reveals a dark streak extending transversely across the back of the globe below the nerve (fig. 42). This streak may be seen almost to the ora serrata both nasally and temporally. It gradually fades out into the surrounding choroid at its ends, but near the middle its borders are fairly sharp. Just below the nerve it is 4 mm. wide, and its center is 3 mm. below the center of the papilla. The apparent function of this thickening of the choroid is to furnish additional nutrition to the visual streak of the retina, which overlies it. In this connection it is interesting to note that the retina of this area

is much thicker than above the nerve, especially in its rod and cone and ganglion-cell layers.

RETINA

As one examines the fundus of the rabbit eye with the ophthalmoscope the striking feature is a large, oval disc, deeply cupped, with two broad white bands of opaque nerve fibers streaming out from it nasally and temporally (figs. 42 and 43). This is seen far above the horizontal plane. The medullary rays were first described by Cuvier, with apparently little idea of their significance. They were mentioned incidentally by Müller in describing the blood-vessels and are described briefly in Krause's textbook; also accurately and in detail by Grosskopf. Johnson publishes an excellent colored figure of the rabbit fundus. The medullary rays extend temporally and nasally until a short distance behind the equator, fading out gradually at their ends. Bundles of medullated fibers stream out from these rays to a slight extent above, more prominently below. According to Grosskopf, the medullary rays are not present at birth. Medullated fibers are first seen eleven to twelve days after birth, are quite prominent by the fourteenth day, and have reached practically the adult condition at the end of three weeks.

The restricted distribution of the retinal blood-vessels was apparently first mentioned by Müller, and Krause gives a good description of this condition. Bruns describes the retinal vascular system in great detail, publishing a figure showing the blood-vessels to their finest branches (fig. 44). The arteria and vena centralis retinæ enter the optic nerve ventrally, between the nerve and the eyeball, about 1 mm. behind the union of nerve and sclera. They course obliquely forward and upward (chiefly upward) to reach the center of the papilla (fig. 45). They divide just before or just after emerging from the nerve into nasal and temporal branches, which mount up the lateral walls of the cup and bend over

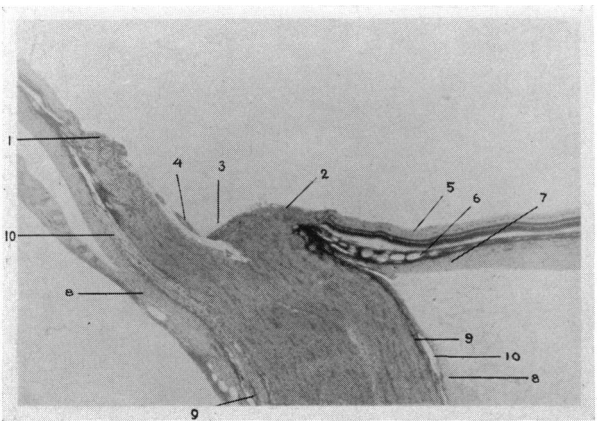

Fig. 51.—Sagittal section of eye in region of optic nerve entrance: 1. Dorsal rim of papilla. 2. Its ventral rim. 3. Optic cup. 4. Retinal vessels. 5. Retina. 6. Choroid. 7. Sclera. 8. Dura. 9. Pia. 10. Intervaginal spaces. 11. Muscle fibers (hematoxylin-eosin, $\times 40$).

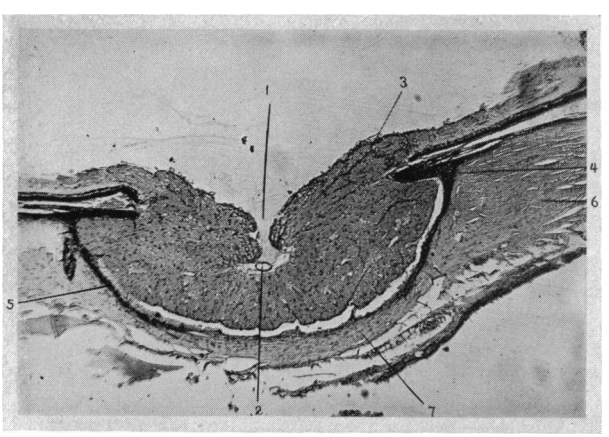

Fig. 52.—Horizontal axial section through region of optic nerve entrance: 1. Optic cup. 2. Central artery. 3. Medullated fibers entering nerve from retina. 4. Junction of choroid and pia. 5. Pia. 6. Sclera. 7. Dura (hematoxylin-eosin, $\times 50$).

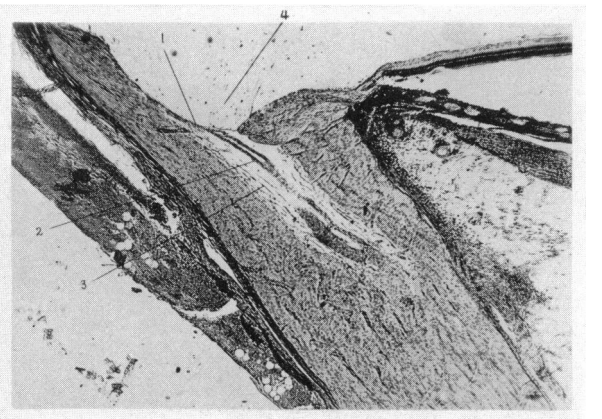

Fig. 53.—Longitudinal section of optic nerve and papilla: 1. Optic cup. 2. Central retinal artery. 3. Central retinal vein. 4. Vitreous fibers attached in optic cup. Other details as in fig. 45 (hematoxylin-eosin, × 50).

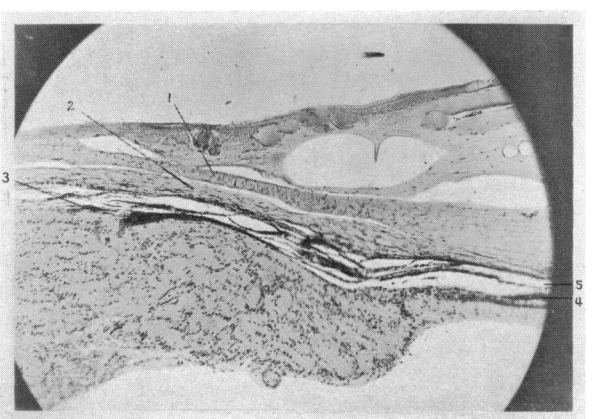

Fig. 54.—Section through dorsal margin of papilla: 1. Superficial portion of the dura, with the fibers running transversely, continuous with the outer portion of the sclera. 2. Deeper portion of dura, with longitudinal fibers continuous with the inner portion of the sclera. 3. Pia. 4. Choroid. 5. Spaces of suprachoroidea continuous with those of nerve-sheaths (hematoxylin-eosin, × 100).

its rim to be distributed along the bundles of medullated nerve fibers. Outside this area the retina is avascular. The larger stems are in the vitreous, inside the hyaloid membrane, as His and Bruns have accurately described them (fig. 46). The capillary loops dip into the nerve-fiber layer, but never penetrate farther than the outer limits of this layer. This distribution of the central retinal vessels suggests that their function is to furnish nourishment to the strongly developed bundles of medullated nerve fibers.

There is no macula in the rabbit eye but there does seem to be a sensitive area, the visual streak, which corresponds to the pigmented streak of the choroid described above. It extends horizontally below the medullated fibers. It is an area from 3 to 4 mm. wide, and its center is located about 3 mm. below the papilla. This area is not usually visible with the ophthalmoscope, although histologically it shows marked differences from the rest of the retina. It has been described by Krause as an area having a greater content of visual purple than the remainder of the retina.

The histologic structure of the retina is essentially the same as in the human eye, with some detailed differences to be noted. The thickness is fairly uniform, though it varies somewhat in different situations; e. g., it is relatively much thicker in the visual streak, whereas under the medullated fibers and near the ora serrata it becomes much thinner. The general thickness is about 120μ, as measured a short distance above the margin of the disc. In the visual streak below the disc it is about 160μ, under the medullated fibers as low as 36μ (not including the fiber layer), near the ora serrata about 90μ. The visual streak shows striking differences from the rest of the retina (figs. 39 and 47). The rods and cones are longer, the external and internal nuclear layers are thicker, and the ganglion cells are more numerous.

Detailed measurements of these regions are given in table I. These measurements are based on a study of six eyes.

TABLE I.—THICKNESS (IN MICRA) OF RETINAL LAYERS IN DIFFERENT REGIONS OF RABBIT RETINA

Layer	Above nerve	In visual streak	Under medullated fibers	Near ora serrata
Rods and cones	25	41	4	12
External nuclei	24	30	14	21
External plexiform	8	7	..	..
Internal nuclei	12	27	6	18
Internal plexiform plus ganglion cell	29	46	12	39
Nerve fibers	19	7	294	..
Totals	117	158	330	90

In Krause's description of the retina the visual streak is inaccurately described; that is, the ganglion cells are recorded as in two to three layers whereas we find only one. He says further that the inner and outer nuclear layers are the same here as under the medullated fibers, whereas we find both layers much thicker in the visual streak. He fails to call attention to the marked increase in thickness of the visual streak as compared to the rest of the retina.

Under the medullary rays (fig. 48) the rods and cones become very short, the external nuclear layer thinner, the inner nuclear layer much thinner, while the ganglion cells are reduced to a few isolated cells between the bundles of nerve fibers. Both plexiform layers are reduced—the outer to a very thin layer which cannot be satisfactorily measured. As one approaches the periphery of the medullary-ray area the retina assumes a more normal appearance.

The layers gradually grow thinner as one approaches the ora serrata, the internal plexiform remaining relatively thicker. At the ora serrata the rods and cones with their nuclei end abruptly (fig. 49), the layers internal to them bend toward the choroid, and then all end except the internal nuclear layer, which becomes continuous with the non-pigmented epithelium of the ciliary body. The pigment epithelium becomes thicker as it goes over onto the orbiculus ciliaris.

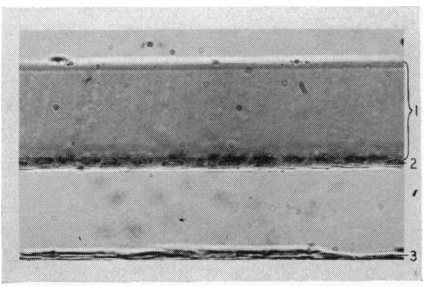

Fig. 55.—Lens capsule at the anterior pole: 1. Capsule. 2. Epithelium. 3. Lens substance artificially detached (hematoxylin-eosin, × 500).

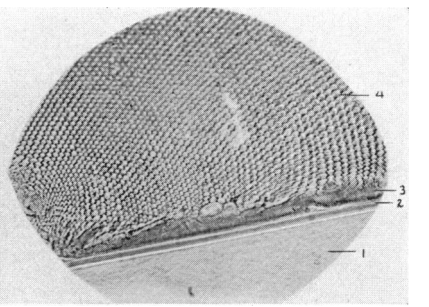

Fig. 56.—Lens near the posterior pole: 1. Vitreous. 2. Capsule. 3. Degenerated lens fibers (probably result of fixation). 4. Lens fibers cut across. 5. Region of posterior suture line (hematoxylin-eosin, × 500).

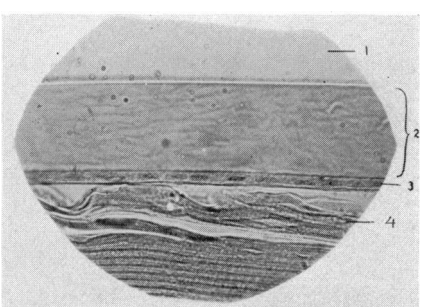

Fig. 57.—Capsule in region of maximum thickness: 1. Posterior chamber. 2. Capsule. 3. Lens epithelium. 4. Lens fibers (hematoxylin-eosin, × 500).

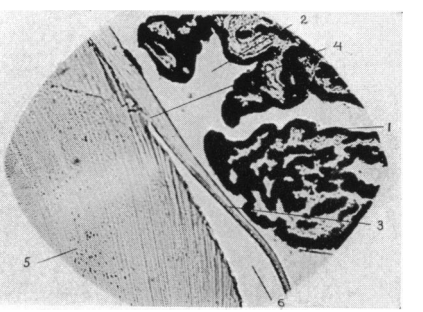

Fig. 58.—Region just in front of equator: 1. Ciliary processes. 2. Posterior chamber. 3. Capsule. 4. Lens epithelium. 5. Lens fibers. 6. Artificial cleft (hematoxylin-eosin, × 90).

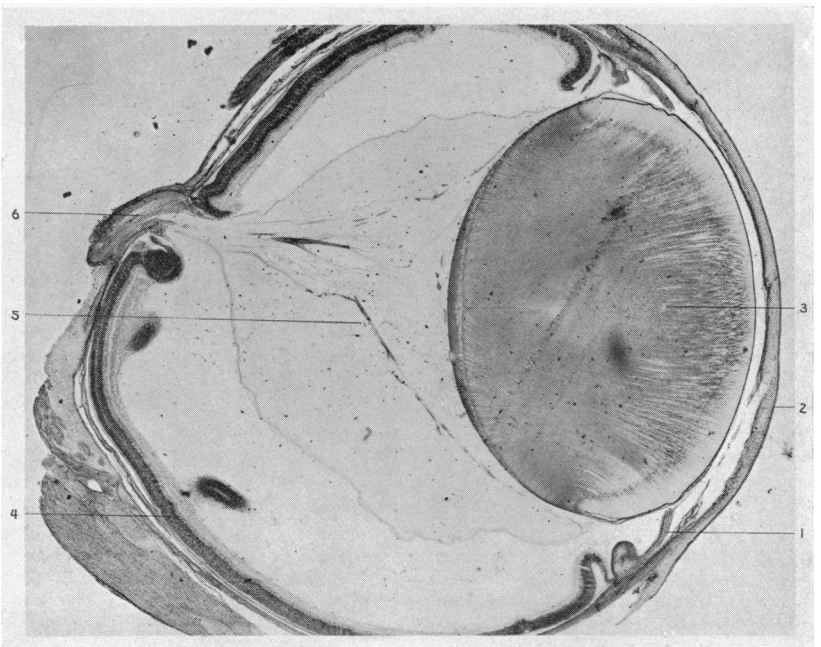

Fig. 59.—Normal eye of new-born rabbit: 1. Iris. 2. Cornea. 3. Lens. 4. Retina. 5. Vitreous with remnants of hyaloid artery. 6. Optic nerve.

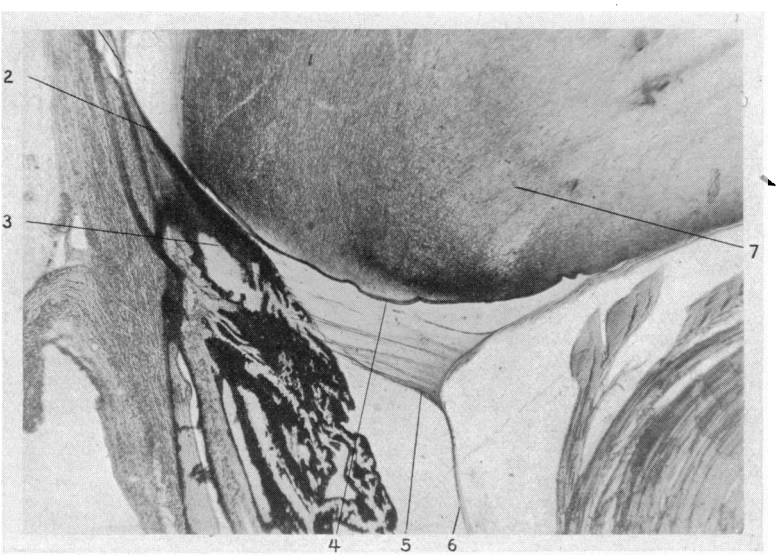

Fig. 60.—Region of limbus of an eye the vitreous of which was injected with India ink: 1. Ora serrata. 2. Orbiculus ciliaris. 3. Ciliary processes. 4. Anterior border membrane of vitreous. 5. Zonule fibers. 6. Lens capsule. 7. Vitreous.

Ganglion cells near the ora serrata are very infrequent. Without further study we are not prepared to state why the internal plexiform layer remains thick.

There are some interesting details to be noted regarding the cellular structure of the retina. The cells of the pigment epithelium, according to Angelucci, are irregular in size—there are large ones with two nuclei and smaller ones with only one nucleus. Surface sections show them to be irregular in arrangement, whereas those of the human retina are regularly hexagonal. The pigment-granules, we have noted, are fusiform, while in the human epithelium they are round. The rods and cones are extremely long and thin. Angelucci computes that there are sixteen to twenty cones and up to one hundred rods for each large pigment cell; half as many for the smaller cells. The rod nuclei, which make up most of the cells of the outer nuclear layer, show a peculiar cross-striped condition, due to the fact that the chromatin is accumulated at the two poles of the nucleus, leaving a clear space between. This is easily brought out by ordinary stains and gives the nucleus a coffee-bean appearance (fig. 50). These nuclei are described by Krause. The cone nuclei are larger, much fewer, and lie in contact with the external limiting membrane. The chromatin is divided into several masses; the cross-striped appearance is not present.

The inner nuclear layer contains a number of different kinds of nuclei, which we are not yet prepared to analyze. Mueller's fibers are quite prominent in ordinary preparations, their inner portions spread out and end on the inner surface of the retina. On the debated question as to whether there is a membrana limitans interna, we are not yet prepared to express an opinion.

OPTIC NERVE

The optic nerve pierces the sclera high up on the posterior aspect of the globe (figs. 1 and 51). The nerve approaches the

globe from below, ascends over the posterior surface in virtual contact with the sclera, penetrating the latter at a very acute angle. The foramen opticum scleræ et choroideæ is horizontally oval. The papilla, or nerve-head, when viewed ophthalmoscopically, shows an unusually deep cupping and is horizontally oval; the margins are indistinct, particularly nasally and temporally, due to the bulging curved surface of the large bundles of medullated nerve fibers which leave the papilla at these margins (fig. 52). The lower margin is more sharply defined, as fewer nerve fibers leave the papilla below. The upper margin is also indistinct, due to the fact that the retinal fibers do not bend sharply at this margin but curve gradually onto the sloping upper surface of the papilla. The deep cupping of the nerve-head is the result of the fact that the scleral opening is larger than the nerve, so that there are not sufficient fibers to fill the opening (fig. 51). The depth is probably also augmented by the weakness or practical absence of a lamina cribrosa. Sections of the nerve show that there are a few weak, branching lamellæ of fibrous tissue derived from the pia and choroid, extending more or less transversely across the papilla (fig. 53), but these are so few as to have little practical effect. In a detailed treatise on the lamina cribrosa in different animals, Hoffman has pointed out the practical absence of this structure in the rabbit.

The sheaths of the optic nerve are more directly continuous with the coats of the eye than in man. This is especially noticeable above the nerve, where sections show the dura going over uninterruptedly into the sclera (figs. 23 and 51). Thus the intervaginal spaces of the nerve do not appear to terminate at the junction of the dura with the sclera but pass uninterruptedly into the spaces of the suprachoroidea, as already mentioned in the description of the choroid (fig. 54). Below the nerve the intervaginal spaces seem to terminate at the point of entrance of the central retinal vessels; beyond this point the sheaths hug the nerve very closely (figs. 45, 51,

and 53). It is probable that the spaces are still present, at least as narrow channels. At the junction with the eye (below) the dura and sclera become extremely thin. The arachnoid seems to end just back of the nerve entrance, the dura fusing with the pia, and the combined layers uniting with the choroid. The sclera thins out almost completely before union with the nerve. At the junction of the pia with the choroid there is a considerable mass of densely pigmented tissue (fig. 51).

This arrangement of the intervaginal spaces (the absence of a blind optic nerve canal) suggests that the production of choked disc would be difficult in the rabbit, though we have performed no experiments of this nature.

LENS

The lens of the rabbit is larger than the human lens and differs from it chiefly in being more spherical. When studied in gross mounts, the capsule shows dentate markings at the equator. These are the site of attachment of the zonule fibers. The curvature of the posterior surface is slightly greater than that of the anterior, the radius of curvature of the former being about 5 mm., that of the latter about 5.3 mm. The thickness or axial diameter is about 7.6 mm., the equatorial diameter about 11 mm., as measured on fresh specimens. Rabl has made an elaborate study of the lenses of a number of animals, including some details on the rabbit. His measurements are 8.79 by 11.89 mm. The sutures of the lens are simple linear markings, the anterior being vertical, the posterior horizontal. The lens capsule is a tough, glass-like membrane, which varies in thickness in different parts of the same lens. At the anterior pole the average thickness is 30μ, varying from 16 to 51μ (fig. 55). At the posterior pole the average is 3.4μ, varying from 1.5 to 6μ (fig. 56). At the equator the average is 9μ, with variations from 5 to 15μ. On the anterior surface there is a

region of maximum thickness located slightly nearer the equator than the anterior pole (fig. 59). This attains a thickness of 36μ, with limits at 60μ and 18μ. Behind this area the capsule thins rapidly to the equator (fig. 59). Behind the equator the thinning is gradual, reaching a minimum at the posterior pole.

Epithelium covers the anterior surface of the lens to its equator. Near the equator it gradually thickens, the cells becoming larger, until it goes over into lens fibers. The row of nuclei in the lens continues for a short distance posteriorly and then bends toward the front to follow the anterior curvature of the lens. This arrangement is similar to that of the human. The arrangement of lens fibers is somewhat different than in man, due to the presence of a single suture instead of a "Y"-shaped suture (fig. 1). The lens is much thicker and therefore the bending of the fibers at the equator is not nearly so sharp as in man. A nucleus is not so sharply marked off as in the human lens.

ZONULE AND VITREOUS

The vitreous of the new-born rabbit appears as a relatively dense fibrous mass containing many blood-vessels (fig. 59). These vessels enter through the optic cup, course through the vitreous, and spread out to encircle the posterior surface of the lens. This is the remnant of the primitive hyaloid system. It has disappeared by the second to third week of life. The vitreous is attached at the optic cup and extends forward to the lens and attaches to the ciliary body. We have made no special study of the adult vitreous; however, our sections show a definite hyaloid membrane (fig. 60). This membrane has no cellular structure. It might be regarded as a simple condensation of the border layers of the vitreous. It takes on a much deeper stain than the body of the vitreous when India ink is injected into the latter, and it stands out as a distinct border or line. This membrane

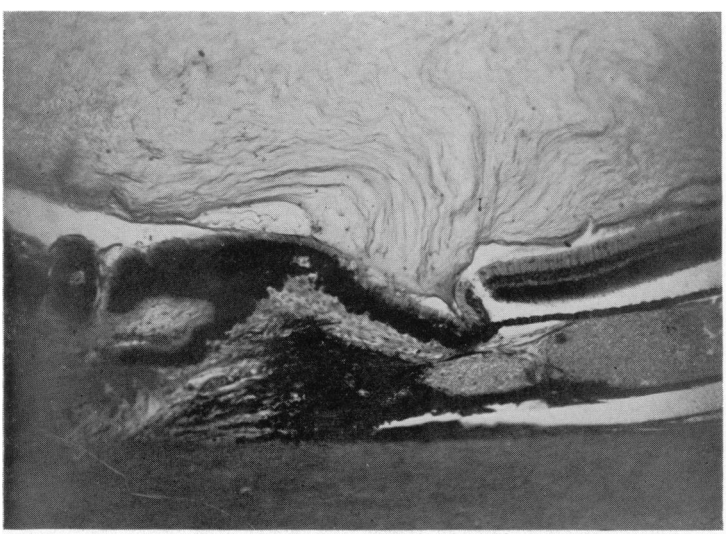

Fig. 61.—Showing attachment of vitreous fibers at orbiculus ciliaris.

appears much more definite in the anterior border of the vitreous, that is, the surface which borders the lens and zonule. In some specimens a definite line or border zone stands out on the vitreous as it comes in contact with the zonule, particularly in the anterior portion of the latter. Far back on the orbiculus, where the most posterior zonule fibers have their origin, this line disappears and the vitreous fibers appear to arise directly from the epithelium covering the orbiculus (figs. 60 and 61). Sections of the vitreous show it to be made up of a delicate, lacy, web-like reticulum.

The zonule fibers very definitely arise from the epithelium of the posterior portion of the ciliary body, as though they were secreted by it (fig. 33). They are derived from the entire surface of the processes posterior to the ciliary shelf, not simply from the valleys, as described for man. They also arise far back on the orbiculus ciliaris. Thus, on the debated question of the ectodermal vs. mesodermal origin of the vitreous, we are inclined toward the ectodermal. The embryonic vitreous is probably mesodermal. Addario believes that the ciliary epithelium is the producer of the vitreous. De Waele believes in its mesodermal origin. Dejean is ambiguous on this point. He feels that the vitreous and zonule are made up of fine lamellæ. Rabl says that the zonule and vitreous are pure ectodermal formations. We have made no attempt to exhaust the literature on the vitreous, but have only incidentally read such articles as mention the rabbit or related animals.

I wish here to express my appreciation and give full acknowledgment to Harvey M. Smith, Ph.D., research assistant in ophthalmology in the University of Wisconsin, for his invaluable services in connection with the preparation of this paper.

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