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普通高等教育"十二五"规划教材
全国高等医药院校规划教材

英文原版改编版

OPHTHALMOLOGY

眼科学

留学生与双语教学用

Textbook of Ophthalmology (sixth edition)

[印]H. V. 内马 [印]尼廷·内马 原著
HV Nema Nitin Nema Original Editors

颜 华 王宁利 姚 克 主编
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赵堪兴 主审
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北 京

内 容 简 介

本书系统地介绍了眼科学的基本知识，包括眼科的解剖、生理、眼科学检查法和各种眼科疾病的诊断与治疗等。内容简明易懂，图文并茂，适合作为临床医学专业本科生中英文双语教学、留学生英文教学、硕士研究生和博士研究生教学的眼科学教材。本书也可以作为其他医学相关专业学生和青年医生学习眼科学的参考教材。

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General Foreword
总序言

随着中国政治、经济、文化的快速发展，中国软实力和国际影响力的不断提升，“留学中国计划”的逐步实施，越来越多的外国人认识到留学中国的未来价值，来华留学生规模不断扩大。2013 年，有来自 200 个国家和地区的 346 499 名外国留学生在我国 746 所高等院校和科研机构学习或进修，我国已经成为亚洲最大的留学目的地国家。

近年，来华学习医学的留学生人数增长尤为迅猛，目前来华学习医学的留学学历生人数已位居来华留学学历生人数的首位，2013 年占比高达 21.76%，为 29 048 名。

为了维护我国高等教育的国际声誉，教育部高度重视来华医学留学生教育教学质量，不断加强对医学留学生教育教学的规范和管理，多种措施付诸实施。2007 年教育部即制定了《来华留学生医学本科教育（英语授课）质量控制标准暂行规定》，要求招生院校严格落实执行。2013 年 7 月，教育部国际合作与交流司下达了《关于对招收本科临床医学专业（英语授课）来华留学生的高等学校进行专项工作检查的通知》，委托中国高等教育学会外国留学生教育管理分会组成专家组对招生院校进行专项工作检查。2013 年 8 月，全国性的“来华留学生（医学）教学专业委员会”成立大会暨第一次学术研讨会在天津医科大学成功召开。2014 年上半年，教育部国际合作与交流司又组织专家组对部分医学院校实施了飞行检查。2014 年 6 月，“来华留学医学教育 2014 学术研讨会暨首届医学院校国际教育学院院长论坛”在安徽医科大学举办。

来华留学生的教学质量是来华留学教育事业可持续发展的核心保障，来华留学生教育的教材建设是保障和提升教学质量非常重要的手段。适合来华医学留学生使用的教材的需求越来越迫切，临床医学专业的教材长期匮乏和不足，教材编写、教材内容、教材形式、教材版权等都需要进行整合和改进完善。

在教育部国际合作与交流司的指导和中国高等教育学会外国留学生教育管理分会的支持下，众多医学院校的领导和专家经过多次讨论、磋商，决定成立“来华医学留学生教育教材建设专家指导委员会”，委托天津医科大学和清华大学出版社共同承担全国性临床医学专业英文版立体化教材编写和出版的具体组织工作。

天津医科大学有近 17 年的英语授课培养外国留学生的历史，在来华医学留学生教育的实践方面开始较早，是教育部指定的第一批计划招生全英文临床医学专业的 30 余所院校之一，也是教育部首批批准的“来华留学教育示范基地”，设有教育部来华留学英语教学师资培训中心（医学），至今已举办 6 期培训班，为全国 52 所医科院校培训英语授课教师 364 人，所编教材在全国 30 余所西医院校教学中被借鉴或使用，在全国医学高等院校来华留学生教育教学

领域里具有代表性和很大的影响力。

清华大学出版社在高等教育综合出版领域里，排名我国第二位，是以出版全方位、多学科、立体化的高等教育教材为主的大社；上级主管单位为教育部，主办单位是清华大学，高质量、创新型、探究型的特色教材是其出版的重点任务，也是其肩负的社会职责所在，其所具有的强烈的社会责任感、主动性和积极性值得肯定。

据悉，该套教材近 50 种，主要供临床医学留学生、七年制或八年制医学生、医学本科生英语或双语教学使用。部分教材由我国长期从事医学留学生教育的教授、学者编写，其余大部分教材由清华大学出版社从多家国外出版社引进，改编出版，以适应我国临床医学专业留学生课堂教学和临床实习所需。

该套教材的陆续出版，是我国对高校来华留学生教育教材系列化、专门化的首次探索。希冀其会对全面提升来华医学留学生教育质量水平，对规范来华医学留学生教育的教材建设，甚至对其他学科的留学生教材建设，起到积极的示范效应和引领性作用。

这是一个良好的开端，希望该套教材在今后教学中经过不断探索、不断总结，得到修订，日臻完善。

中国高等教育学会外国留学生教育管理分会
副会长兼秘书长 贺向民

2014 年 10 月

Preface
前 言

Increased numbers of abroad students study medicine in China, in which ophthalmology is an essential branch. In spite of the advancement of ophthalmology, most of medical colleges accepting abroad students use self-edited teaching materials rather than formal ones. Except for the abroad students, more and more domestic medical undergraduate and post-graduate students lean to learn professional ophthalmology in English. Aiming to unify the textbooks more applicable for all students to acquaint with ophthalmological knowledge, we built and designed this book in way that provides the maximum amount of information in a concise and clean manner, with the support of Tsinghua University Press. Additionally, the edition of this book relied on the assistances of authorities in special fields, as well as the guidance of Textbook Of Ophthalmology edited by HV Nema.

The present book is organized into 32 clearly divided chapters which cover the essential topics that medical students require to master. A thorough knowledge of ocular anatomy and physiology is comprehensively dealt with, for its essential role in a proper understanding of ophthalmology. Definitely, the main contents focused on the common eye diseases, including etiology, pathological mechanism, clinical features, diagnostic tests, differential diagnosis, complications, and treatment. Additionally, practical instruments, clinical entities, diagnostic procedures, clinical and surgical modalities have been encompassed in the present book, which will help the students cultivate the logic of clinical thought effectively.

Nearly all chapters are profusely illustrated colored photographs and tables to highlight the retention of the clinical features and grab the differential diagnosis easily. At the end of each chapter, materials and clinical trials we referred to are added.

We hope that this book will be instructive to the readership, both undergraduate and postgraduate students, to strengthen the basic and clinical knowledge study, we wish you success in your future careers.

Yan Hua

Oct 1, 2015

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OVERVIEW

This chapter will:
- Describe anatomy, blood supply and nerve supply of eyeball
- Discuss development of the eye.

Anatomy

Eyeball

The eyeball (Fig. 1.1) lies in a quadrilateral pyramid-shaped bony cavity situated on either side of the root of the nose called *orbit*. Each eyeball is suspended by extraocular muscles and their fascial sheaths. Generally, the eyeball protrudes about 12-14 mm beyond the external orbital rim. The eyeball is protected anteriorly by the eyelids and the eyelashes and posteriorly there lies a pad of fat behind the eyeball to provide a protective cushion.

At birth, the eyeball measures antero-posteriorly about 17.5 mm and reaches 24 mm in adults. The horizontal and vertical diameters of the eyeball are 23.5 and 23 mm, respectively. As it is flattened from above downwards, its shape resembles with an oblate spheroid. Because the eyeball is shaped roughly like the globe of the earth, it is said to have poles.

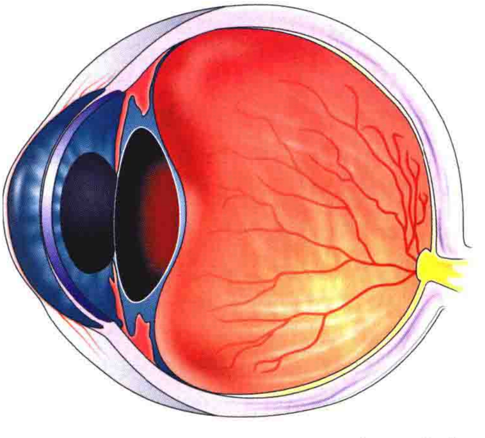

Fig. 1.1: A sagittal section through the eyeball

The central points on maximum convexities of the anterior and posterior curvatures of the eyeball are called *anterior* and *posterior poles* (Fig. 1.2). The axis of the eyeball passes through the poles. The line joining the poles is called *meridian*. The optic nerve leaves the eyeball 3 mm medial to the posterior pole and passes along the axis of the orbit, therefore, the axes of the eyeball and the orbit do not coincide but make an angle between them.

Tunics of Eyeball

The eyeball is composed of three concentric tunics (Fig. 1.3).

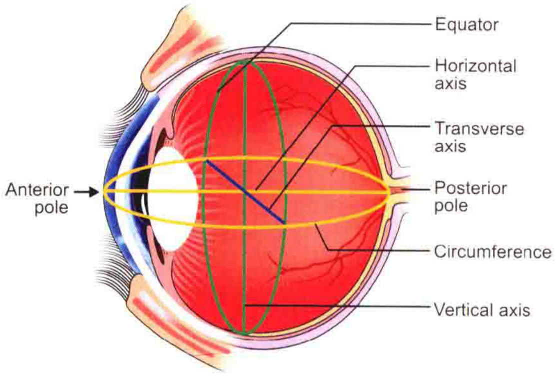

Fig. 1.2: The poles, axes, meridians and equator of the eyeball

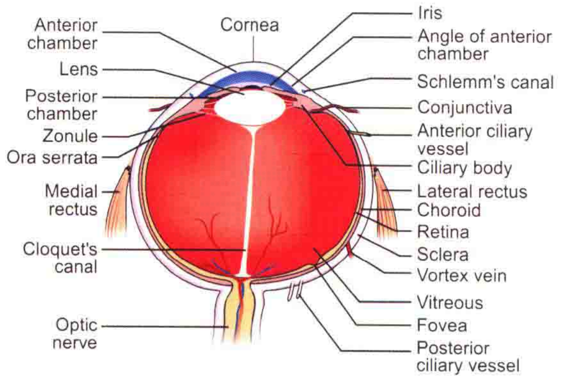

Fig. 1.3: Horizontal section of eyeball

1. The outer tunic consists of anterior one-sixth transparent part, the cornea and the remainder five-sixths opaque part, the sclera. The anterior part of the sclera is covered by a mucous membrane, the conjunctiva, which is reflected over the eyelids and also adhered firmly around the periphery of the cornea, the limbus. With this membrane in place, a conjunctival sac is formed when the eyelids are closed, and the upper and lower extensions of this sac are the superior and inferior conjunctival fornices.
2. The intermediate vascular tunic comprises from behind forward: the choroid, the ciliary body and the iris.
3. The innermost sentient layer, the retina, serving the primary purpose of photoreception and transformation of light energy into electrical impulses, is connected with the central nervous system by a tract of nerve fibers, the optic nerve. At the macular's center lies the fovea, rich in cones and responsible for color vision and the highest visual acuity.

Segments of the Eye

The eyeball can be divided into an anterior and a posterior segments.

Anterior segment of the eyeball consists of the cornea, anterior chamber, iris, posterior chamber, lens and part of ciliary body. The lens is suspended from the ciliary body by fine delicate fibrils called *suspensory ligament of the lens* (zonules).

The anterior chamber is bounded anteriorly by the posterior surface of the cornea and posteriorly by the anterior surface of the iris and the lens. The volume of anterior chamber is about 0.2 ml. It is approximately 2.5 mm deep in the center and contains clear aqueous humor. The anterior chamber has a peripheral recess known as *angle of anterior chamber* through which the drainage of aqueous humor takes place. The anterior wall of anterior chamber angle is corneoscleral coat, from the ending of corneal Descemet's membrane to the scleral spur. The past wall is the anterior end of the ciliary body and iris root.

The posterior chamber is a triangular space lined anteriorly by the posterior surface of the iris, anterolaterally by a part of ciliary body, and posteriorly by the ciliary body, lens and zonules. Its volume is about 0.06 ml.

Both the chambers contain aqueous humor and communicate with each other through the pupil. The aqueous humor filters from the capillaries of the ciliary processes into the posterior chamber and a portion of it freely diffuses through the vitreous humor in the posterior segment while the remainder flows into the anterior segment. After flowing through the pupil into the anterior chamber, it drains into the venous blood via the scleral venous sinus, and unusual venous channel that encircles the eye in the angle at the sclera-cornea junction. Aqueous humor supplies nutrients and oxygen to the lens and cornea and to some cells of retina, and it carries away their metabolic wastes.

Posterior segment of the eyeball includes the vitreous, retina, choroid and optic nerve. This segment is filled with a transparent, gelatinous substance, unlike aqueous humor, cannot be replaced.

Blood Supply of Eyeball

The arteries of the eyeball are derived from the ophthalmic artery, a branch of internal carotid artery. Given off immediately after the internal carotid artery leaves the cavernous sinus. The ophthalmic artery passes into the orbit through the optic canal with the optic nerve.

Blood Supply of Retina

The retina gets its blood supply from the central retinal artery, a branch of ophthalmic artery, which enters the optic nerve about 10 mm behind the eyeball. After running outward and forward, it reaches the optic nerve head and gives superior and inferior papillary branches, from each of which comes off a nasal and a temporal branch. Each branch continues to divide dichotomously spreading over the retina and reaching the ora serrata. The central retinal artery nourishes inner 5 layers of the retina. In few persons, a part of the retina gets nourishment from cilioretinal artery derived from ciliary artery.

The veins of retina do not accurately follow the course of the arteries, except at the disk, where they join to form the central retinal vein, which accompanies the central retina lartery.

Blood Supply of Uvea

The uveal tract is supplied by ciliary arteries arranged into three groups: the short posterior ciliary, the long posterior ciliary and the anterior ciliary arteries (Fig. 1.4).

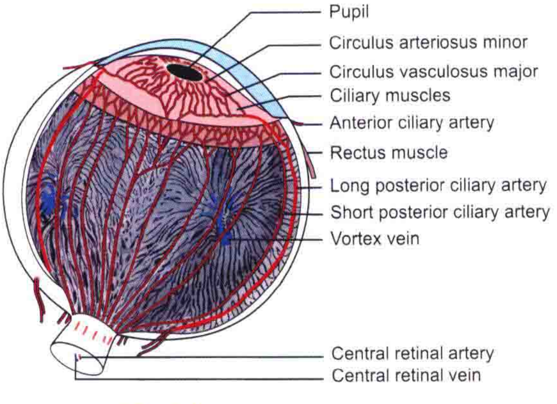

Fig. 1.4: Blood supply of eyeball

The short posterior ciliary arteries (20 in number) pierce the sclera around the optic nerve and supply the choroid. They nourish the choroid and the retinal outer layers.

The long posterior ciliary arteries (two in number) pierce the sclera obliquely in the horizontal meridian on either side of the optic nerve and run anteriorly between the sclera and the choroid without giving off any branch. They divide in the ciliary body and anastomose with the anterior ciliary arteries to form circulus arteriosus major at the root of iris.

The anterior ciliary arteries are derived from the muscular branches of the ophthalmic artery to the four rectus muscles. They pierce the sclera 3 to 4 mm behind the limbus to join the long posterior ciliary artery. Before piercing, they give branches to the conjunctiva, limbus and episclera.

The venous drainage of the uveal tract occurs through the ciliary veins, which form three groups:

1. Short posterior ciliary veins
2. Venae vorticosae, and
3. Anterior ciliary veins.

The short posterior ciliary veins receive blood only from the sclera, and the anterior ciliary veins from the outer part of the ciliary muscles. The bulk of the blood is drained through the venae vorticosae (vortex veins) comprising four large trunks, which open into the ophthalmic vein.

Nerve Supply of Eyeball

The sensory nerve supply to the eyeball is derived from the ophthalmic division of trigeminal nerve (Fig. 1.5). It comes mainly by the nasociliary nerve either directly through

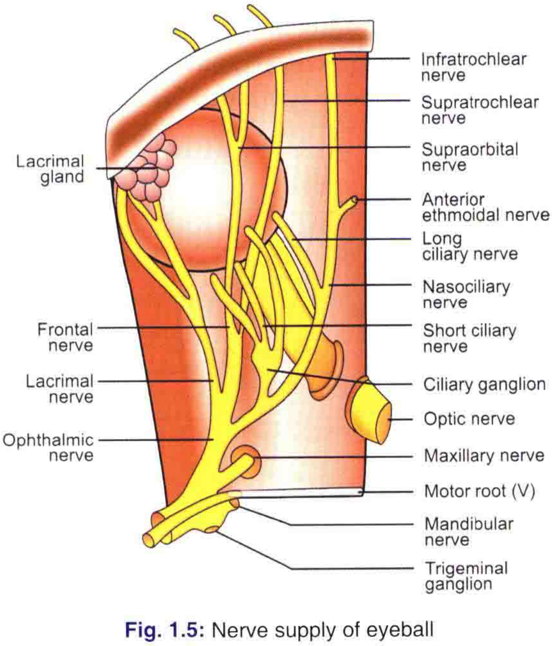

Fig. 1.5: Nerve supply of eyeball

the long ciliary nerve or indirectly through the short ciliary nerves. This branch enters the posterosuperior aspect of the ganglion, and carries sensory fibers, which pass through the ganglion and continue along the short ciliary nerves to the eyeball. These fibers are responsible for sensory innervation to all parts of the eyeball.

The long ciliary nerves (two in number) pierce the sclera in the horizontal meridian on either side of the optic nerve and run forwards between the sclera and the choroid to supply the iris, ciliary body, dilator pupillae and cornea.

The short ciliary nerves (about 10 in number) come from the ciliary ganglion and run a wavy course along with the short ciliary arteries. They give branches to the optic nerve and ophthalmic artery and pierce the sclera around the optic nerve. They run anteriorly between the choroid and the sclera, reach the ciliary muscles where they form a plexus, which innervates the iris, ciliary body and cornea.

The motor root of ciliary ganglion, derived from the branch of the oculomotor nerve to inferior oblique, supplies the sphincter pupillae and ciliary muscles.

Development of Eye

The eyeball develops as a part of the central nervous system. The latter develops from the neural groove, which invaginates to form the neural tube. The tube sinks into the underlying mesoderm and detaches itself from the surface epithelium. A thickening appears on either side of the anterior part of the neural tube that grows to form the primary optic vesicle (Fig. 1.6) at 4 mm human embryo stage.

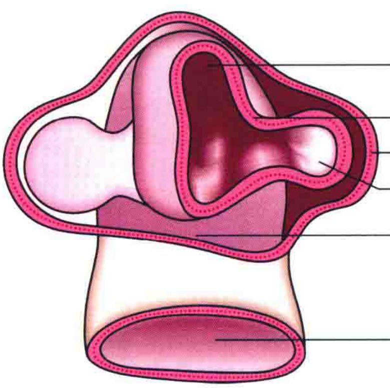

Fig.1.6: Forebrain and optic vesicle in a 4 mm human embryo

The optic vesicle comes in contact with the surface ectoderm and invaginates to form the optic cup. The inner layer of the cup forms the future retina, epithelium of ciliary body and iris, and sphincter and dilator pupillae, while the outer layer forms a single layer of pigment epithelium. At the anterior border of the cup, paraxial mesoderm invades to form the stroma of the ciliary body and the iris.

Lens

The development of the lens begins early in embryogenesis. When optic vesicles enlarge, they come in contact with the surface ectoderm.

Lens Plate

The surface ectoderm overlying optic vesicle thickens at about 27 days of gestation and forms the lens plate or lens placode (Fig. 1.7).

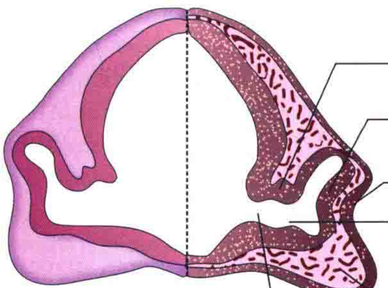

Fig. 1.7: Transverse section through forebrain of a 5 mm human embryo

Lens Pit

A small indentation appears in the lens plate at 29th day of gestation to form the lens pit which deepens and invaginate by cellular multiplication.

Lens Vesicle

At about 33 days of gestation, lens vesicle (Fig. 1.8) is formed due to continued invagination of the lens pit, which later detaches from the surface ectoderm. The lens vesicle is a single layer of cuboidal cells that is encased within a basement membrane, the lens capsule. The vesicle is complete by around day 56 and measures about 400 μm.

Primary Lens Fibers

At about 40 days of gestation, the posterior cells of lens vesicle elongate to form the primary lens fibers.

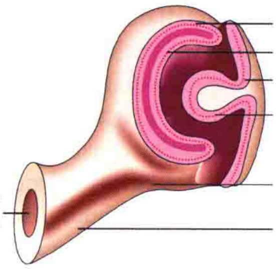

Fig. 1.8: Formation of lens vesicle

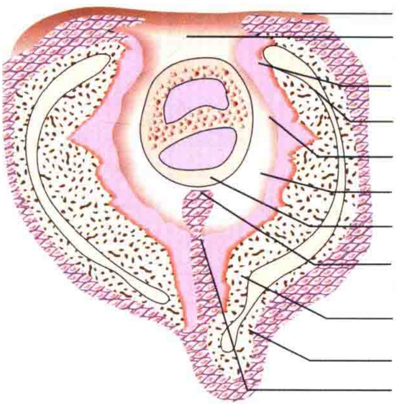

Fig. 1.9: Eye and fetal fissure of a 15 mm human embryo

They fill up the cavity of the lens vesicle and form the embryonic nucleus. The linear primary fibre cells align parallel to the optic axis. Epithelial cells in the lens germinative zone (anterior to the equator) undergo mitosis and the daughter cells migrate to the transitional zone (posterior to the equator) where they differentiate and elongate into the secondary fibre cells.

Secondary Lens Fibers

The cuboidal cells of the anterior lens vesicle, also known as the lens epithelium, multiply and elongate to form the secondary lens fibers. The mature secondary fibre cells span half the circumference of the lens, meeting in the centre of the anterior and posterior surfaces where their ends overlap to form the sutures (upright Y anteriorly and inverted Y posteriorly). The fibers formed between second and eighth months of gestation form the fetal nucleus. The growth and proliferation of secondary lens fibers continues at a decreasing rate throughout life.

Optic Stalk and Optic Fissure

A deep groove appears of the ventral surface of the optic cup and stalk, called fetal fissure. The mesenchyme enters the optic cup through the optic fissure. The hyaloid system of vessels develops in the mesenchyme to provide nourishment to the developing lens (Fig. 1.9). The vascular system gradually atrophies with the closure of the optic fissure at about sixth week of gestation and is replaced by the vitreous, presumed to be secreted by the surrounding neuroectoderm.

Cornea

The development of the cornea starts at about 33 days of gestation by appearance of two rows of epithelial cells derived from the surface ectoderm. Mesenchymal cells from the edges of optic cup grow between these rows to form the corneal endothelium. At about 24 mm stage, mesenchymal cells grow again between the epithelium and the endothelium to form the future stroma of cornea. The condensation of most anterior layer of stroma forms Bowman's membrane. The synthetic activity of the endothelial cells develops Descemet's membrane.

Sclera

The condensation of mesenchyme around the optic cup forms the sclera that differentiates anteriorly into the limbus. The initial scleral part of the lamina cribrosa begins to be formed in the 5 th month fetus. The fibrous tissue originating from the choroid and optic nerve sheath contributes the formation of the lamina cribrosa in the 8th month fetus. At this time, the morphology of lamina cribrosa is similar to that of an adult, but the thickness of the structure is still increasing till one year after birth.

Anterior Chamber

A cleft is formed due to the disappearance of the mesoderm lying between the developing iris and cornea, the anterior chamber (Fig. 1.10). The canal of Schlemm appears as a vascular channel at about fourth month of gestation. The iridocorneal angle is covered by a continuous monolayer of polyhedronal endothelial cells up to about 8 months gestation age.

Uveal Tract

Choroid

The endothelial blood spaces develop very early in the mesenchymal tissues lying close to the outer layer

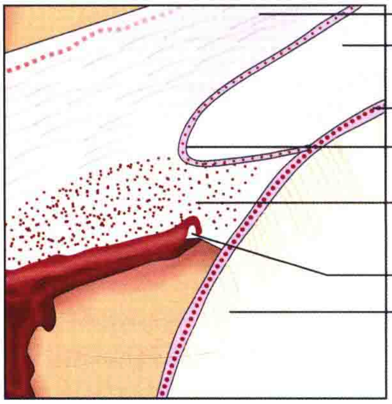

Fig. 1.10: Development of angle of anterior chamber at 75 mm human embryo stage

of optic cup. At about the end of second month, the vascular plexus forms the choriocapillaris. Large and medium sized vessels are formed during fourth to fifth month of gestation.

Ciliary Body

Ciliary body develops from both neuroectoderm and mesenchyme. During the third month, two-layered neuroectodermal optic cup grows and extends in front of the lens and gets differentiated into the ciliary body and the iris. These two parts are nonphotosensitive and are called as pars caeca retinae. At the 65 mm stage, 70 to 75 radial folds appear in the pigmented epithelium, the future ciliary processes. The ciliary muscle develops from the mesoectoderm at about the fourth month of gestation.

Iris

The development of iris begins at the end of third month by the forward extension of both walls of optic cup. The sphincter and dilator papillae are neuroectodermal in origin. The posterior epithelium of iris is a continuation of non-pigmented epithelium of the ciliary body.

Retina

The histogenesis of retina starts very early even before the closure of neural tube (2.2 mm stage). The inner layer of optic vesicle forms the retina and the outer forms the retinal pigment epithelium. The inner layer has an outer nuclear zone and an inner anuclear zone. The neuroepithelial cells actively divide and differentiate into inner and outer neuroblastic layers in the seventh week of gestation.

The ganglion cells, Müller's cells and amacrine cells are derived from the inner neuroblastic layer. The rods and cones, the bipolar cells, and the horizontal cells are derived from the outer neuroblastic layer. The retinal differentiation starts after completion of cell division (120 mm stage). The differentiation of macular area starts relatively late. The macular region is thicker than the rest of the retina until the eighth month, when macular depression begins to develop. Macular development is not complete in anatomic terms until 6 month after birth.

Optic Nerve

The optic stalk forms a connection between the primary optic vesicle and the forebrain. With the closure of optic fissure (19–20 mm stage), the optic stalk becomes a tube. The hollow optic stalk is filled by the axons of ganglion cells of the retina forming the optic nerve. At about two months of gestation, the optic nerve is composed of bundles of nerve fibers divided by parallel rows of glia. The condensation of the mesoderm around the optic cup differentiates to form the outer coats of the eyeball (choroid and sclera) and structures of the orbit. Mesenchymal elements enter the surrounding tissue to form the vascular septa of the nerve. Myelination extends from the brain peripherally down the optic nerve and at birth has reached the lamina cribrosa. Myelination is completed by age 3 month.

Vitreous

The source of development of vitreous body is controversial. Some embryologists think that it is entirely of ectodermal origin, while others believe that all the three layers, ectoderm, mesoderm and neuroectoderm, contribute to the development of vitreous. Like vitreous, the source of origin of zonules is also disputed. Whether they are derived from mesenchyme or ectoderm is not yet resolved. There are three stages in the development of vitreous:

1. Primary vitreous is seen at optic cup-lens vesicle stage. It is partly surface-ectodermal and partly mesenchymal in origin. At about the 4.5 mm stage, mesenchymal cells and fibroblasts derived from the embryonic lens and the inner layer of the optic vesicle, from the vitreous fibrils of the primary vitreous. Ultimately, the primary vitreous comes to lie just behind the posterior pole of the lens in