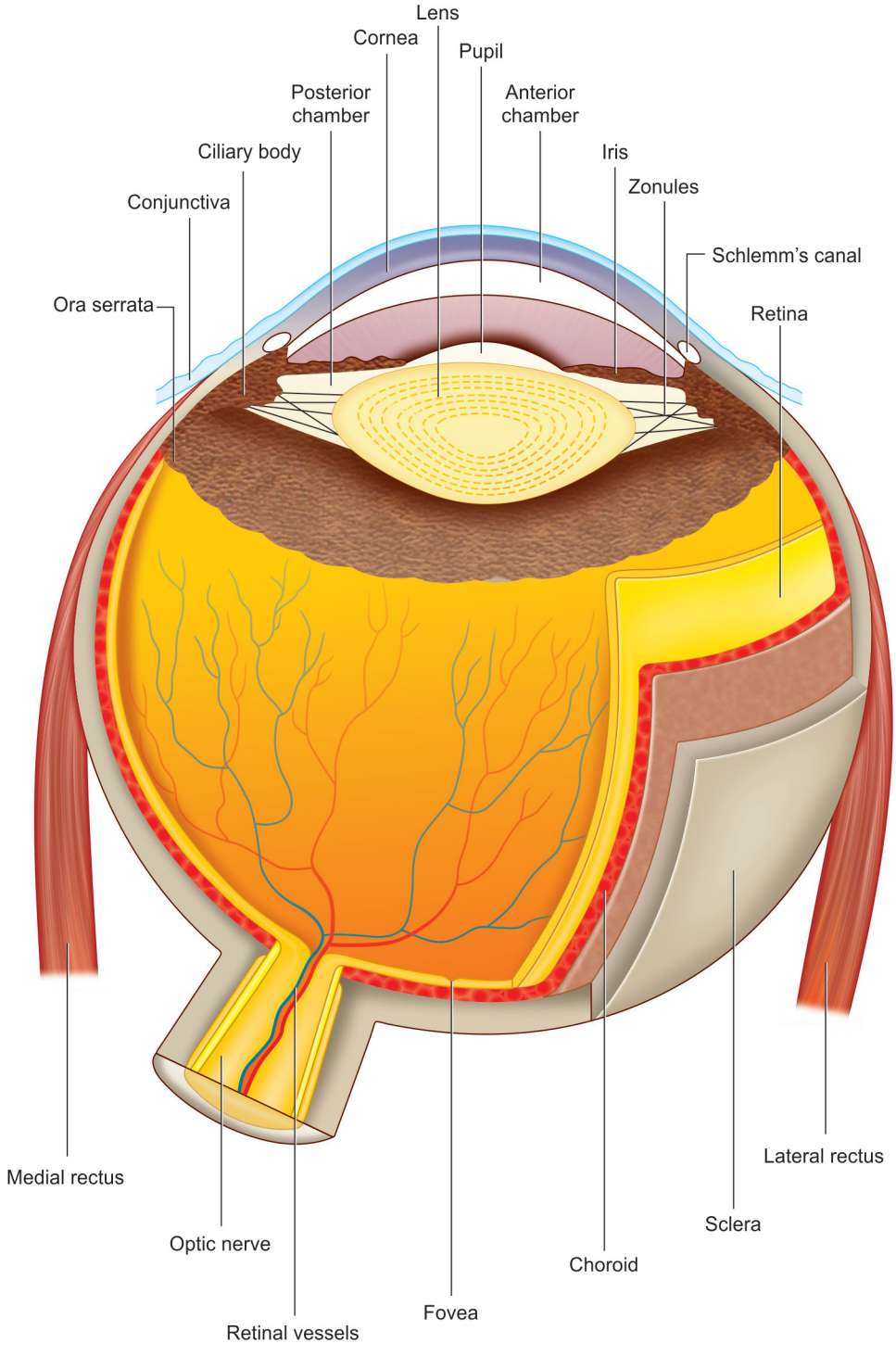

Fig. 1.1. *Gross anatomy of the eyeball.*

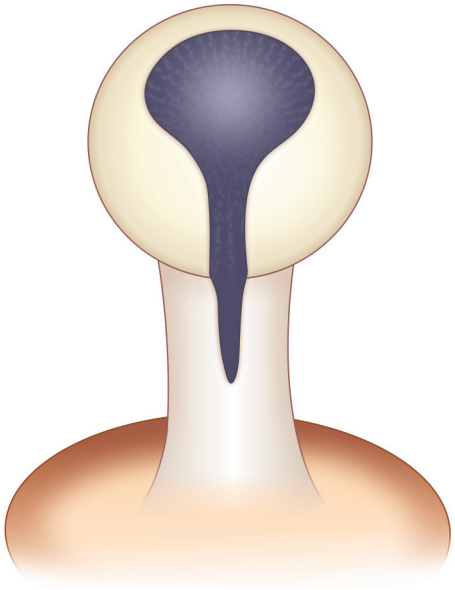

Fig. 1.9. *Optic cup and stalk seen from below to show the choroidal fissure.*

cells embedded in a matrix rich in glycosaminoglycans.

Mesenchymal cells may be derived from serosal sources, namely mesoderm (dermatome or sclerotome component of the somite or lateral plate mesoderm) or neural crest. Thus this descriptive term mesenchyme does not imply an origin from any particular embryonic germ layer. The mesenchyme surrounding the neural tube subsequently condenses to form meninges. An extension of this mesenchyme also surrounds the optic vesicle, except at its apex, which is closely apposed to the surface ectoderm on the lateral side of the developing head. This mesenchyme may be derived from the cephalic neural crest and indeed from crest cells detaching from the outer surface of the optic vesicle itself. Later, this mesenchyme differentiates to form a superficial fibrous layer (corresponding to dura), which will form the sclera and cornea and a deeper vascular layer (corresponding to pia arachnoid) which will form stroma of uveal tissue (Fig. 1.10).

With the formation of optic cup, part of the inner vascular layer of mesenchyme is carried into the cup through the choroidal fissure. With the closure of this fissure, the portion of mesenchyme which has made its way into the

Box 1.2 ***Clinical pearls: Malformations of the neural tube and optic vesicle***

These occur in the 1st month of embryonic life and include:

- *Anophthalmia*, which is extremely rare, and is due to a failure of formation of the optic vesicle. The orbits do not contain ocular tissue, but the extraocular muscles (mesoderm) and lacrimal gland (ectoderm) are present.
- *Nanophthalmia and microphthalmia*. Farmation of the optic vesicle without proper subsequent development produces a rudimentary eye in the orbit nanophthalmia(or dwarf eye).

  In microphthalmia, there is a small but recognizable eye that contains recognizable elements, e.g. lens, choroid, and retina.
- *Synophthalmia*. Fusion of the two eyes may result from a malformation of the mesodermal tissue between the optic vesicles or faulty inductive processes. Only rarely is a single eye (cyclops) formed by this mechanism and in most cases there are two recognizable corneas and lenses, and identifiable ports of the iris and ciliary body. The midline scleral and uveal tissue may be absent and the optic nerve may be single or duplicate. This malformation may be associated with a deletion of chromosome 18.
- *Congenital cystic eye*. A disorganized cystic structure may arise owing to disturbances in the process of invagination of the retinal disc.

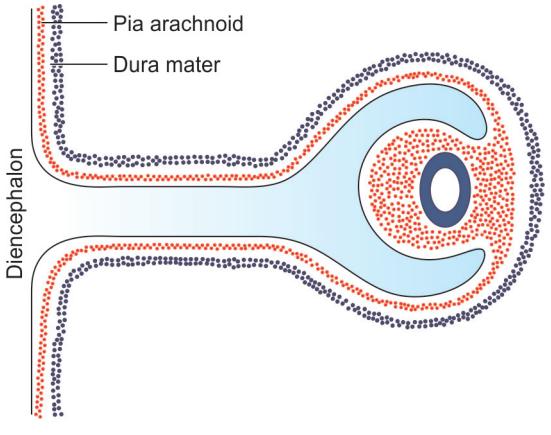

Fig. 1.10. *Developing optic cup surrounded by mesoderm.*

amacrine and Muller cell bodies and shortly afterwards the bipolar and the horizontal cells differentiate from the outer neuroblastic layer and migrate into this new nucleated layer (Fig. 1.13C).

- *Outer nuclear layer* is formed by the remaining components of the outer neuroblastic layer containing the cell bodies of photoreceptors (rods and cones).
- *Outer plexiform layer* (Fig. 1.13D) is constituted by zone where fibres from this layer intermingle with those of the inner nuclear layer.
- *External limiting membrane* (not a membrane per se) of the retina is identifiable in the early stages as rows of tight junctions between, adjacent neuroblasts.

Differentiation of the retinal layer thus starts during 6th week of gestation and by 5½ months of gestation, all the layers of the adult retina are recognizable. In the macular area, the development is delayed up to 8th month of gestation. Further differentiation of the retina and specialization of the macular region continues until several months after birth.

Some important landmarks in retinal development include:

- *Synaptogenesis in cone pedicles* occurs at approximately 4 months and in rod spherules around 5 months.
- *Photoreceptor outer segment formation* commences around the 5th month.
- *Horizontal cells become distinguishable* around the 5th month.
- *Microglia* (resident tissue macrophages) invade the retina via the retinal vasculature (4 months) and peripheral subretinal space (10 weeks onwards).
- *Terminal expansions of Muller cells* beneath the inner limiting membrane mature around 4.5 months, at around the same time as their processes can be identified between the rods and cones.

Brief summary of scheme of the general development of the retina and the pathway that the various cellular layers and membranes take in their formation is illustrated in Fig. 1.14.

Retinal pigment epithelium

Cells of the outer wall of the optic cup become pigmented around 6th week of gestation. Its posterior part forms the retinal pigment epithelium (RPE) of the retina and the anterior part continues forward in ciliary body and iris as their pigmented epithelium. Initially, the RPE comprises a mitotically active pseudostratified columnar ciliated epithelium. The cilia disappear as melanogenesis commences. The mitotic activity ceases by birth, thereafter growth of eye and consequently of the RPE itself is accommodated by hypertrophy or enlargement of existing cells. The mature RPE cells are hexagonal in shape, homogenous in size and in section appear as simple cuboidal epithelium. Melanin production in the pigment epithelial cells is gene-regulated and may be defective in albinism (Box 1.3).

RETINAL VESSELS

The fetal fissure along the optic stalk closes around the hyaloid artery, and the portions of the vessel within the stalk become the central retinal artery. A branch of the primitive maxillary vein located within the optic stalk is

Box 1.3 *Clinical pearls: Ocular albinism*

Melanocytes that derive their pigment from neural crest (i.e. those located in the choroid, skin, and hair) show a variance that is related to race. Melanocytes that are neuroectodermal in derivation (i.e. retinal pigment, iris, and ciliary body epithelia) are densely pigmented in all races. Melanin production is gene-regulated, and in an individual with albinism either or both types of melanocytes can be affected. Because normal development of sensory retina is influenced by a melanin-related agent produced in the RPE, when pigment is absent from this layer, as occurs in ocular albinism, a number of retinal abnormalities are present at birth in addition to the absence of pigmentation. The macula is underdeveloped and the fovea may be absent. The number of rods may be decreased. Abnormal optic nerve projection to the lateral geniculate nucleus occurs, with more crossed fibres than normal, often resulting in binocular problems.

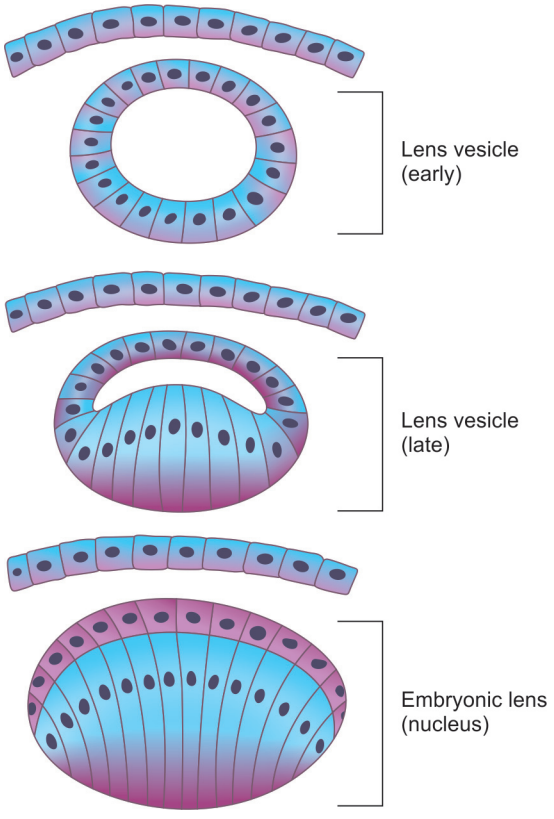

Fig. 1.15. *Development of the crystalline lens.*

initial lens fibres of fetal nucleus reach both the anterior and posterior poles and they surround the embryonic nucleus. This process mandates that the primary lens fibres (embryonic nucleus) lose their original attachments with the lens epithelium anteriorly and their basal laminae posteriorly. The subsequently formed fibres of fetal nucleus can no longer extend from one pole to the other. Instead they meet at radiating lines or sutures that appear as an erect Y anteriorly and an inverted Y posteriorly (Fig. 1.17). Later in gestation and following birth, the growth of the lens fibres is asymmetric. Therefore, instead of simple Y sutures, a more complicated dendritic pattern is observed in infantile and adult nucleus.

- ***Infantile nucleus*** refers to the secondary lens fibres formed during the last weeks of fetal life to puberty.
- ***Adult nucleus*** is formed by the secondary lens fibres formed after the puberty.
- ***Cortex*** consists of the recently formed superficial secondary lens fibres.

Note. Congenital cataract may develop due to faulty development of lens fibres (Box 1.6).

Formation of lens capsule

The true lens capsule is a membranous noncellular envelope that surrounds the lens. It is a true basement membrane produced as a result of basal laminae material deposited by the lens epithelium on its external aspect.

Tunica vasculosa lentis

During embryonic and fetal development, the lens receives nourishment via an intricate vascular capsule, the tunica vasculosa lentis, that completely encompasses the lens by approximately 9 weeks. It is formed from the mesenchyme that surrounds the lens. Three components of tunica vasculosa are anterior pupillary membrane, capsulopupillary membrane and

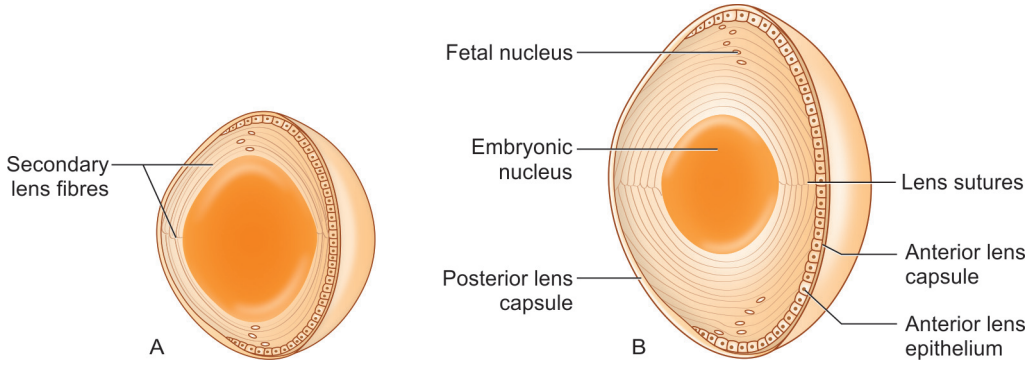

Fig. 1.16. *Formation of: (A) secondary lens fibres 7 weeks; and (B) fetal nucleus.*

Contents