2. ***Superficial cortex.*** It is further stratified into three layers in the beam of slit-lamp:
- C1α. First cortical clear zone or the sub-capsular clear zone.
- Cl β. First zone of disjunction, seen as a bright narrow, scattering zone of discontinuity.
- C2. Second cortical clear zone or the subclear zone of cortex.

3. ***Deep cortex*** is stratified into the following two perinuclear zones which autofluoresce a brilliant green under blue exciting light:
- C3. It is the bright light scattering zone of deep cortex.
- C4. It is the relatively clear zone of deep cortex.

4. ***Nucleus*** **(N)** represents the prenatal part of the lens. It shows following further stratifications:
- Central part of nucleus, which lacks scattering of light, represents the embryonic nucleus.
- Anterior and posterior peripheral light scattering zones of nucleus.

SURGICAL ANATOMY OF THE LENS

From the surgical viewpoint, the lens can be divided into four parts (Fig. 1.7B):
- A *central hard nucleus* surrounded by
- An *epinuclear plate* (EN) of varying thickness surrounded by
- A *layer of cortex*, and the outermost
- *Capsule*

GRADING OF NUCLEUS HARDNESS

Grading of nucleus hardness (sclerosis) in cataractous lens is important for setting the parameters of the machine for effective phacoemulsification. The sclerosis (hardness) of nucleus, depending upon its colour, can be graded as below (Fig. 1.7C):
- Grade I: Whitish/green yellow
- Grade II: Yellow
- Grade III: Amber
- Grade IV: Brown
- Grade V: Black.

The hardness of the lens nucleus can also be classified into:
- Ultra-soft (grade I)
- Soft (grade I+)
- Soft-medium (grade II)
- Medium-hard (grade III)
- Hard (grade IV)
- Ultra-hard (grade V).

CILIARY ZONULES

The ciliary zonules (zonules of Zinn or suspensory ligaments of lens) consist essentially of a series of fibres which run from the ciliary body and fuse into the outer layer of the lens capsule around the equatorial zone. Thus, they hold the lens in position and enable the ciliary muscle to act on it.

STRUCTURE

The zonular fibres are transparent, stiff and not elastic. Each zonular fibre has a diameter of about 0.35 to 1.0 μ. It is composed of microfibrils with a diameter varying from 8–40 nm. Zonular fibres are composed of glycoproteins and muco-polysaccharides and are similar in structure to the microfibrils of the elastic fibres. Their susceptibility to hydrolysis by α-chymotrypsin has been *used to advantage in intracapsular cataract surgery.* Structurally, three different types of zonular fibres have been described.
- *First type fibres.* These are thick, about 1 μ in diameter, wavy and usually lie near the vitreous.
- *Second type fibres.* These are thin and flat.
- *Third type fibres.* These are very fine and run a circular course.

Gross Appearance

Grossly, the ciliary zonules form a complete ring of fibres, which extend from ciliary body to the lens equator circumferentially (Fig. 1.8). On cut section, the ciliary zonules appear to be arranged in a triangular form. The base of the triangle is towards the equator of the lens and apex towards the ciliary body. The space between the triangle is filled with the zonular fibres except for a circumferential space around the equator of the lens between anterior and posterior zonular fibres—the canal of Hannover.

ARRANGEMENT OF ZONULAR FIBRES

A. Classical concept

I. *Main fibres of the ciliary zonules*

The main fibres of the ciliary armies which bind the lens with the ciliary body, depending upon their arrangement can be classified into the following four groups (Fig. 1.9A):

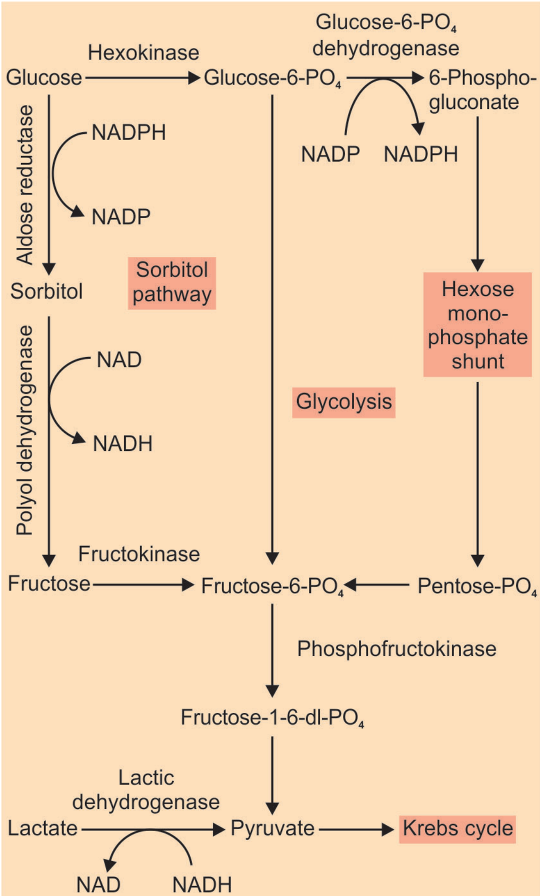

Fig. 1.10. *Pathways of glucose metabolism in the crystalline lens.*

In this pathway, glucose is converted into sorbitol (by the enzyme aldose reductase) which in turn is converted into fructose by the enzyme polyol dehydrogenase. The fructose is converted into fructose-6-phosphate (by the enzyme fructokinase) which enters into the glycolytic pathway (Fig. 1.10).

PROTEIN METABOLISM

Protein synthesis. Mechanisms occurring in the lens are similar to those occurring in all other tissues of the body. Proteins are synthesized from free amino acids which are actively transported into the lens from the aqueous. The formation of peptides from amino acids requires ATP and the appropriate RNA template. The ATP is acquired from glucose metabolism. Incorporation of amino acids into the RNA to form lens proteins occurs at a rather slow rate. It has been reported that glycine and serine are incorporated at no more than 5% per day. Further, rate of protein synthesis varies in different parts of the lens, nucleus being the slowest.

Protein breakdown in the lens is catalyzed by the enzyme peptidases and proteases. *In vitro* under sterile conditions, the lens undergoes autolysis. However, normally *in vivo,* the process of autolysis is inhibited.

PERMEABILITY AND TRANSPORT MECHANISMS OF THE LENS

Active and passive (permeability dependent) transport mechanisms of the lens are essential to provide nutrients for metabolism, to dispose of waste products of metabolism and to regulate water and cation balance in the lens. The salient features of biochemical composition of the lens vis-a-vis aqueous humour and the chemical exchange between the two is depicted in Fig. 1.11.

Active transport mechanisms are concerned with the transport of amino acid, potassium, taurine, inositol and extrusion of sodium. As discussed earlier, about 90% of the energy in

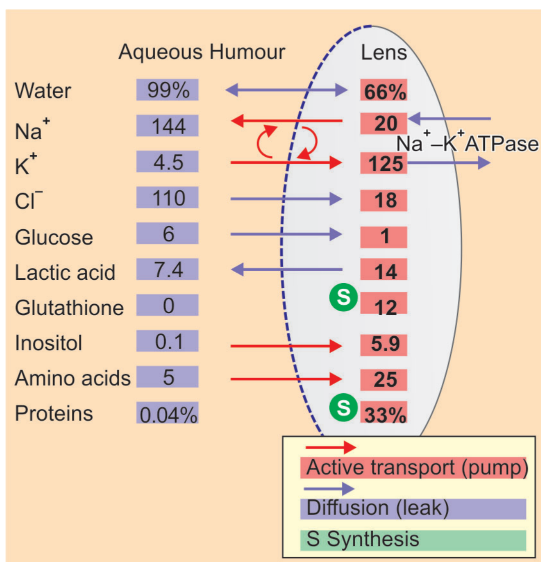

Fig. 1.11. *Chemical composition of the lens vis-à-vis aqueous humour and chemical exchange (pump-leak mechanism) between them. Values are in mmol/kg of lens water unless otherwise stated.*

The imaging techniques show that the apex of the ciliary muscle moves antero-inward and the equatorial edge of the lens moves away from the sclera during accommodation (about 250 μm for 10 D of accommodation). Goniovideography shows that the zonular fibres extending from the ciliary processes to the lens equator are relaxed during accommodation. UBM imaging shows the posterior zonular fibre extending between the posterior attachment of the ciliary muscle, and the ciliary processes are stretched during accommodation by the forward and axial movement of the apex of ciliary muscle.

Points against relaxation theory

There are some points against this theory. According to Helmholtz hypothesis, since the equatorial diameter increases with age (i.e. since the crystalline lens equator is getting closer to the ciliary muscle), the zonules should relax. As one ages, the power of the crystalline lens should increase while viewing distant objects in the accommodated state. One should become more myopic and the crystalline lens should become unstable, but in fact, one becomes slightly hyperopic and the crystalline lens remains stable. Helmholtz theory also is not consistent with the decrease in spherical aberration that occurs during accommodation.

Helmholtz attributes the universal linear decrease in the amplitude of accommodation with age to hardening of the crystalline lens. No tissue in the body hardens in a linear fashion with age.

Role of lens capsule

Although, at first, Helmholtz regarded the lens to be an elastic body as a whole which would assume the spherical shape of its own when made free from the tension of zonules. However, he soon realized his fallacy that being a semisolid mass the lens may be deformed by the external force but being inelastic cannot return to its original shape when the deforming force is removed. Helmholtz found it necessary, therefore, to attribute elastic properties to the lens capsule to account for the change in the shape of lens when it was free from the tension of zonules. It was seen that the lens surfaces were not perfectly spherical in contour; the anterior surface, in particular, is more convex centrally during accommodation. Fincham suggested that variations in thickness of lens capsule (Fig. 1.2) account for the local variations in curvature. He proposed that during accommodation the thicker ring of anterior capsule surrounding the central region contracts under the lessened zonular traction, while the thinner central capsule bulges forward in a more pronounced fashion. The physiological anterior lenticonus thus formed has a short radius of curvature and high refraction.

Gullstrand mechanical model of accommodation

Based on the Helmholtz hypothesis, Gullstrand devised a mechanical model to explain the mechanism of accommodation. Description of Gullstrand's model (as shown in Fig. 1.18) is as below: The cord between the two springs represents the zonules. The upper spring represents the lens, and its contraction represents change of the shape of the lens during accommodation. The lower spring represents the elasticity of choroid. In the eye, at rest this spring is sufficiently strong to overcome the pull of the upper string, which must always be slightly on the stretch and, therefore, must be the weaker of the two (presently now the lower spring is thought to be represented by relaxation of the fibres of the ciliary muscle and not the choroid). A cord passed over the pulley supporting the weight represents the pull of the circular fibres of the ciliary muscle. In the unaccommodated eye (Fig. 1.18 A), the weight is at rest and exerts no pull. When accommodation at place (Fig. 1.18B) due to pull exerted by the contraction of ciliary muscle, the lower spring pulled, and the zonules are slackened; this allows the upper spring to contract (i.e. change in the shape of lens).

2. Theory of increased tension (Tscherning theory)

This theory attributes to the increased curvature of the capsule increasing tension on the zonules. It states that contraction of the ciliary muscle pulls on the zonules directly and increases the

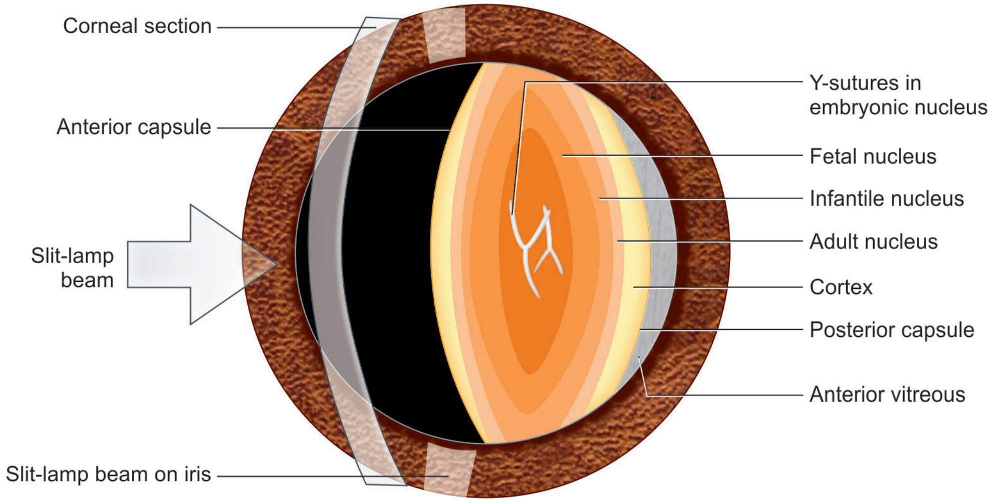

Fig. 2.5. *Y-shaped sutures around the embryonic nucleus can be seen on slit-lamp examination.*

month of gestation, the zonules have reached the lens and merge with both the anterior and posterior capsules.

Changes in the developing lens shape

The lens undergoes the following changes in shape during development:

- During initial development, the lens is elongated anteroposteriorly.
- It is nearly spherical, soft and reddish in tint at the 18–24 mm stage.
- As more and more secondary lens fibres are added to the equator, the lens becomes ellipsoid, a trend that continues till birth.
- At birth, the lens is almost spheroidal, being slightly wider in the equatorial plane. The anteroposterior diameter of lens at birth is nearly that of an adult, but its equatorial diameter is about two-thirds of that reached in the adult.

CONGENITAL ANOMALIES OF THE LENS

COLOBOMA OF LENS

- *Coloboma of lens* refers to focal inferior flattening or truncation of the lens in the lower

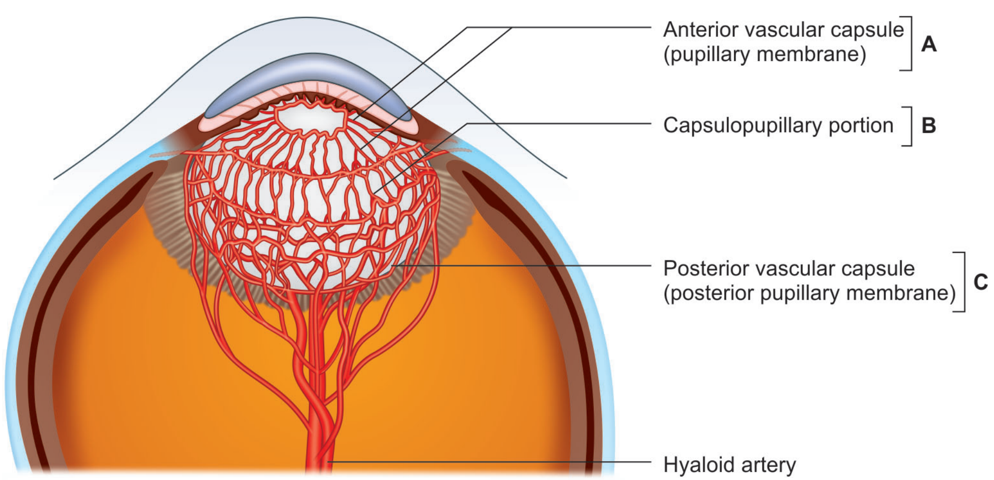

Fig. 2.6. *Three components of tunica vasculosa: **(A)** anterior pupillary membrane, **(B)** capsular pupillary membrane; and **(C)** posterior pupillary membrane.*