Developmental Biology of the Eye & Cell Types and Cell Biology of the Retina

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Lecture Overview

- Evolution of Light Detection and Visual Systems
- Development of the Vertebrate Eye
- Genetic Programm of Eye Development
- Cell Types and Cell Biology of the Retina

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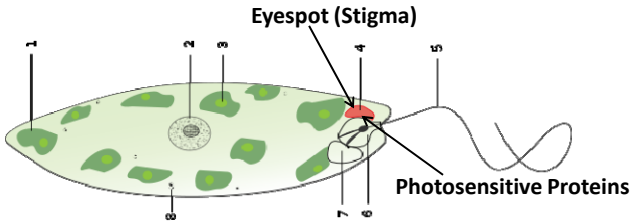
Evolution of Light Detection and Visual Systems

(1) Phototaxis in (photosynthetic) motile Bacteria, Cyanobacteria, Algae and Protozoa
Based on various molecular mechanisms involving photosynthetic or specific light-sensitive proteins (e.g. flavoproteins, channelrhodopsins)

Euglena



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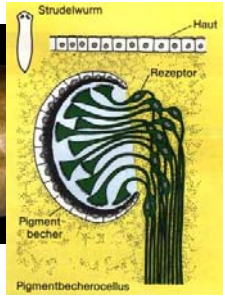
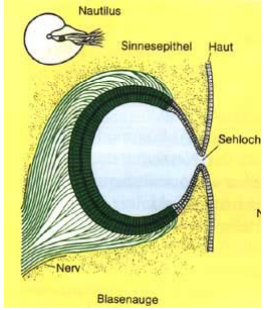
Evolution of Light Detection and Visual Systems

(2) Pigmented Cup-shaped Eyes and Pinhole Eyes in Plathelminthes and Molluscs

- ★Detects Light Intensity and Direction
- ★ Differentiated photosensitive Neurons
- ★ Rhodopsin-like Photopigments





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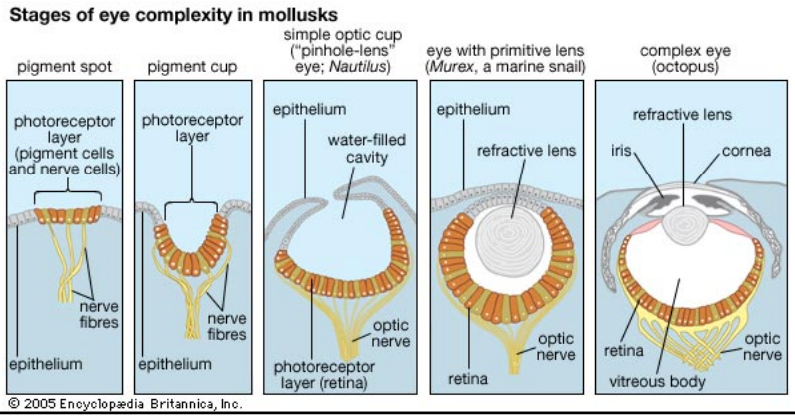
Evolution of Light Detection and Visual Systems

(3) From Light-sensing to Image-forming Optic Structures in Non-Vertebrates (e.g. Molluscs)



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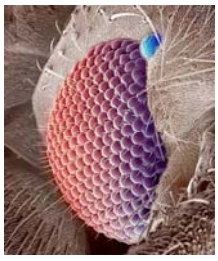
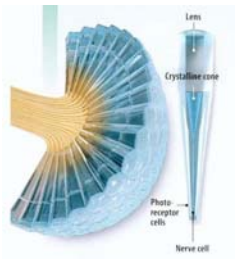
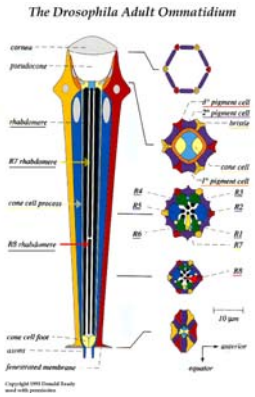
Evolution of Light Detection and Visual Systems

(4) From Light-sensing to Image-forming Optic Structures in Non-Vertebrates: Compound Eye in Arthropods







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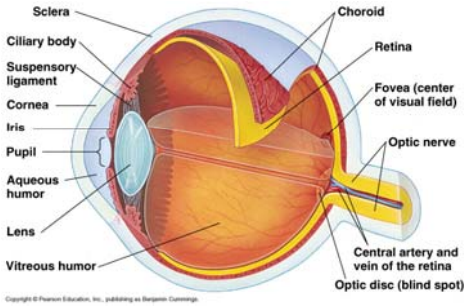
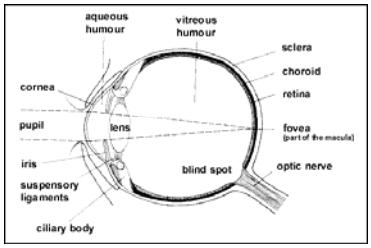
Evolution of Light Detection and Visual Systems

(5) The Vertebrate Eye





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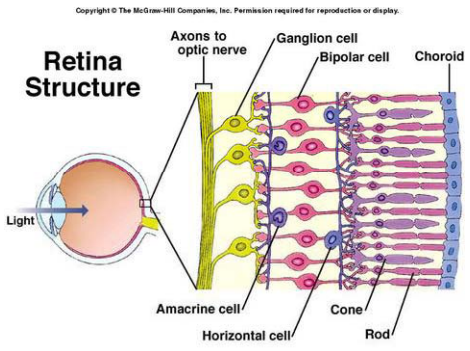
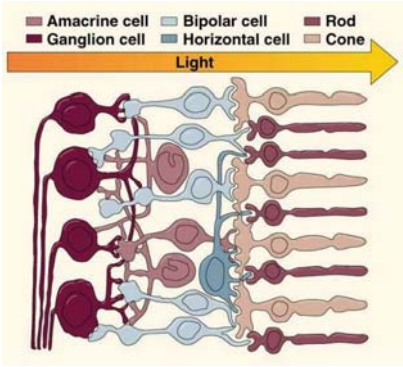
Evolution of Light Detection and Visual Systems

(6) The Vertebrate Eye





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Developmental Biology of the Eye &
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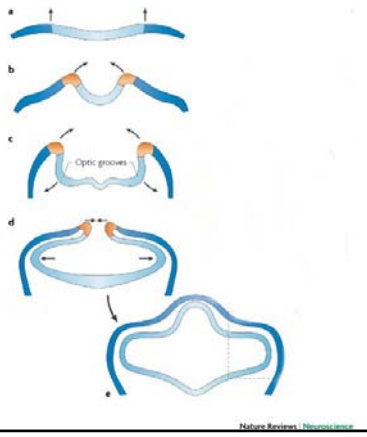
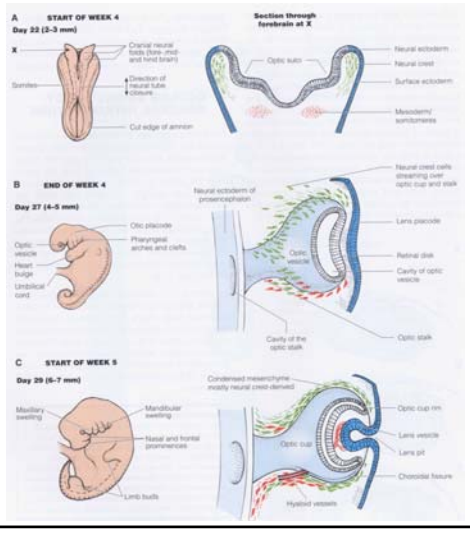
Development of the Vertebrate Eye

(1) The Vertebrate Eye





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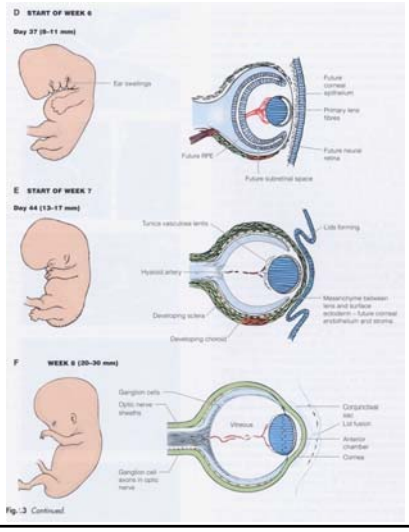
Development of the Vertebrate Eye

(2) The Vertebrate Eye



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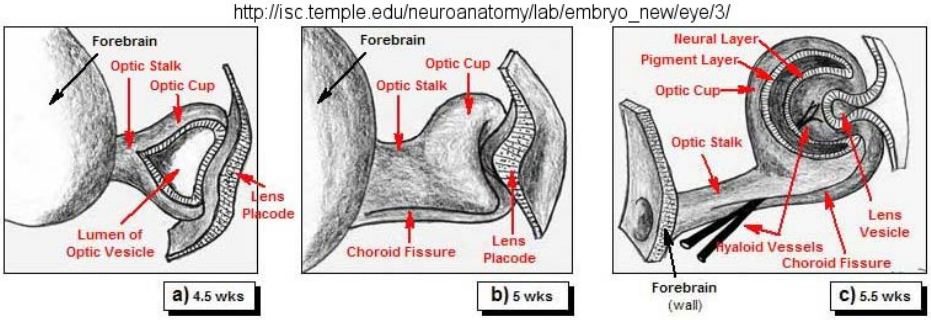
Development of the Vertebrate Eye

(3) The Vertebrate Eye

http://isc.temple.edu/neuroanatomy/lab/embryo_new/eye/3/



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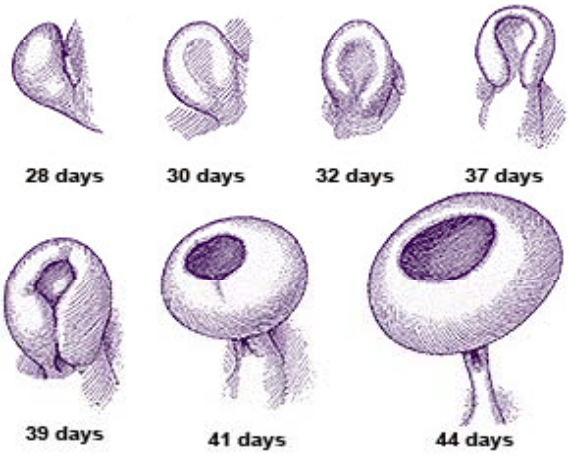

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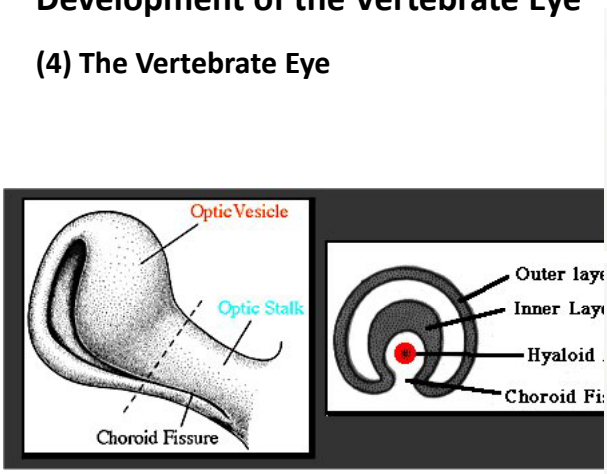
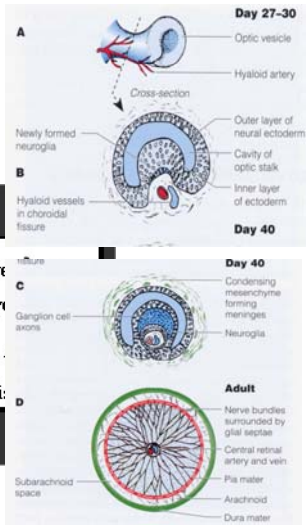
Development of the Vertebrate Eye

(4) The Vertebrate Eye





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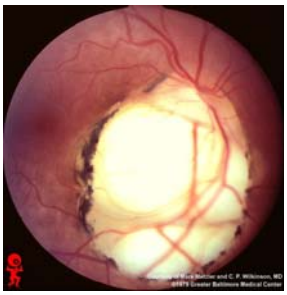
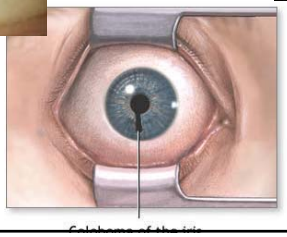
Development of the Vertebrate Eye

(5) Coloboma





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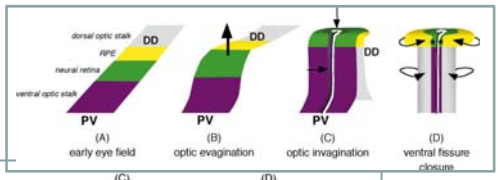
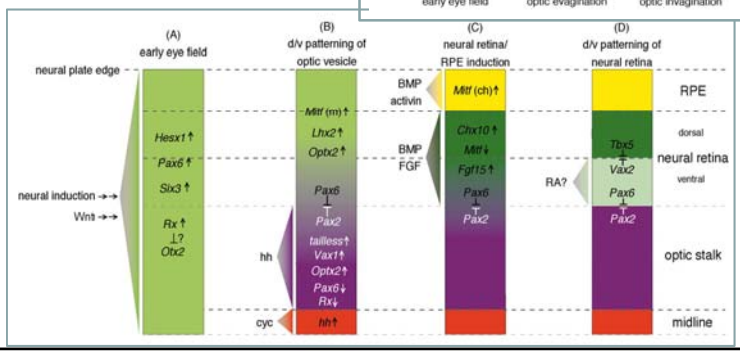
Development of the Vertebrate Eye

(6) Genetic Programm of Eye Development





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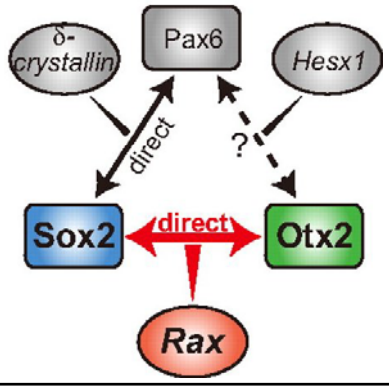
Development of the Vertebrate Eye

(7) *Master Genes in Early Eye Development*

Transcription Factors that in Concert Control the Expression of downstream „modules“

- ★**PAX6**
- ★**SOX2**
- ★**OTX2**
- ★**RAX1 (RX1)**



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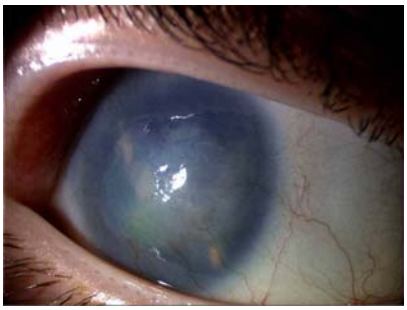
Sensory Systems – Basics and Principles I
Developmental Biology of the Eye &
Cell Types and Cell Biology of the Retina

Development of the Vertebrate Eye

(5) ***Master Genes in Early Eye Development***

- ★homozygous Mutants are mostly lethal
- ★heterozygous Mutants show Ocular Malformations
  (Aniridia, Cataract, Ant. Chamber MF, Micro-/Anophthalmia)



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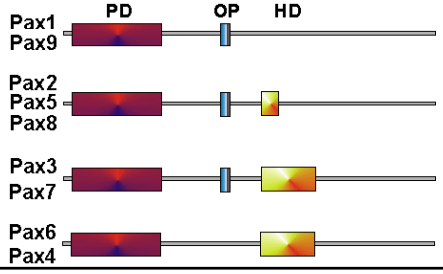
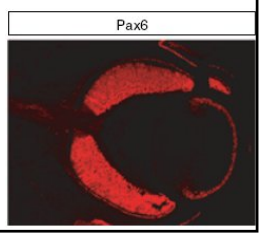
Development of the Vertebrate Eye

(8) ***PAX6: A Conserved Master Gene In Animal Eye Development***

- ★Member of the Paired Box Domain Family
  - 9 PAX Genes in Mammals
  - Critical Role in Embryonic Patterning and Organogenesis:
    Eye, Kidney, Ear, Brain, Skeleton, Thyroid, Pancreas, etc
- ★DNA Binding Domains: Paired Box (PD) & Homeodomain (HD)





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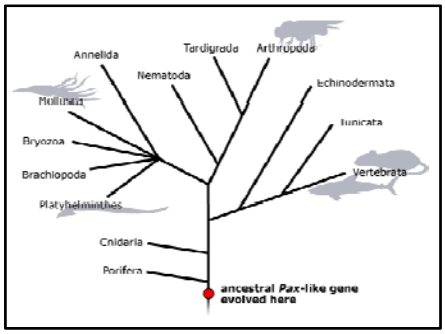
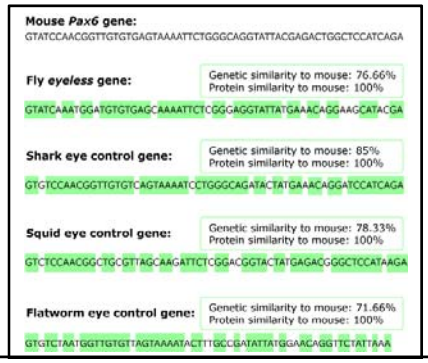
Development of the Vertebrate Eye

(9) *PAX6: A Conserved Master Gene In Animal Eye Development*

- ★PAX Genes can be traced back to early multicellular Metazoan Species
- ★Strong Sequence Conservation in DNA Binding Domains





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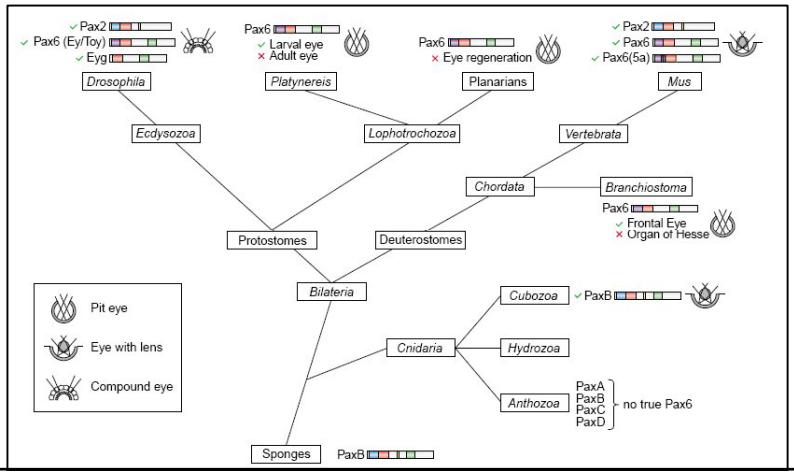
Development of the Vertebrate Eye

(10) *PAX6: A Conserved Master Gene In Animal Eye Development*

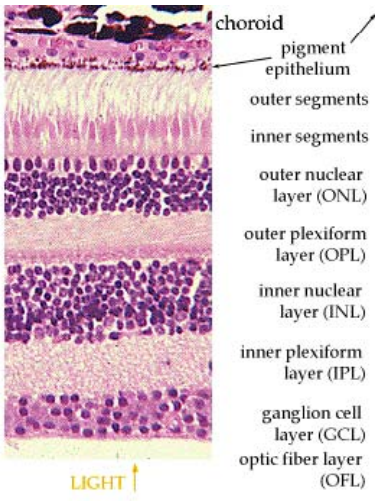


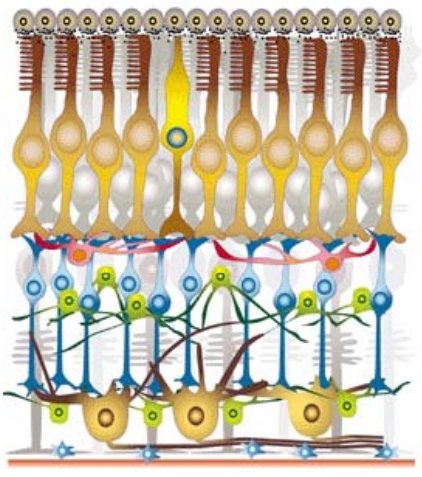
Development of the Vertebrate Eye

(11) ***PAX6: A Conserved Master Gene In Animal Eye Development***

- ★Conserved Function in Eye Development
- ★*ey* (*eyeless*) and *toy* (*twin of eyeless*) in Drosophila
- ★Complemented by vertebrate PAX6 gene
- ★Ectopic Expression of *ey* induced Eye formation on Antennae, Legs, Wings, etc.

Cell Types and Cell Biology of the Retina

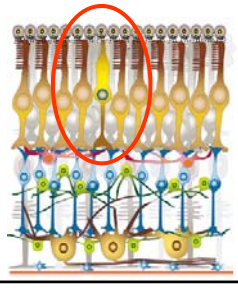


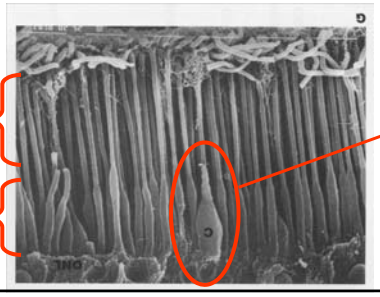


Cell Types and Cell Biology of the Retina

(1) ***Photoreceptors***

- ★Light sensitive Cells
- ★Rod Photoreceptor: Maximally light sensitive vision under dim light conditons
- ★Cone Photoreceptor: high acuity daylight vision, high contrast and chromatic vision

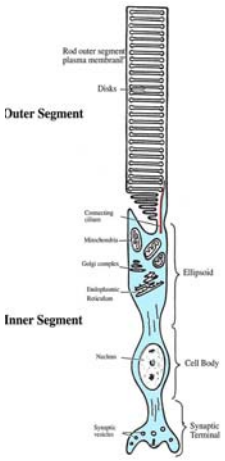




Cell Types and Cell Biology of the Retina

(2) ***Photoreceptors***

- ★Ciliated Type of Photoreceptor
  Connecting Cilium (9+0) between IS and OS
- ★ Phototransduction Cascade in OS
- ★ Discs in Rods and PM Lamellae in Cones Rod



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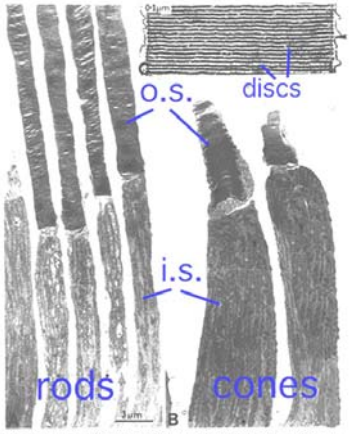

Fig 2. Low magnification EM image of monkey rods and cones with an enlargement of the outer segment discs.

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Sensory Systems – Basics and Principles I
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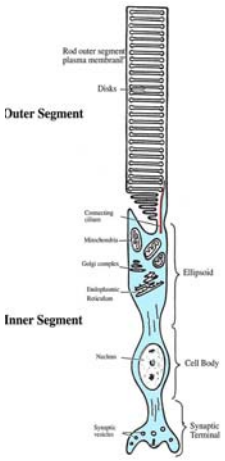
For Internal Use Only

Cell Types and Cell Biology of the Retina

(2) ***Photoreceptors***



- ✯ Ciliated Type of Photoreceptor
  Connecting Cilium (9+0) between IS and OS
- ✯ Phototransduction Cascade in OS
- ✯ Discs in Rods and PM Lamellae in Cones Rod
- ✯ Constant Renewal and Shedding of Discs
- ✯ Expanded Synaptic Terminals on BPC and HC:
  Rod - Spherules; Cone – PediclesConstant

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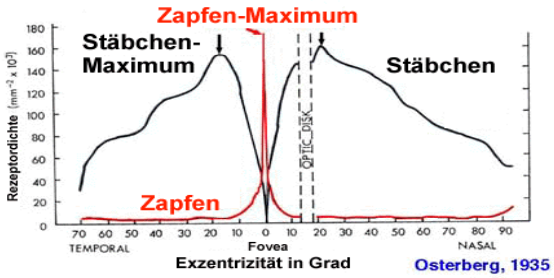
Cell Types and Cell Biology of the Retina

(3) *Photoreceptors*

- ★ Ratio of Rods to Cones varies among Species depending on Lifestyle (nocturnal/diurnal); in Humans: ~ 20:1
- ★ Unequal spatial Distribution
  e.g. Fovea in Humans, Visual Streak in many Species



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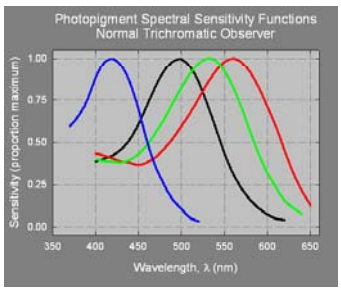
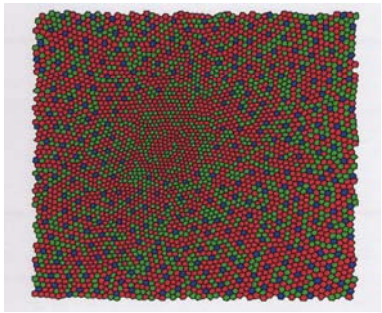
Cell Types and Cell Biology of the Retina

(4) *Photoreceptors*

- ★ Multiple Types of Cone Photoreceptors
  express spectrally different Photopigments
- ★ Three Cones Types in Primates: Trichromatic Vision
- ★ Unequal spatial Distribution of Cones: Cone Mosaic

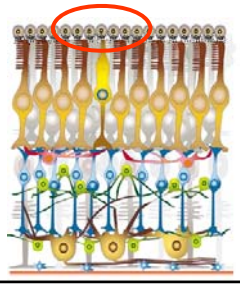


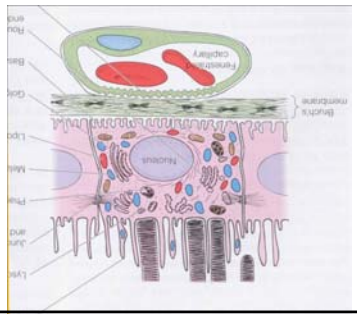


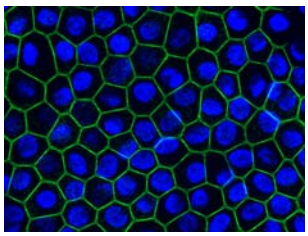
Cell Types and Cell Biology of the Retina

(5) ***Retinal Pigment Epithelial Cells***

- ★Neuroectoderm-derived polarized Epithelial Cells
- ★apikal Membrane with Microvilli contacts on PR
- ★ Nutrient and Metabolite Supply for PR from Choroid
  active transport & selective permeability (oBRB)



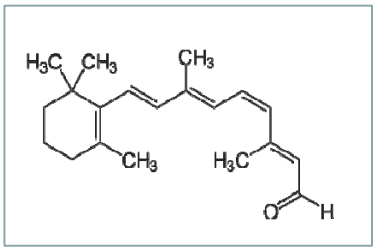


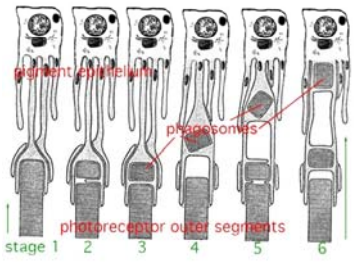


Cell Types and Cell Biology of the Retina

(6) ***Retinal Pigment Epithelial Cells***

- ★high Content of Melanosomes: light absorption,
  reduce light scatter, Free Radical Scavenger
- ★Important Role in Visual Cycle:
  Storage of Retinoids, 11-cis Retinal Recycling
- ★ Phagocytosis of Rod Outer Segments

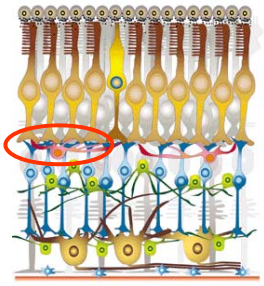




Cell Types and Cell Biology of the Retina

(7) *Horizontal Cells*

- ★ Neurons that form Interconnections between Synapses of multiple Photoreceptors (between cones, rods to cones)
- ★ Few Subtypes, integrative function in visual processing
- ★ Mostly inhibitory: GABA as neurotransmitter



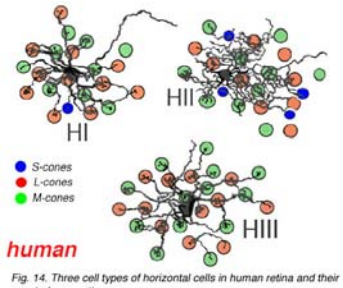
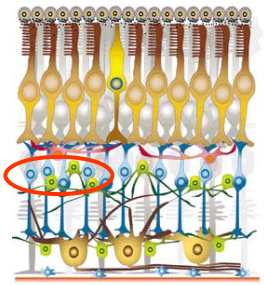


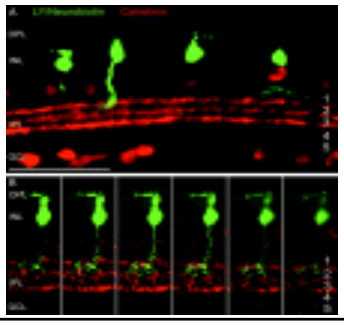
Fig. 14. Three cell types of horizontal cells in human retina and their spectral connections.

Cell Types and Cell Biology of the Retina

(8) *Bipolar Cells*

- ★ First Order Interneuron in the Retina
- ★ Dentric Contacts with Photoreceptors and HC, axonal Contacts with Ganglion Cells and Amacrine Cells
- ★ Glutamate release excite (OFF-BP) or inhibits (ON-BP) Bipolar Cell Activity





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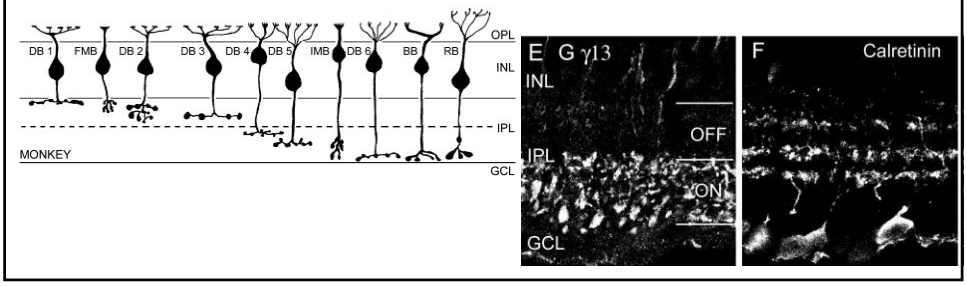
Cell Types and Cell Biology of the Retina

(9) ***Bipolar Cells***

- ★Various Subtypes of Bipolar Cells:
  Rod BP, Midget BP, Diffuse Cone BP, Blue Cone BP, etc
- ★Characterized by Synaptic Contact, dendritic Arbours, and Stratification of Synatic Termini in the Inner Plexiforme Layer



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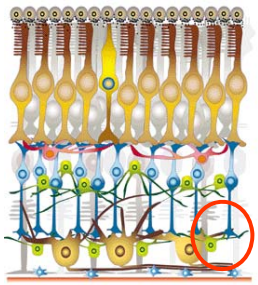
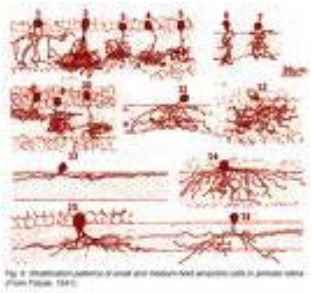
Cell Types and Cell Biology of the Retina

(10) ***Amacrine Cells***

- ★Interconnectiong Neurons between Bipolar Cells (e.g. Rod BP on Cone BP) and Ganlion Cells
- ★ Various Subtypes characterized by Synaptic Contact, dendritic Arbours, and Stratification in the IPL

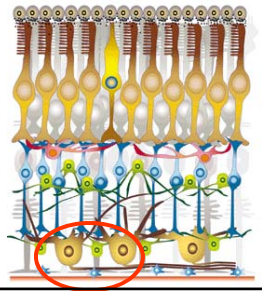


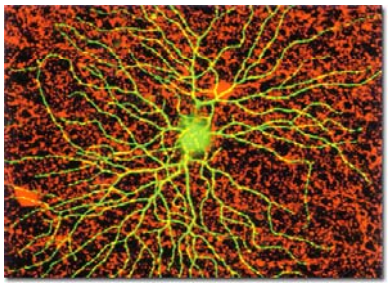


Cell Types and Cell Biology of the Retina

(11) *Ganglion Cells*

- ★ Form dendritic Contacts with Bipolar Cells and Amacrine Cells
- ★ Highest Level of Convergence in Retinal Signal Processing: ~ 1 Mio GC vs ~ 120 Mio PR

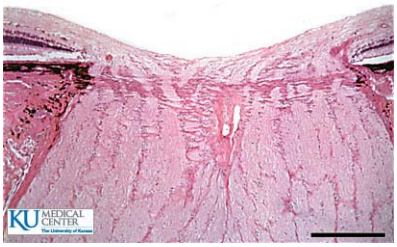


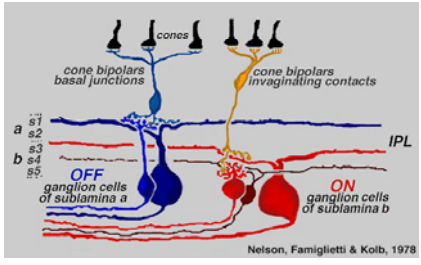


Cell Types and Cell Biology of the Retina

(12) *Ganglion Cells*

- ★ Various Subtypes of Ganglion Cells: Midget Ganglion Cells, Parasol Ganglion Cells, etc.
- ★ Characterized by Synaptic Input, Size, dendritic Arbours
- ★ Axons tracks towards the papillae and form the optic nerve, > optic tract





Cell Types and Cell Biology of the Retina

(13) ***Glial Cells***

- ★ Muller Cells: Glutamate Synthesis and Clearance,
  Nutritions and Growth Factor Supply,
  Scaffold Function for Neurons
  Processes form OLM and ILM
  may function as Optic Cables to transmit light PR
- ★ Astrocytes
- ★ Microglia