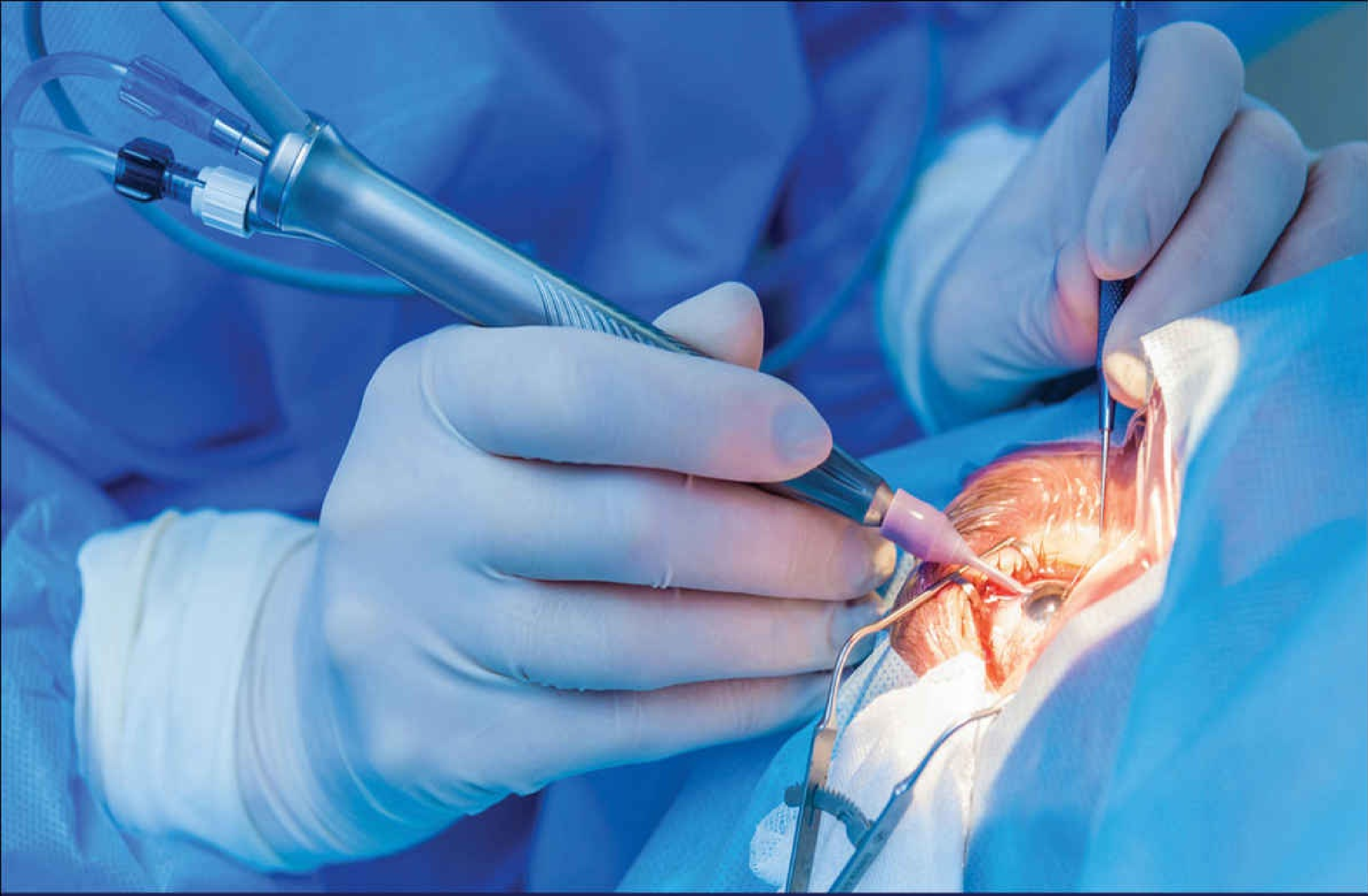

19th edition

Vaughan & Asbury's GENERAL OPHTHALMOLOGY

Paul Riordan-Eva • James J. Augsburger

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… Now do you not see that the eye embraces the beauty of the whole world? It is the lord of astronomy and the maker of cosmography; it counsels and corrects all the arts of mankind; it leads men to the different parts of the world; it is the prince of mathematics, and the sciences founded on it are absolutely certain. It has measured the distances and sizes of the stars; it has found the elements and their locations; it … has given birth to architecture, and to perspective, and to the divine art of painting. Oh excellent thing, superior to all others created by God! … What peoples, what tongues will fully describe your true function? The eye is the window of the human body through which it feels its way and enjoys the beauty of the world. Owing to the eye the soul is content to stay in its bodily prison, for without it such bodily prison is torture.

Leonardo da Vinci (1452–1519)

a LANGE medical book

Vaughan & Asbury's GENERAL OPHTHALMOLOGY

NINETEENTH EDITION

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This edition of
General Ophthalmology
is dedicated with gratitude and in memory of

Roderick (“Rick”) Biswell, MD,
(1937-2015)

who was a chapter author for many previous editions.

Contents

Authors

Preface

Acknowledgments

1. Anatomy & Embryology of the Eye

Paul Riordan-Eva, FRCOphth

2. Ophthalmologic Examination

David F. Chang, MD

3. Ophthalmic Emergencies

Paul Riordan-Eva, FRCOphth

4. Lids & Lacrimal Apparatus

M. Reza Vagefi, MD

5. Conjunctiva & Tears

Francisco J. Garcia-Ferrer, MD, James J. Augsburger MD, and Zélia M. Corrêa MD, PhD

6. Cornea

Ahmed Al-Maskari, FRCOphth, and Daniel F. P. Larkin, MD, FRCOphth

7. Uveal Tract & Sclera

Emmett T. Cunningham, Jr., MD, PhD, MPH, James J. Augsburger, MD, Zélia M. Corrêa, MD, PhD, and Carlos Pavesio, MD, FRCOphth

8. Lens

Richard A. Harper, MD

9. Vitreous

Steve Charles, MD

10. Retina

Raeba Mathew, FRCS, Sobha Sivaprasad, FRCOphth, James J. Augsburger, MD, and Zélia M. Corrêa, MD, PhD

11. Glaucoma

John F. Salmon, MD, FRCS

12. Strabismus

W. Walker Motley, MS, MD

13. Orbit

M. Reza Vagefi, MD

14. Neuro-Ophthalmology

Paul Riordan-Eva, FRCOphth

15. Ocular Disorders Associated with Systemic Diseases

Alastair Stuart, BMBS FRCOphth, and Edward Pringle, MRCP, FRCOphth

16. Immunologic Diseases of the Eye

Munir M. Iqbal, MD, and William G. Hodge, MD, MPH, PhD, FRCSC

17. Special Subjects of Pediatric Interest

Paul Riordan-Eva, FRCOphth

18. Ophthalmic Genetics

James J. Augsburger, MD, and Zélia M. Corrêa, MD, PhD

19. Ophthalmic Trauma

Jonathan Pargament, MD, Zélia M. Corrêa, MD, PhD, and James J. Augsburger, MD

20. Causes and Prevention of Vision Loss

Dustin Curts, MD, and William G. Hodge, MD, PhD, FRCSC

21. Optics & Refraction

Paul Riordan-Eva, FRCOphth

22. Ophthalmic Therapeutics

Paul Riordan-Eva, FRCOphth, Frederick W. Fraunfelder, MD, MBA, and Lindsey M. McDaniel, MD

23. Lasers in Ophthalmology

James McHugh, FRCOphth, and Edward Pringle, MRCP, FRCOphth

24. Low Vision

Gwen K. Sterns, MD

25. Vision Rehabilitation

August Colenbrander, MD

Appendix: Functional Vision Score

August Colenbrander, MD

Glossary

Index

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Preface

For almost six decades, General Ophthalmology has served as a concise, current, and authoritative review of the subject for medical students, ophthalmology residents, practicing ophthalmologists, nurses, optometrists, and colleagues in other fields of medicine and surgery, as well as health-related professionals. The nineteenth edition has been revised and updated in keeping with that goal. It contains the following changes from the eighteenth edition:

- All relevant illustrations in color
- Major revision of Chapters 6 (Cornea), 10 (Retina), 13 (Orbit), 14 (Neuro-Ophthalmology), 16 (Immunologic Diseases of the Eye), 20 (Causes and Prevention of Vision Loss) and 23 (Lasers in Ophthalmology).

We are grateful to Toby Chan, Victor Chong, Eleanor Faye, Allan Flach, Emily Fletcher, Douglas Fredrick, Elizabeth Graham, William Hoyt, Lisa Nijm, Adnan Pirbhai, Shefalee Shukla Kent, John Shock, Ivan Schwab and John Sullivan for their contributions to previous editions. We warmly welcome our new authors, Ahmed Al-Maskari, Dustin Curts, Munir Iqbal, Frank Larkin, Raeba Mathew, Lindsey McDaniel, James McHugh, Jonathan Pargament, Sobha Sivaprasad and Alastair Stuart.

Paul Riordan-Eva, FRCOphth
James J. Augsburger, MD
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1

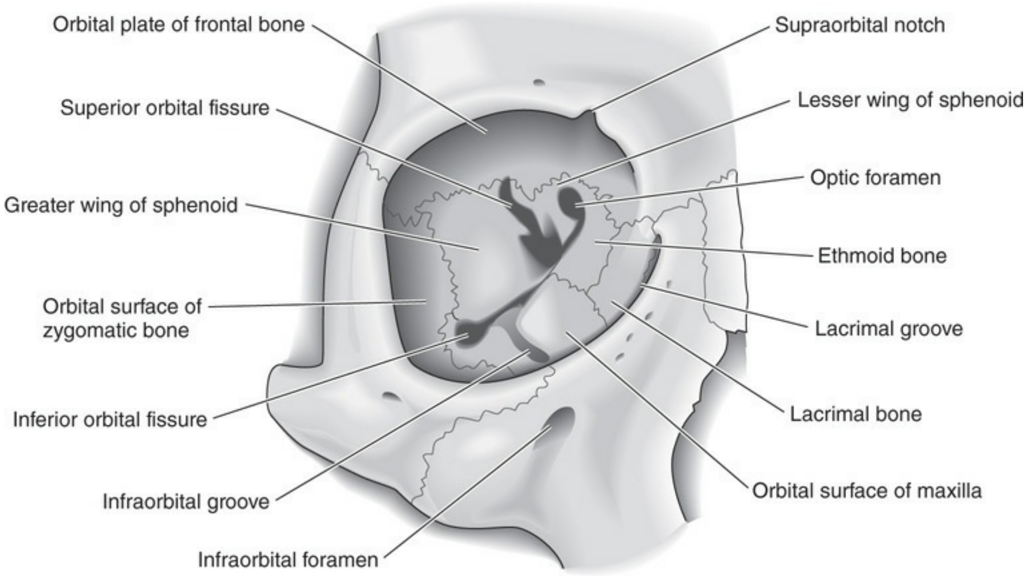
Anatomy & Embryology of the Eye

Paul Riordan-Eva, FRCOphth

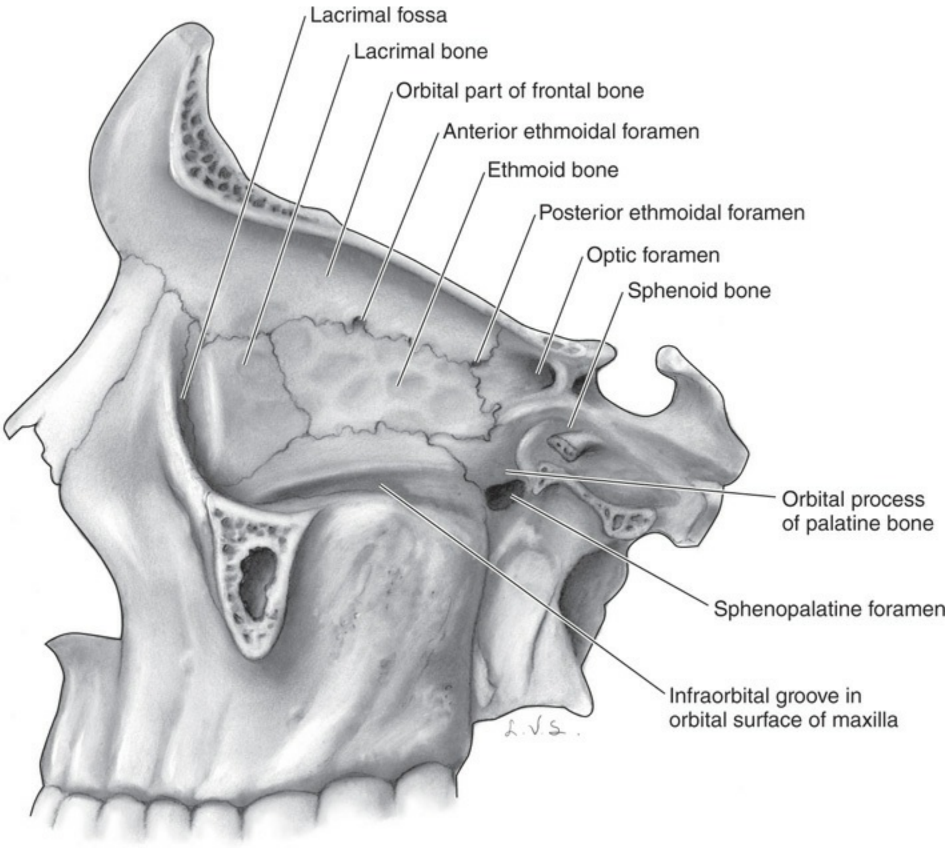
A thorough understanding of the anatomy of the eye, orbit, visual pathways, upper cranial nerves, and central pathways for the control of eye movements is a prerequisite for proper interpretation of diseases having ocular manifestations. Furthermore, such anatomic knowledge is essential to the proper planning and safe execution of ocular and orbital surgery. Whereas most knowledge of these matters is based on anatomic dissections, either postmortem or during surgery, noninvasive techniques—particularly magnetic resonance imaging (MRI), ultrasonography, and optical coherence tomography (OCT)—are increasingly providing additional information. Investigating the embryology of the eye is more difficult because of the relative scarcity of suitable human material, and thus there is still great reliance on animal studies with the inherent difficulties in inferring parallels in human development. Nevertheless, a great deal is known about the embryology of the human eye, and—together with the recent expansion in molecular genetic—this has led to a much deeper understanding of developmental anomalies of the eye.

I. NORMAL ANATOMY

THE ORBIT (FIGURES 1–1 AND 1–2)



▲ **Figure 1–1.** Anterior view of bones of right orbit.



▲ **Figure 1–2.** Medial view of bony wall of left orbit.

The orbital cavity is schematically represented as a pyramid of four walls that converge posteriorly. The medial walls of the right and left orbit are parallel and are separated by the nose. In each orbit, the lateral and medial walls form an angle of 45°, which results in a right angle between the two lateral walls. Anteriorly, parts of the **frontal bone**, **zygomatic (malar) bone**, and **maxilla** form a sturdy approximately circular bony aperture that is slightly smaller in cross-sectional dimension than the base of the pyramid, thus providing protection to the globe.

The volume of the adult orbit is approximately 30 mL, and the eyeball occupies only about one-fifth of the space. Fat and muscle account for the bulk of the remainder.

The anterior limit of the orbital cavity is the **orbital septum**, which acts as a barrier between the lids and orbit (see Lids later in this chapter).

The orbits are related to the paranasal sinuses. The thin orbital floor and paper-thin medial wall (lamina papyracea) are easily damaged by direct trauma to the globe, resulting in a "blowout" fracture with herniation of orbital contents inferiorly into the maxillary antrum or medially into the ethmoid sinus. Infection within the ethmoid and sphenoid sinuses can spread into the orbit or affect the optic nerve respectively. Defects in the roof (eg, neurofibromatosis) may result in visible pulsations of the globe transmitted from the brain.

Orbital Walls

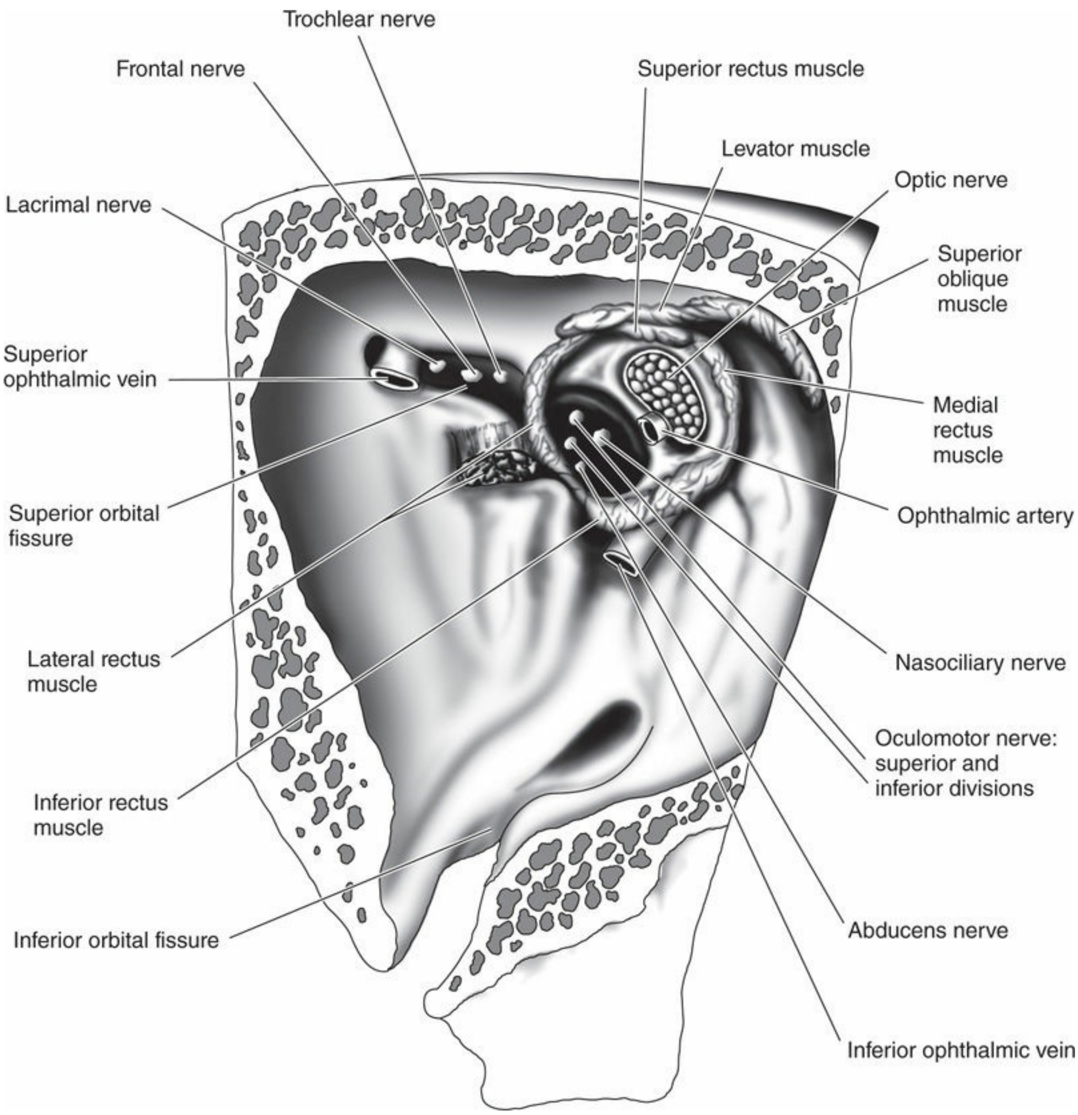
The roof of the orbit is composed principally of the orbital plate of the frontal bone. The lacrimal gland is located in the lacrimal fossa in the anterior lateral aspect of the roof. Posteriorly, the lesser wing of the sphenoid bone containing the optic canal completes the roof.

The lateral wall is separated from the roof by the superior orbital fissure, which divides the lesser from the greater wing of the sphenoid bone. The anterior portion of the lateral wall is formed by the orbital surface of the zygomatic bone. This is the strongest part of the bony orbit. Suspensory ligaments, the lateral palpebral tendon, and check ligaments have connective tissue attachments to the lateral orbital tubercle.

The orbital floor is separated from the lateral wall by the inferior orbital fissure. The orbital plate of the maxilla forms the large central area of the floor and is the region where blowout fractures most frequently occur. The frontal process of the maxilla medially and the zygomatic bone laterally complete the inferior orbital rim. The orbital process of the **palatine bone** forms a small triangular area in the posterior floor.

The boundaries of the medial wall are less distinct. The **ethmoid bone** is paper-thin but thickens anteriorly as it meets the **lacrimal bone**. The body of the sphenoid forms the most posterior aspect of the medial wall, and the angular process of the frontal bone forms the upper part of the posterior lacrimal crest. The lower portion of the posterior lacrimal crest is made up of the lacrimal bone. The anterior lacrimal crest is easily palpated through the lid and is composed of the frontal process of the maxilla. The lacrimal groove lies between the two crests and contains the lacrimal sac.

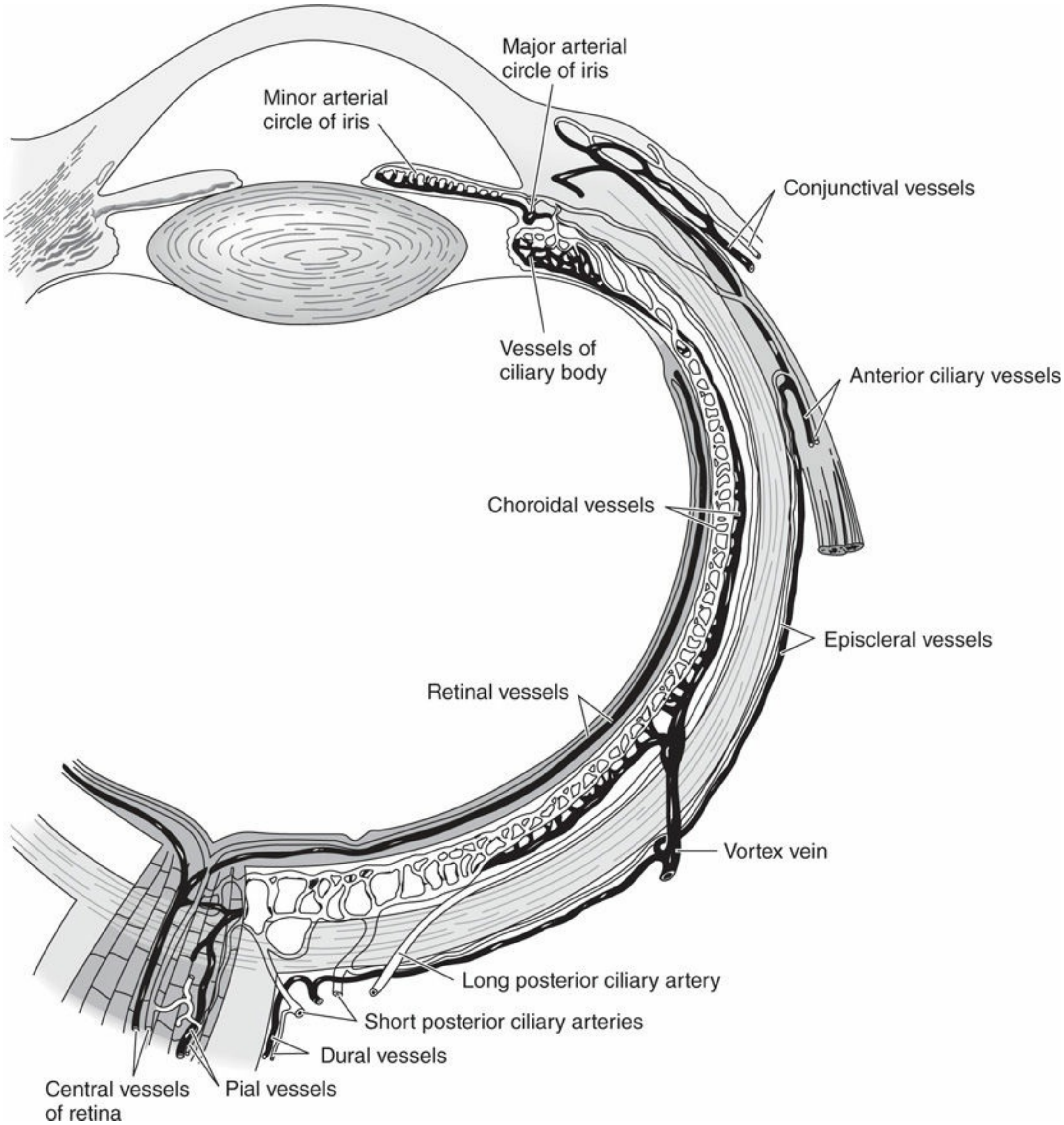
Orbital Apex (Figure 1–3)



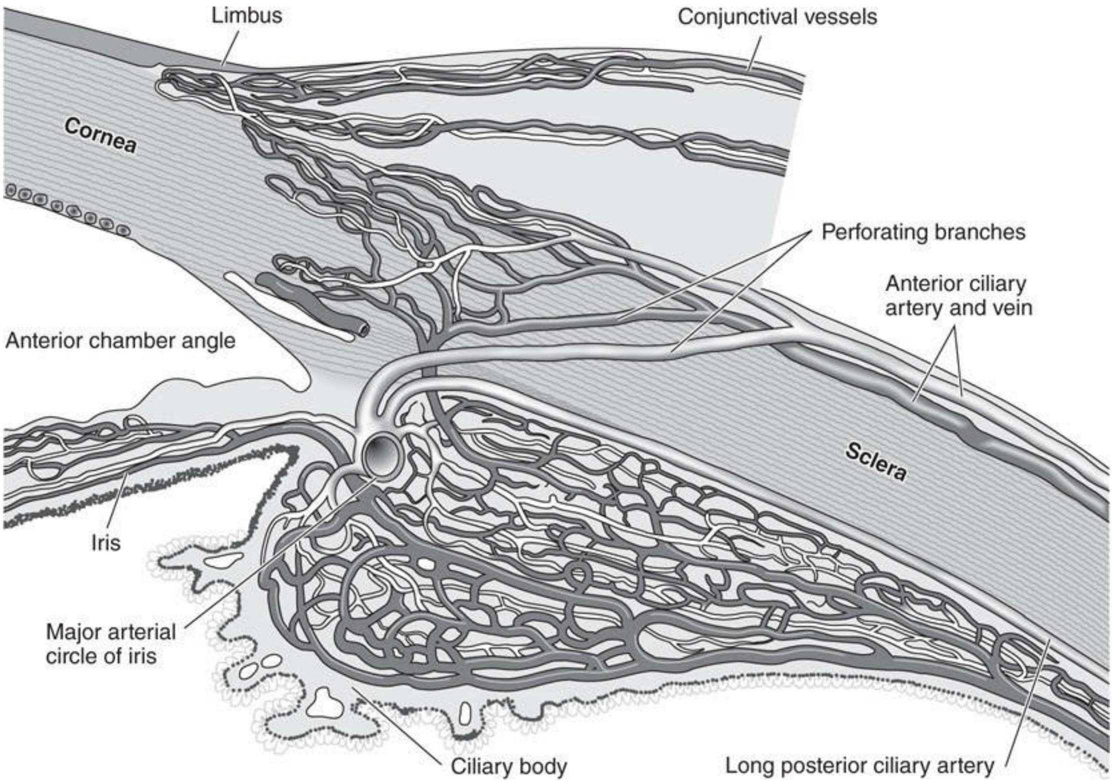
▲ **Figure 1–3.** Anterior view of apex of right orbit.

The apex of the orbit is the main portal for all nerves and vessels to the eye and the site of origin of all extraocular muscles except the inferior oblique. The **superior orbital fissure** lies between the body and the greater and lesser wings of the sphenoid bone. The superior ophthalmic vein and the lacrimal, frontal, and trochlear nerves pass through the lateral portion of the fissure that lies outside the annulus of Zinn. The superior and inferior divisions of the oculomotor nerve and the abducens and nasociliary nerves pass through the medial portion of the fissure within the annulus of Zinn. The optic nerve and ophthalmic artery pass through the optic canal, which also lies within the annulus of Zinn. The inferior ophthalmic vein frequently joins the superior ophthalmic vein before exiting the orbit. Otherwise, it may pass through any part of the superior orbital fissure, including the portion adjacent to the body of the sphenoid that lies inferomedial to the annulus of Zinn, or through the inferior orbital fissure.

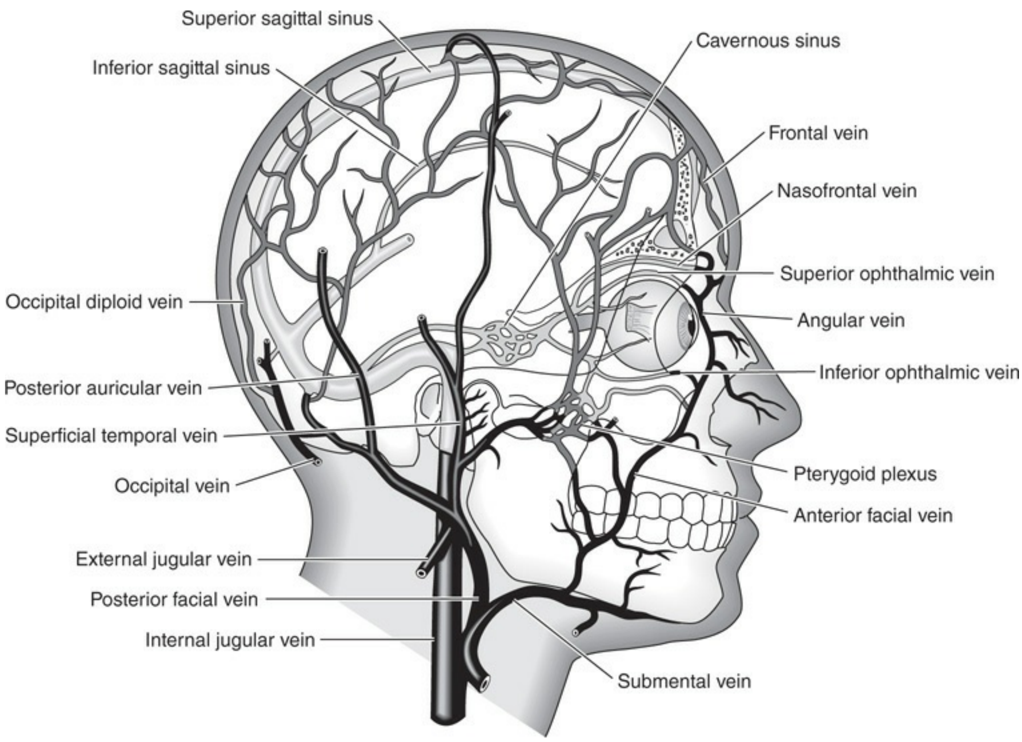
Blood Supply (Figures 1–4, 1–5, and 1–6)



▲ **Figure 1–4.** Vascular supply to the eye. All arterial branches originate with the ophthalmic artery. Venous drainage is through the cavernous sinus and the pterygoid plexus.



▲ **Figure 1–5.** Vascular supply of the anterior segment.



▲ **Figure 1–6.** Venous drainage system of the eye.

The principal arterial supply of the orbit derives from the ophthalmic artery, the first major branch of the intracranial portion of the internal carotid artery. This branch passes beneath the optic nerve and accompanies it through the optic canal into the orbit. The first intraorbital branch is the central retinal artery, which enters the optic nerve about 8–15 mm behind the globe. Other branches of the ophthalmic artery include the lacrimal artery, supplying the lacrimal gland and upper lid; muscular branches to the various muscles of the orbit; long and short posterior ciliary arteries; medial palpebral arteries to both lids; and the supraorbital and supratrochlear arteries. The short posterior ciliary arteries supply the choroid and parts of the optic nerve. The two long posterior ciliary arteries supply the ciliary body and anastomose with each other and with the anterior ciliary arteries to form the major arterial circle of the iris. The anterior ciliary arteries are derived from the muscular branches to the rectus muscles. They supply the anterior sclera, episclera, limbus, and conjunctiva and contribute to the major arterial circle of the iris. The most anterior branches of the ophthalmic artery contribute to the formation of the arterial arcades of the lids, which make an anastomosis with the external carotid circulation via the facial artery.

The venous drainage of the orbit is primarily through the superior and inferior ophthalmic veins, into which drain the vortex veins, the anterior ciliary veins, and the central retinal vein. The ophthalmic veins communicate with the cavernous sinus via the superior orbital fissure and the pterygoid venous plexus via the inferior orbital fissure. The superior ophthalmic vein is initially formed from the supraorbital and supratrochlear veins and from a branch of the angular vein, all of which drain the skin of the periorbital region. This provides a direct communication between the skin of the face and the cavernous sinus, thus forming the basis of the potentially lethal cavernous sinus thrombosis, secondary to superficial infection of the periorbital skin.

THE EYEBALL

The normal adult globe is approximately spherical, with an anteroposterior diameter averaging 24 mm.

THE CONJUNCTIVA

The conjunctiva is the thin, transparent mucous membrane that covers the posterior surface of the lids (the palpebral conjunctiva) and the anterior surface of the sclera (the bulbar conjunctiva). It is continuous with the skin at the lid margin (a mucocutaneous junction) and with the corneal epithelium at the limbus.

The **palpebral conjunctiva** lines the posterior surface of the lids and is firmly adherent to the tarsus. At the superior or inferior margin of the tarsus, the conjunctiva is reflected posteriorly (at the superior and inferior fornices) and covers the episcleral tissue to become the bulbar conjunctiva.

The **bulbar conjunctiva** is loosely attached to the orbital septum in the fornices and is folded many times. This allows the eye to move and enlarges the secretory conjunctival surface. (The ducts of the lacrimal gland open into the superior temporal fornix.) Except at the limbus (where Tenon's capsule and the conjunctiva are fused for about 3 mm), the bulbar conjunctiva is loosely attached to Tenon's capsule and the underlying sclera.

A soft, movable, thickened fold of bulbar conjunctiva (the **semilunar fold**) is located at the inner canthus and corresponds to the nictitating membrane of some lower animals. A small, fleshy, epidermoid structure (the **caruncle**) is attached superficially to the inner portion of the semilunar fold and is a transition zone containing both cutaneous and mucous membrane elements.

Histology

The **conjunctival epithelium** consists of two to five layers of stratified columnar epithelial cell—superficial and basal. Conjunctival epithelium near the limbus, over the caruncle, and near the mucocutaneous junctions at the lid margins consists of stratified squamous epithelial cells. The **superficial epithelial cells** contain round or oval mucus-secreting goblet cells. The mucus, as it forms, pushes aside the goblet cell nucleus and is necessary for proper dispersion of the precorneal tear film. The **basal epithelial cells** stain more deeply than the superficial cells and may contain pigment near the limbus.

The **conjunctival stroma** is divided into an adenoid (superficial) layer and a fibrous (deep) layer. The **adenoid layer** contains lymphoid tissue and, in some areas, may contain "follicle-like" structures without germinal centers. The adenoid layer does not develop until after the first 2 or 3 months of life. This explains why in the newborn inclusion conjunctivitis is papillary, whereas thereafter it is follicular. The **fibrous layer** is composed of connective tissue that attaches to the tarsal plate. This explains the appearance of the papillary reaction in inflammations of the conjunctiva. The fibrous layer is loosely arranged over