of proteins, glycoproteins, GAGs and proteoglycans such as chondroitin sulphate. The IPM has a diverse range of functions, including retinal attachment and adhesions in molecular trafficking, facilitation of phagocytosis and probably photoreceptor outer segment alignment IRBP accounts for 70% of the soluble proteins in the IPM. In humans, it is produced by photoreceptors (mainly cones) and can bind all-*trans-retinol*, 14-*cis*-retina, α-tocopherol, retinoic acid and cholesterol. Although the primary function of IRBP is the efficient transport of retinoids between the photoreceptors and the retinal pigment epithelium, it may also serve to minimize fluctuations in retinoid availability, and to protect the plasma membranes from the damaging effects of high retinoid concentrations. IRBP is not the only binding protein found in the retina. Cellular retinoid binding proteins are a subgroup of the fatty acid binding proteins that orchestrate reisomerisation in the retinal pigment epithelium and may also have a role in early retinal development. Cellular fatty acid binding proteins (cellFABP) are also found in the retina. They protect retinal processes from toxic effects of fatty acids and take part in cell growth and differentiation.

3. EXTERNAL LIMITING MEMBRANE

In low magnification, it appears as a fenestrated membrane extending from the ora serrata to the edge of the optic disc; through which pass processes of the rods and cones. Electron microscopy studies show that the external limiting membrane is formed by the junctions (zonulae adherentes) between the cell membrane of photoreceptors and Müller's cells and thus it is not a basement membrane.

4. OUTER NUCLEAR LAYER

This layer is primarily formed by the nuclei of rods and cones; cone nuclei are somewhat larger (6–7 µm) than the rod nuclei (5.5 µm) and lie in a single layer next to the external limiting membrane. Rod nuclei form the bulk of this multilayered outer nuclear layer except in the cone dominated foveal region. The number of rows of nuclei and thickness of this layer varies from region to region as follows:

- Nasal to the disc—8 to 9 layers of nuclei and 45 µm thickness.
- Temporal to disc—4 rows of nuclei and 22 µm thickness.
- Foveal region—10 rows of nuclei and 50 µm thickness.
- Rest of the retina except ora serrata—one row of cone nuclei and 4 rows of rod nuclei with a thickness of 27 mm.

5. OUTER PLEXIFORM LAYER

This layer contains the synapses between the rods spherules and cone pedicles with the dendrites of the bipolar cells and processes of the horizontal cells (Fig. 1.11). In other words, this layer marks the junction of the end organs of vision and first-order neurons in the retina. It is thickest at the macula (51 µm) and consists predominantly of oblique fibers that have deviated from the fovea and is also known as Henle's layer.

6. INNER NUCLEAR LAYER

Under microscope, this layer resembles the outer nuclear layer except that it is very thin. This layer disappears at fovea and in rest of the retina consists of the following:

- Bipolar cells
- Horizontal cells
- Amacrine cells
- The soma of the Müller's cells
- Capillaries of the central retinal vessels.

I. BIPOLAR CELLS (NEURONS)

These are the neurons of first order of vision. The body of the bipolar cells consists entirely of the nucleus which lies in the inner nuclear layer. Their dendrites arborize with the rod spherules and cone pedicels in the outer plexiform (molecular) layer and their axons arborize with the dendrites of ganglion cells in the inner molecular layer. On the basis of morphology and synaptic relationship, nine types of bipolar cells are seen under light microscopy:

- Rod bipolar cells
- Invaginating midget bipolar cells
- Flat midget bipolar cells
- Invaginating diffuse bipolar cells
- Flat diffuse bipolar cells
- On-centre blue cone bipolar cells

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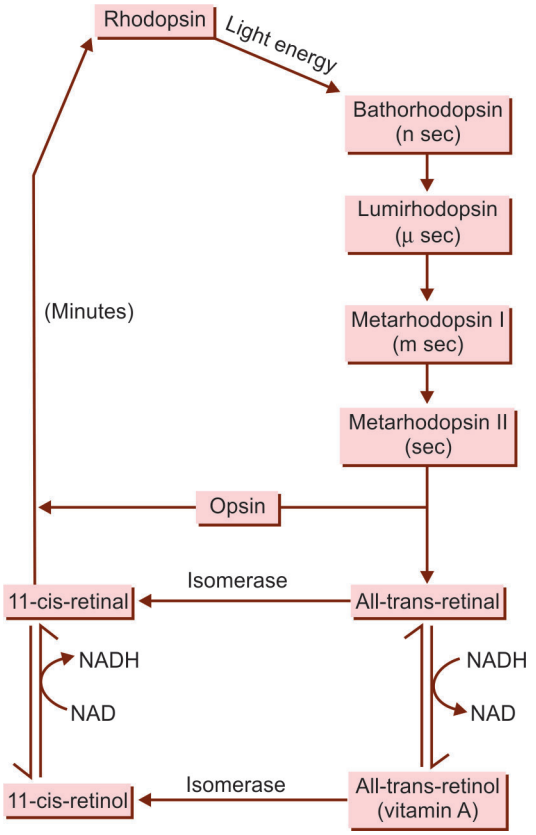

Fig. 2.6 *The scheme for the reactions set into motion by light falling on the rhodopsin*

mediates which exist for a transient period (Fig. 2.6). One of the intermediate compounds (*metarhodopsin II,* also called as activated rhodopsin) of the above isomerization chain reaction acts as an enzyme to activate many molecules of transducin. The transducin is a GTP/GDP exchange protein present in an inactive form bound to GDP in the membranes of discs and cell membrane of the rods. The activated transducin (bound to GTP) in turn activates many more molecules of phosphodiesterase (PDE) which catalyses conversion of cyclic guanosine monophosphate (cGMP) to GMP, leading to a reduction in concentration of cyclic GMP (cGMP) within the photoreceptor (Fig. 2.7). The reduction in cyclic GMP is responsible for producing the electrical response (receptor potential), which marks the beginning of the nerve impulse. Further details are described in the section on *electroneurophysiology of vision.*

The all-trans-retinal (produced from light-induced isomerization of 11-cis-retinal) can no longer remain in combination with the opsin and thus there occurs separation of opsin and all-trans-retinal. This process of separation is called *photodecomposition* and the rhodopsin is said to be bleached by the action of light.

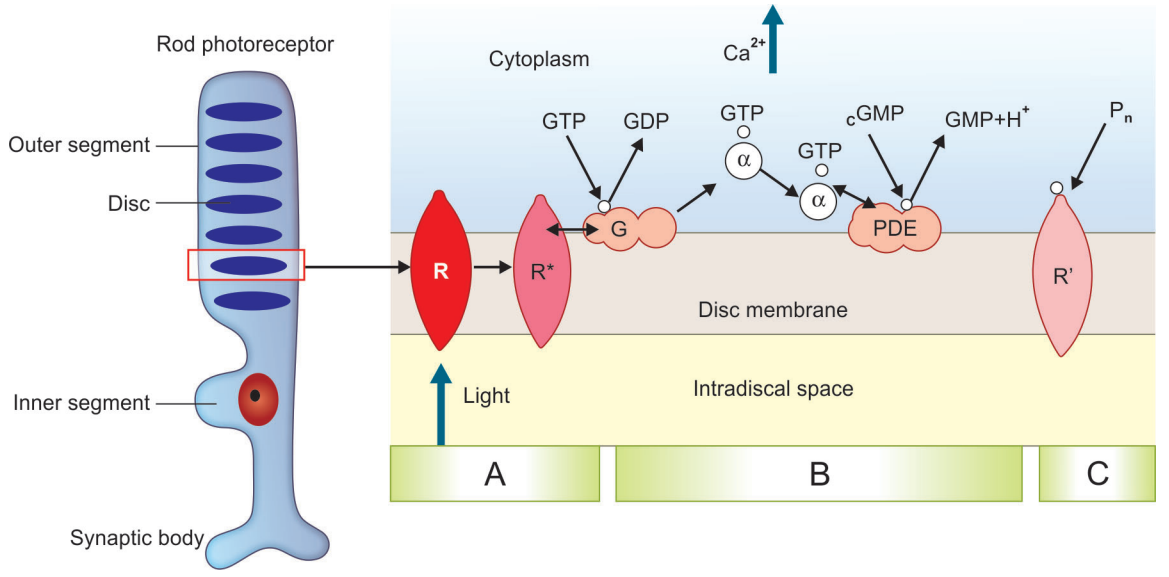

Fig. 2.7 *The scheme for reactions triggered by rhodopsin bleaching which affect cGMP:* ***(A)*** *Light-induced conversion of rhodopsin (R) into the active form (R*);* ***(B)*** *activation of G-protein (G), GTP/GDP exchange and activation of cGMP phosphodiestrase (PDE) protein; and* ***(C)*** *phosphorylation of photolysed rhodopsin (R')*

process of differentiation and modification, of various parts of the globe.

ENTRAPMENT OF VASCULATURE

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 the mesenchyme which has made its way into the eye through the fissure is cut off from the surrounding mesenchyme and gives rise to hyaloid system of the vessels (Fig. 3.1).

DERIVATION OF VITREOUS

a. ***Primary or primitive vitreous*** is mesenchymal in origin and is a vascular structure having the hyaloid system of vessels. It is present in the first month of gestation (Fig. 3.1). Surface ectodermally derived elements that surround the lens during invagination are also thought to contribute to the primary vitreous. Thus the primary vitreous may be of mixed ectodermal and mesenchymal origin.

b. ***Definitive or secondary or vitreous proper*** is secreted by neuroectoderm of optic cup from 2nd month of gestation onwards. This is an avascular structure, basically an extracellular matrix, consisting mainly of a compact network of type II collagen fibrils and primitive hyalocytes. The precise origin of hyalocytes is presumed to be from the phagocytic monocytes of the primary vitreous. The content of hyaluronic acid is very low during the prenatal period, but increases after birth. When this vitreous fills the cavity by 5th to 6th month of gestation, primitive vitreous is reduced to a small central space, *Cloquet's canal,* which courses between the optic nerve head and the posterior surface of the lens.

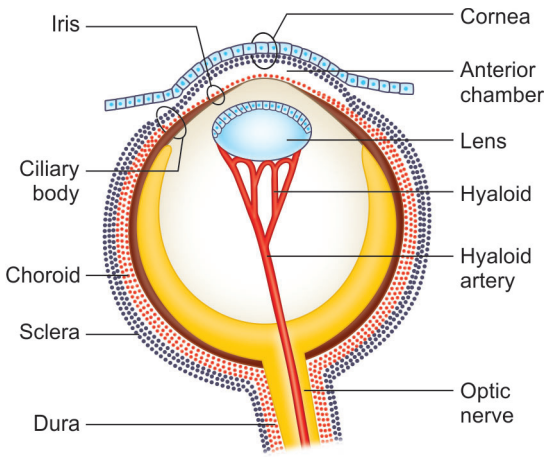

Fig. 3.1 *Derivation of various structures of the eyeball*

c. ***Tertiary vitreous*** is developed from neuroectoderm in the ciliary region during 4th month of gestation and is represented by the vitreous base and ciliary zonules.

ANATOMY OF VITREOUS

GENERAL FEATURES

- Vitreous humour is an inert, transparent, colorless, jelly-like, hydrophilic gel that serves the optical functions and also acts as important supporting structure for the eyeball.
- The vitreous cavity is bounded anteriorly by the lens and ciliary body and posteriorly by the retina.
- It weighs nearly 4 g and occupies a volume of almost 4 cc which is approximately two-thirds the volume of the entire globe.
- Vitreous is an extracellular material composed of approximately 99 per cent water.

STRUCTURE

The vitreous body is the largest and simplest connective tissue present as a single piece in the human body. However, for descriptive purposes, it may be divided into three parts—the hyaloid layer or membrane, the cortical vitreous and the medullary vitreous (Fig. 3.2).

1. *HYALOID LAYER OR MEMBRANE*

It is not a true membrane but the outermost surface layer or condensation of the vitreous body. It has a structure of connective tissue and shows striations due to its fibrils which run parallel with the surface.

A. ANTERIOR HYALOID MEMBRANE (ANTERIOR LIMITING MEMBRANE LAYER)

It covers the vitreous body anteriorly starting from a point approximately 1.5 mm from the ora serrata. The anterior hyaloid membrane, thus, lies in contact with the part of pars plana,