

BASICS OF NEUROBIOLOGY

VISUAL SYSTEM

ZSOLT LIPOSITS

Basics of Neurobiology: Visual system

FEATURES OF THE VISUAL SYSTEM

THE VISUAL SYSTEM IS PART OF THE CNS. IT CONSISTS OF THE RETINA AND ITS PROJECTIONS, THE LATERAL GENICULATE BODY, THE OPTIC RADIATION, THE PRIMARY AND SECONDARY CORTICAL PROCESSING CENTERS. IN ASSOCIATION WITH THE SYSTEM, THE OCULOMOTOR REFLEX AND ACCOMMODATION ARE FUNCTIONALLY IMPORTANT MECHANISMS

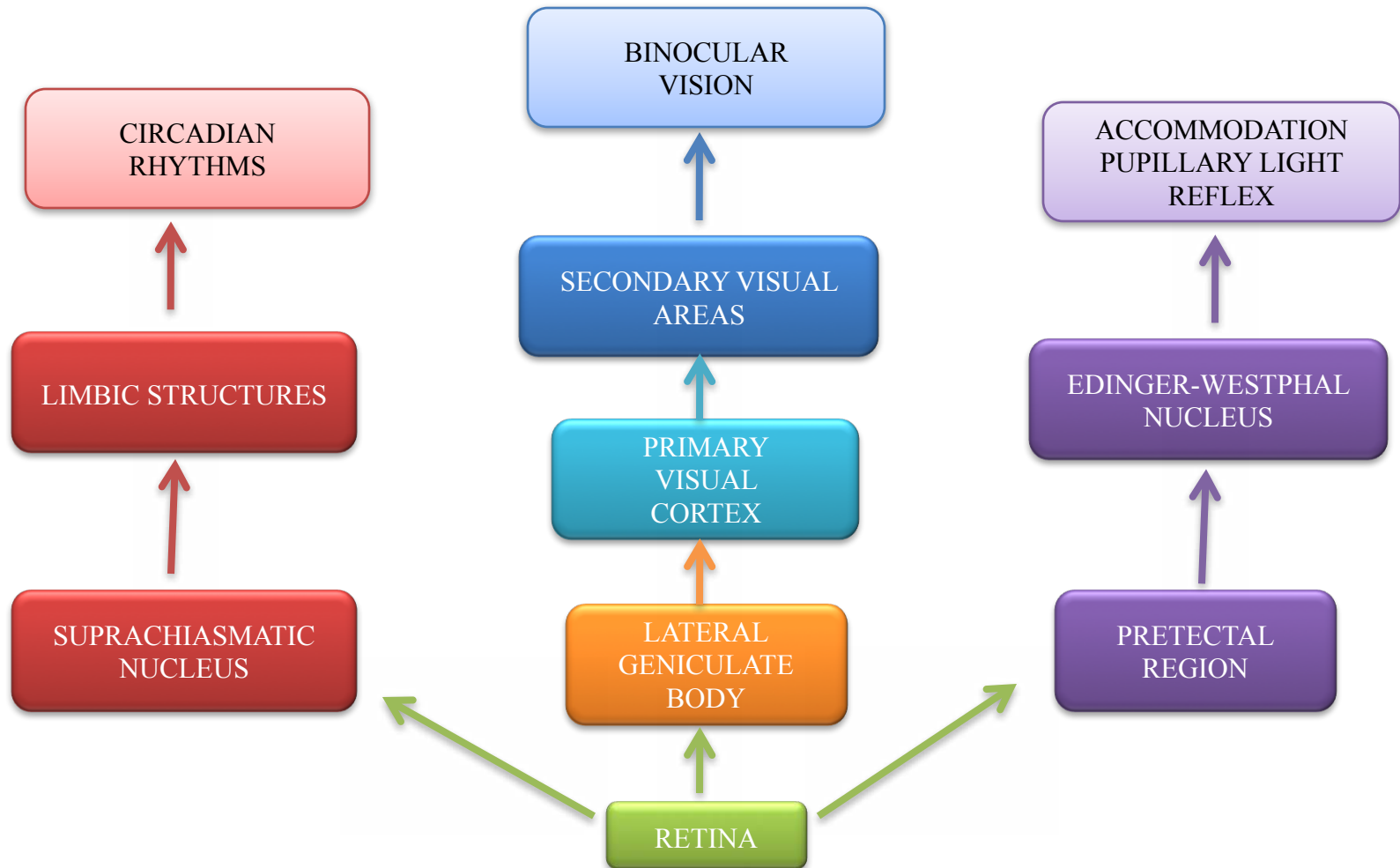
THE MAIN TASK OF THE VISUAL SYSTEM IS THE CONSCIOUS PERCEPTION OF THE VISUAL SCENE. THE INFORMATION ABOUT THE LIGHT/DARK PERIODS OF THE DAY IS DIRECTED TO THE SUPRACHIASMATIC NUCLEUS OF THE HYPOTHALAMUS THAT ORCHESTRATES THE DIURNAL (CIRCADIAN) RHYTHM OF SEVERAL NEURONAL, ENDOCRINE AND METABOLIC FUNCTIONS

ALTHOUGH THE VISUAL FIELD IS REPRESENTED IN ALL KEY UNITS OF THE VISUAL SYSTEM FROM THE RETINA TO THE CORTICAL VISUAL AREAS, THE PROPER BINOCULAR VISION (SHAPE, SIZE, SHARPNESS, DEPTH, COLOR OF OBJECTS) REQUIRES A DELICATE COOPERATION OF PROCESSING STRUCTURES PERFORMING AT DIFFERENT LEVELS IN THE HIERARCHY OF THE NEURONAL ORGANIZATION

THE IMAGE AND SPECIAL ATTRIBUTES OF THE OBJECTS SEEN IN THE BINOCULAR VISUAL FIELD ARE GRADUALLY BUILD UP FROM SIMPLEX (RETINA) TO COMPLEX (VISUAL CORTEX) PROCESSING LEVELS

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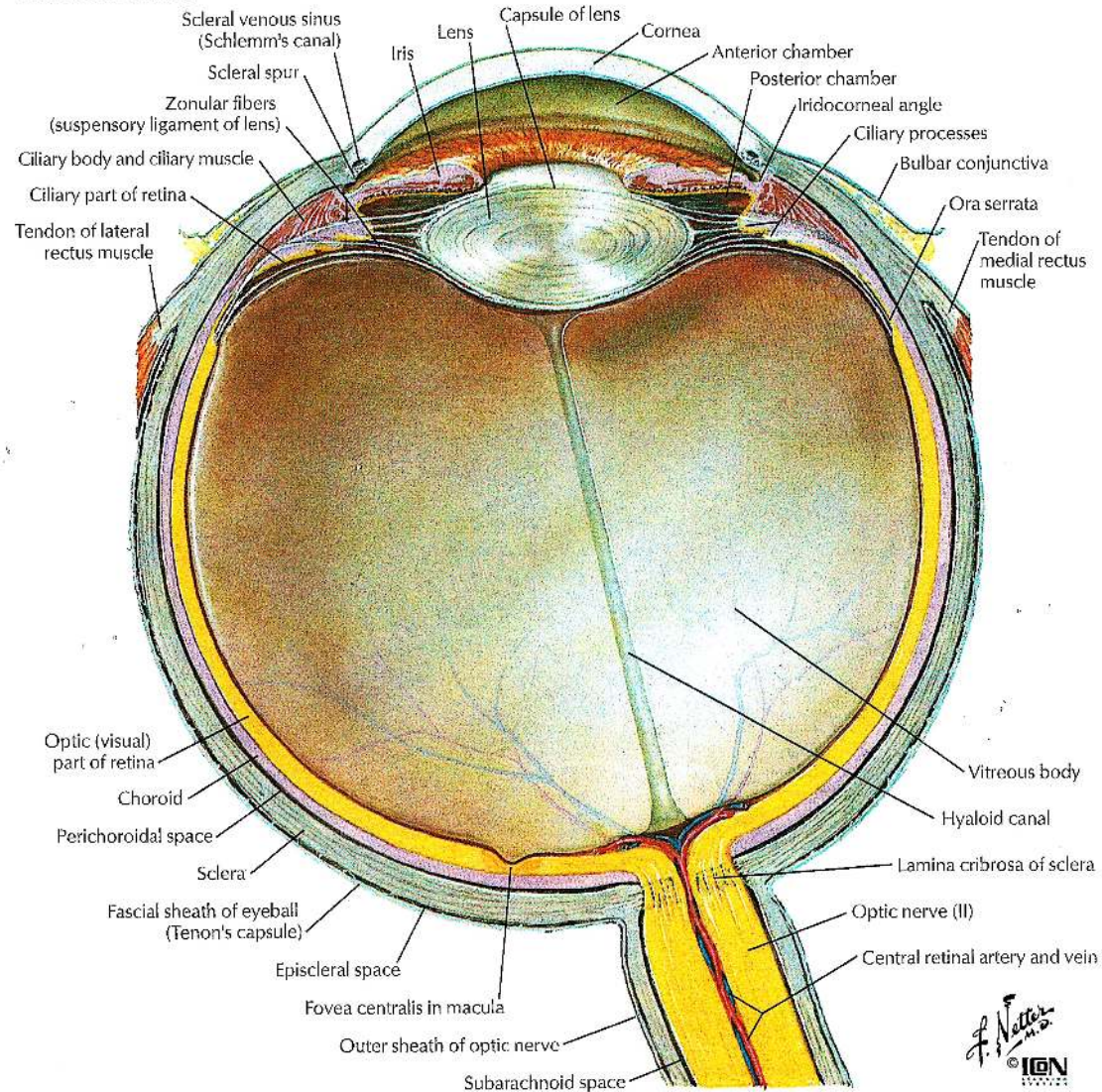
SCHEME OF THE ORGANIZATION OF THE VISUAL SYSTEM



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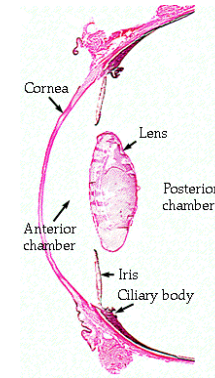
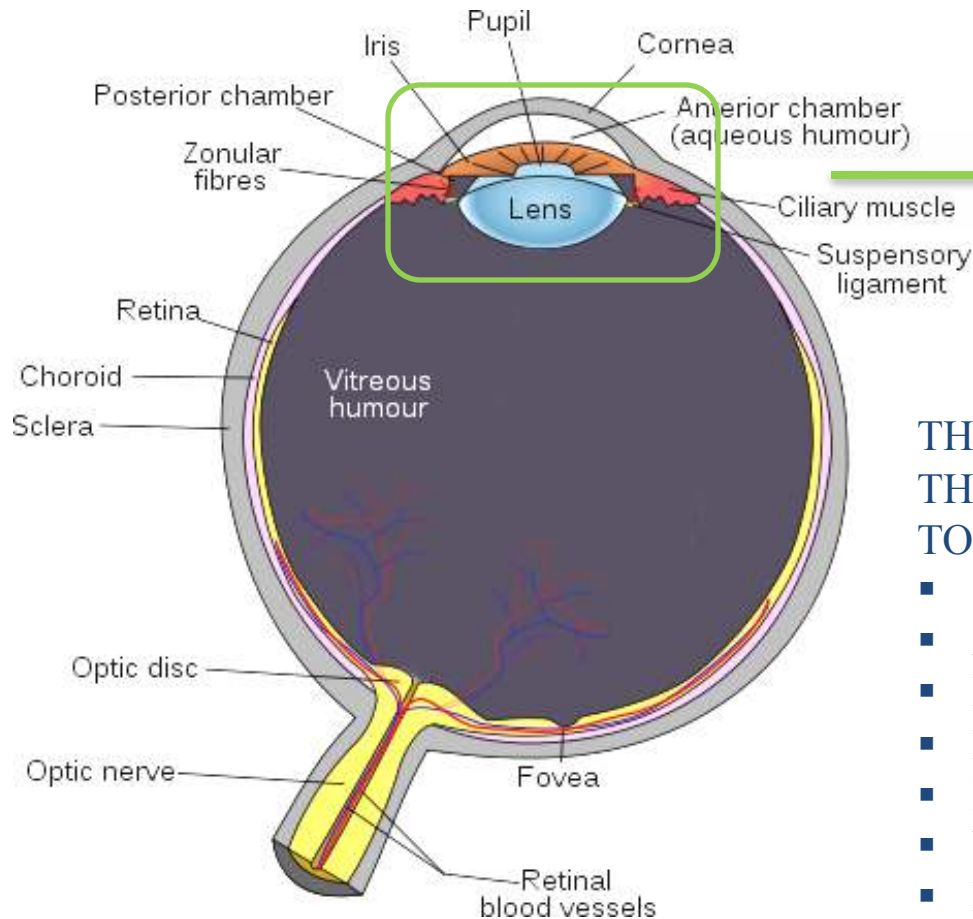
ANATOMY OF THE EYE BALL

Horizontal section



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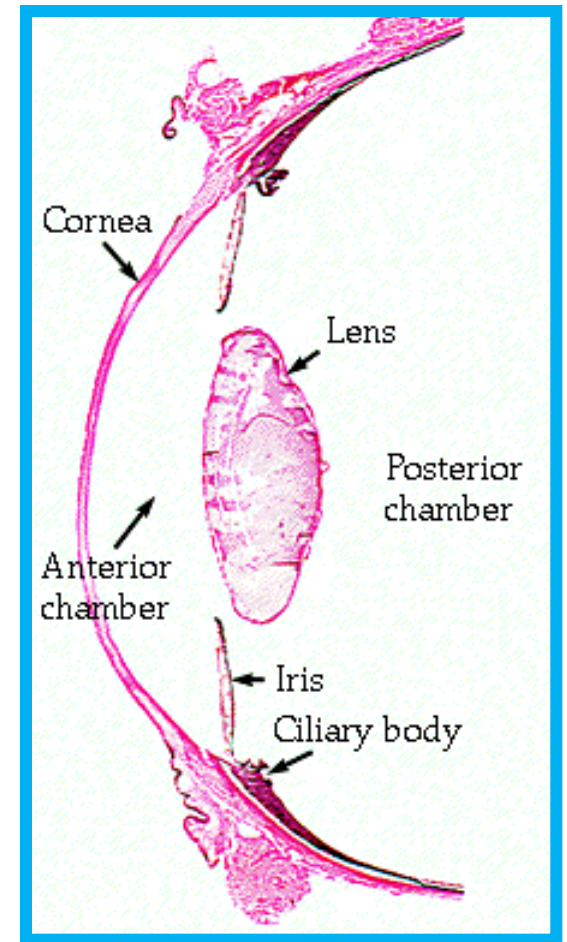
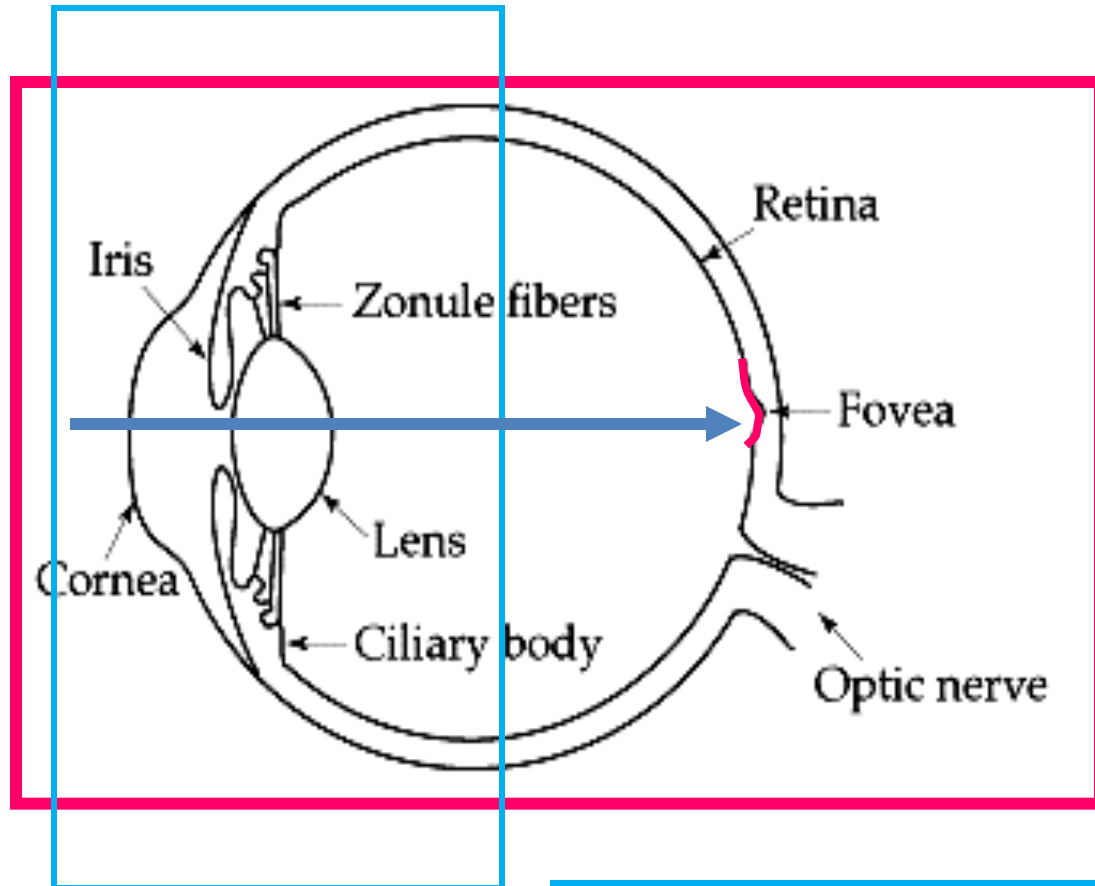
THE REFRACTIVE STRUCTURES OF THE EYE BALL



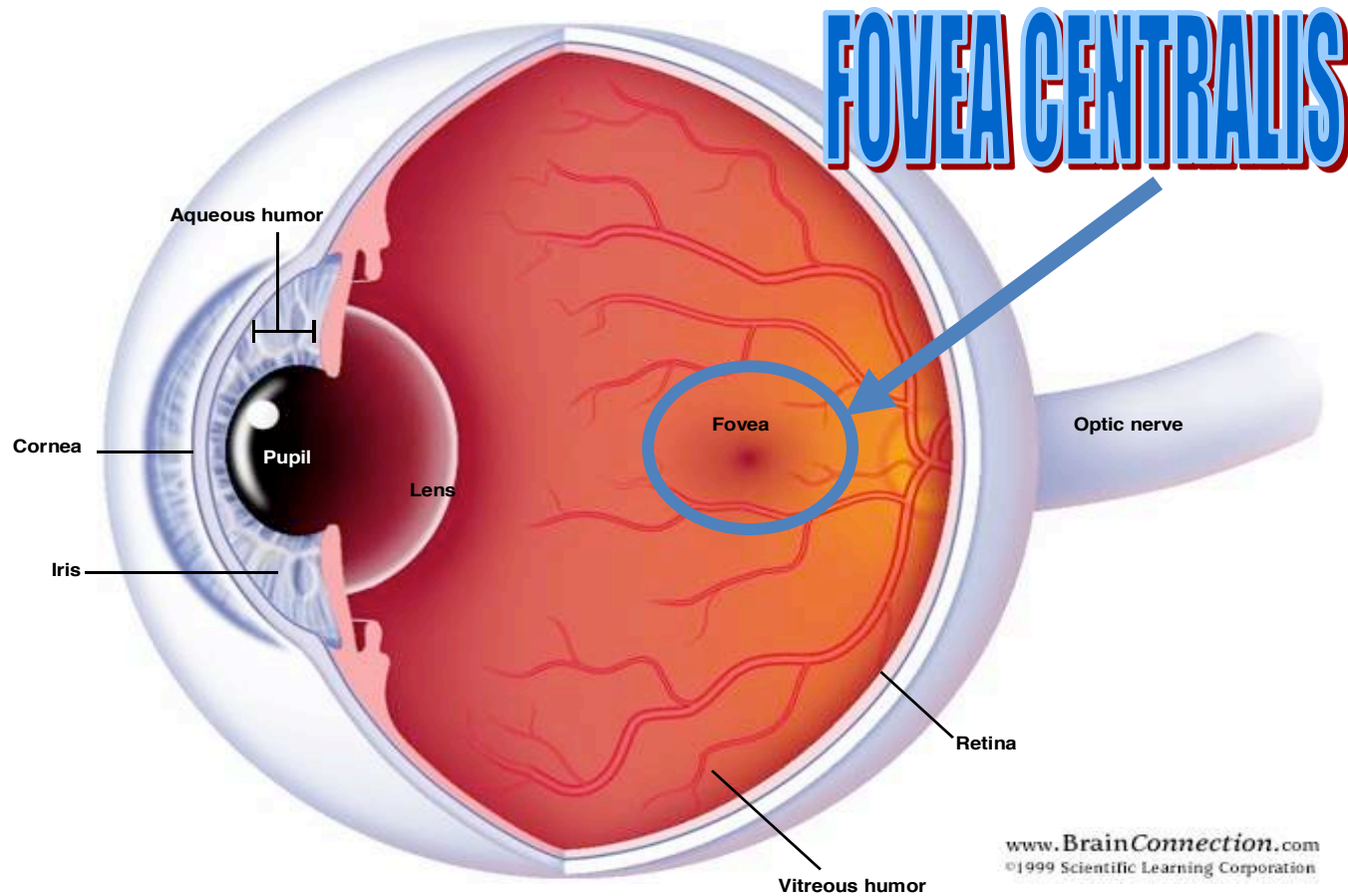
THE LIGHT RAY TRAVERSES THROUGH THE FOLLOWING STRUCTURES EN ROUTE TO THE PHOTORECEPTORS:

- CORNEA
- ANTERIOR CHAMBER
- PUPIL
- POSTERIOR CHAMBER
- LENS
- VITREOUS BODY
- RETINA

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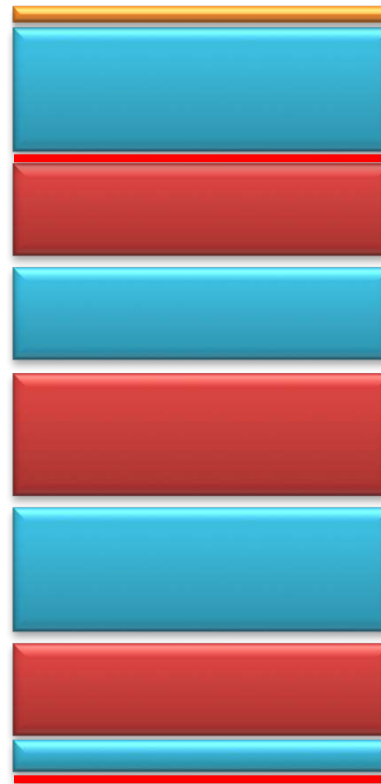
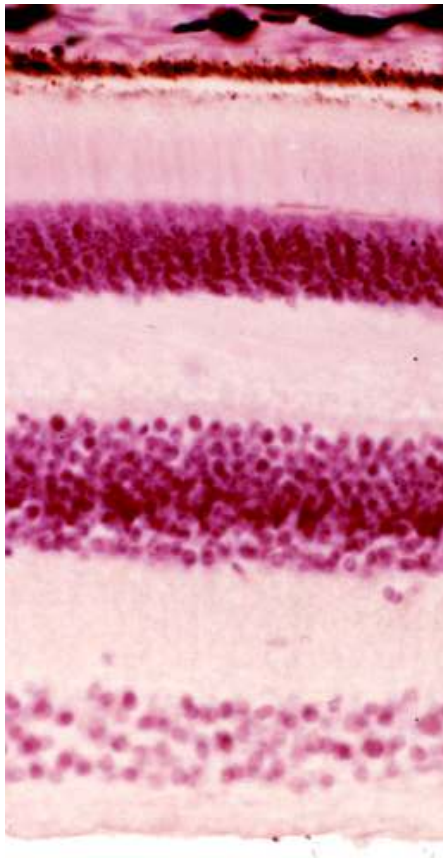


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THE STRUCTURE OF THE RETINA



1. PIGMENT CELL LAYER

2. LAYER OF RODS AND CONES

← 3. OUTER LIMITING MEMBRANE

4. OUTER NUCLEAR LAYER

5. OUTER PLEXIFORM LAYER

6. INNER NUCLEAR LAYER

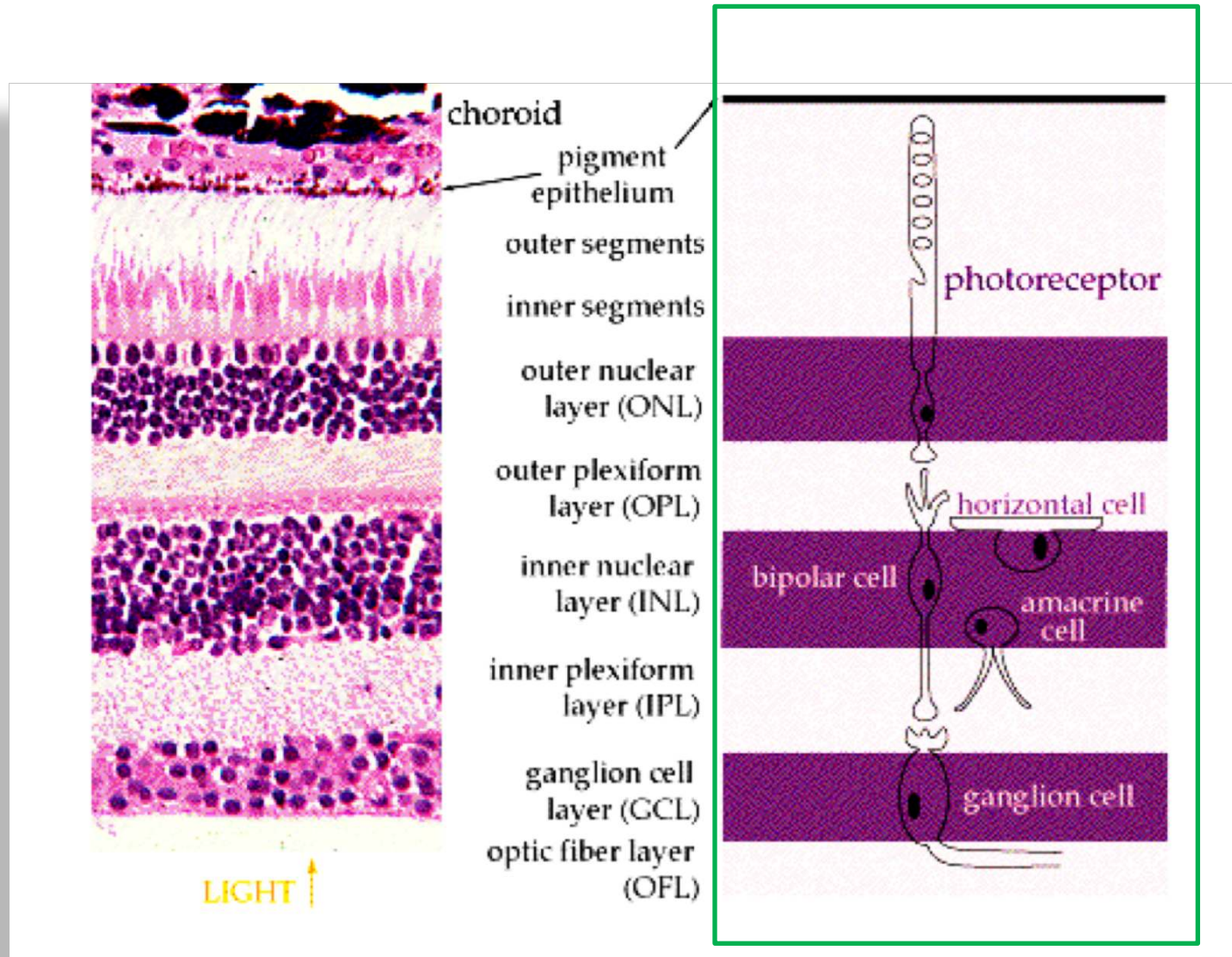
7. INNER PLEXIFORM LAYER

8. GANGLION CELL LAYER

9. OPTIC NERVE FIBER LAYER

← 10. OUTER LIMITING MEMBRANE

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PHOTORECEPTOR CELLS OF THE RETINA

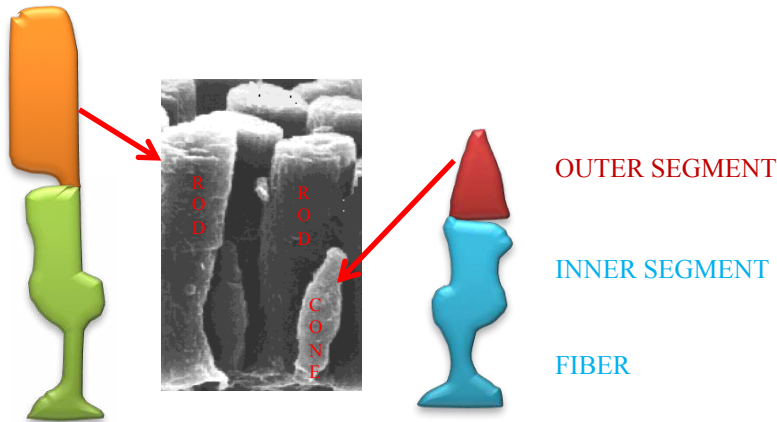
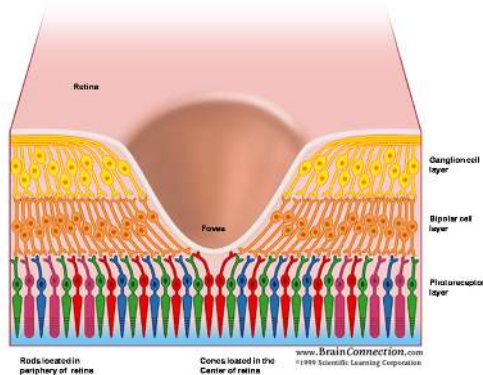
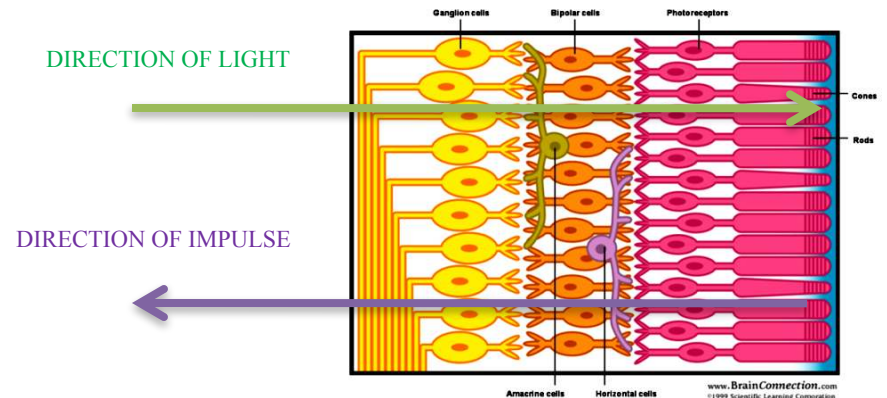


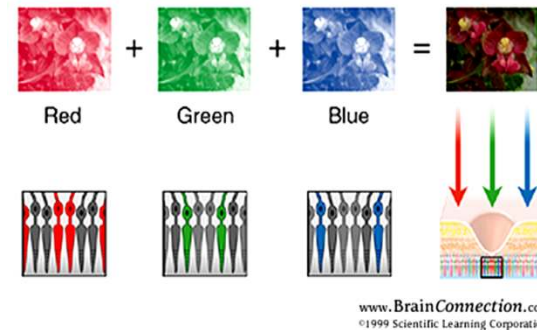
ILLUSTRATION OF RODS AND CONES, THE PHOTORECEPTORS OF THE RETINA



DEPICTION OF THE FOVEA CENTRALIS. NOTE THE EXCLUSIVE PRESENCE OF CONES

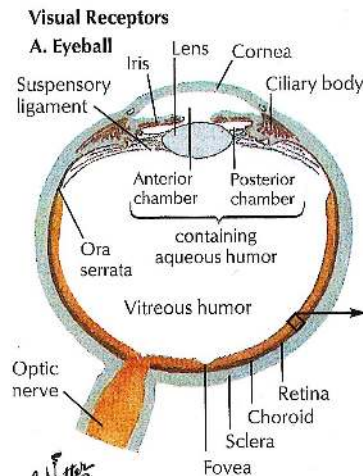


NETWORKING OF PHOTORECEPTOR, BIPOLAR, HORIZONTAL, GANGLION AND AMACRINE CELLS IN THE RETINA. NOTE THE CONVERGENCE

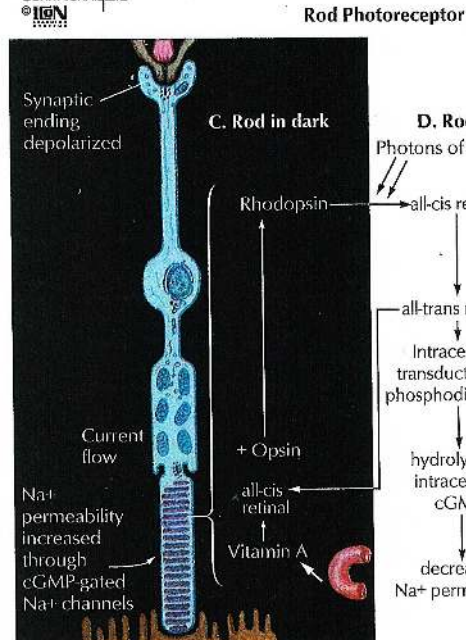
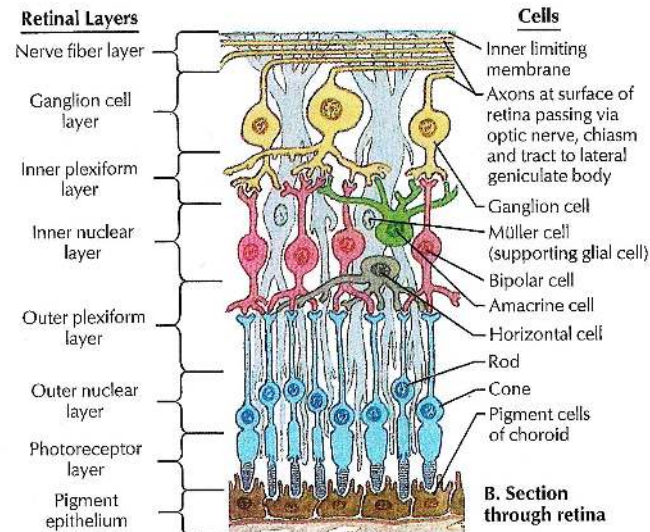


THE TRICOLOR MECHANISM OF COLOR DETECTION. SPECTRUM SENSITIVE CONES

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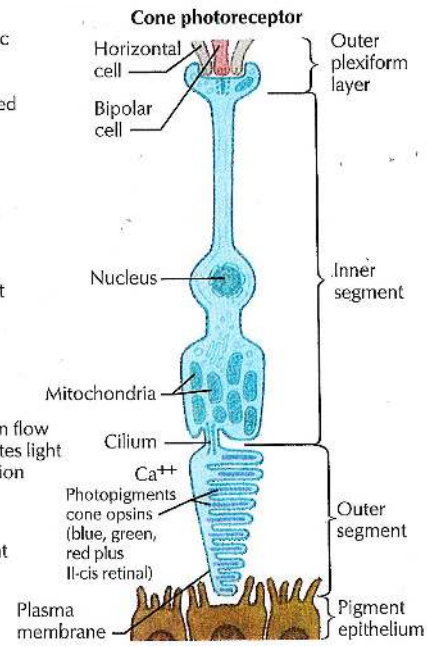
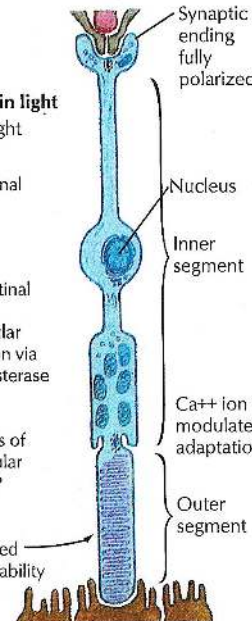


JOHN A. CRAIG, MD
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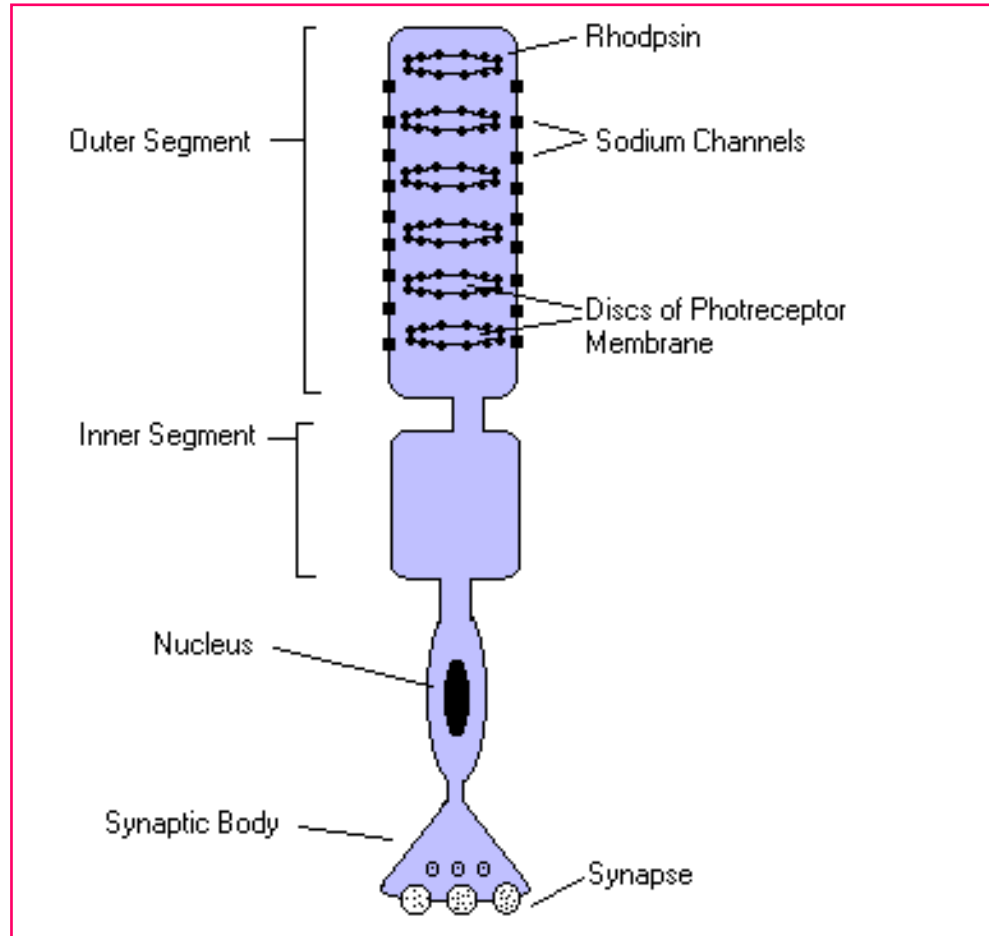
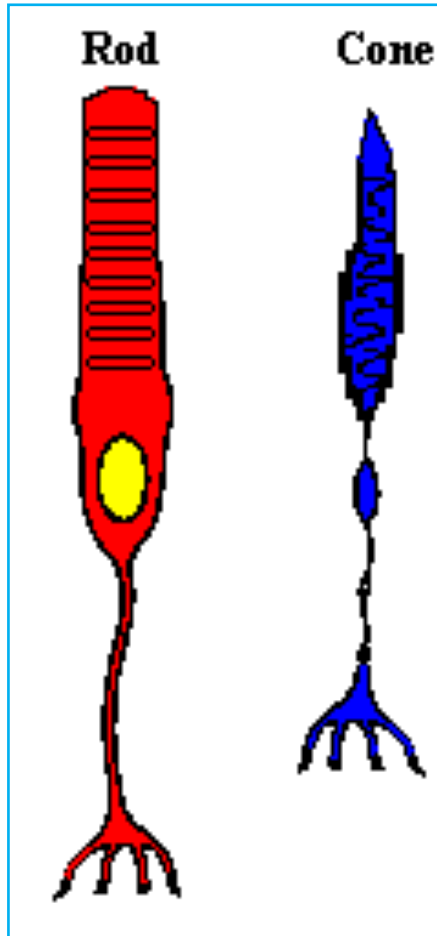


D. Rod in light

Photons of light → all-cis retinal → all-trans retinal → Intracellular transduction via phosphodiesterase → hydrolysis of intracellular cGMP → decreased Na⁺ permeability



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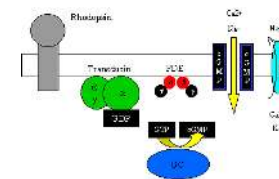
SIGNAL TRANSDUCTION IN THE RETINA

THE LIGHT RAY PASSES THROUGH THE INNER LAYERS OF THE RETINA AND REACHES THE OUTER SEGMENTS OF PHOTORECEPTOR CELLS, THE RODS AND CONES

SHINING LIGHT ON PHOTORECEPTORS LEADS TO HYPERPOLARIZATION OF THE RECEPTOR CELLS

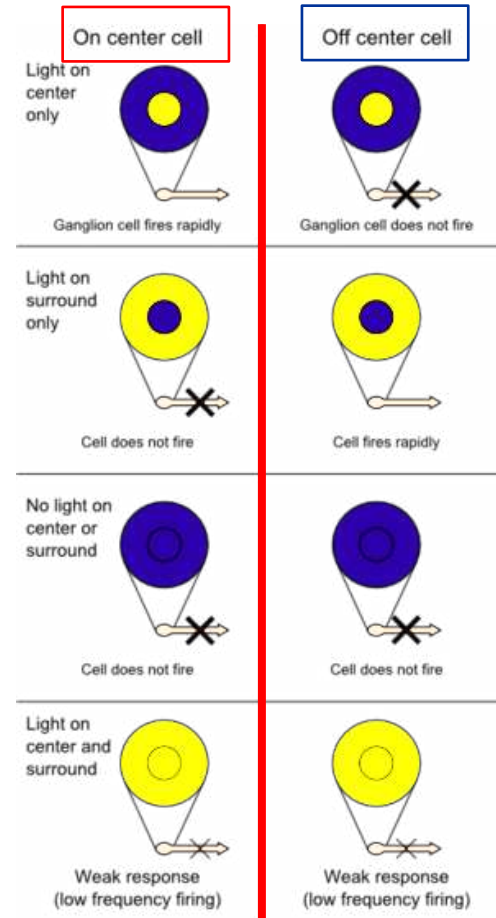
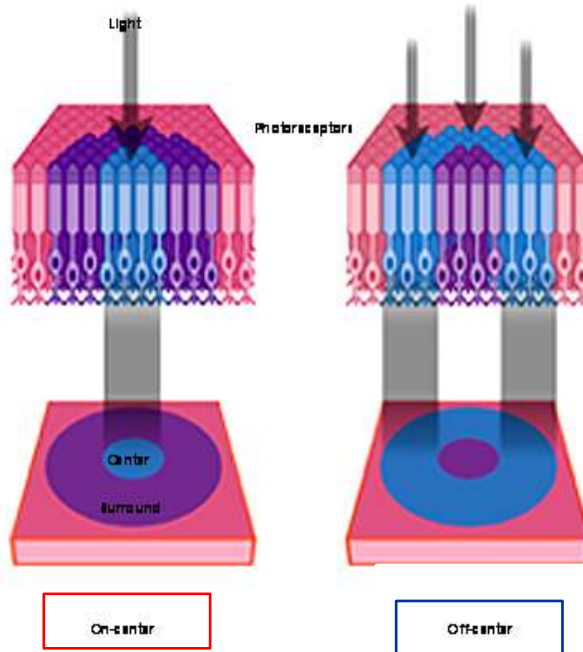
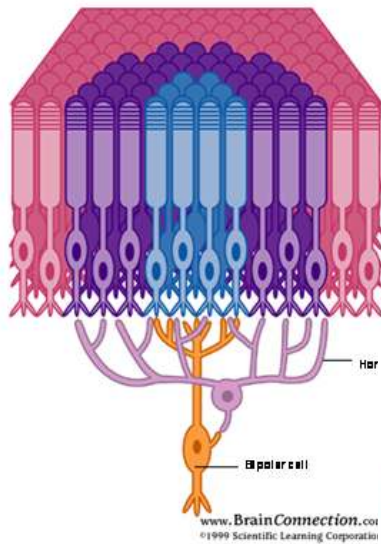
IN DARK, THE RECEPTOR CELLS ARE DEPOLARIZED RESULTING IN SODIUM AND CALCIUM INFLUX THROUGH CYCLIC GUANOSINE MONOPHOSPHATE (cGMP)-GATED CHANNELS. THIS INWARD CURRENT AT THE OUTER SEGMENT IS OPPOSED BY AN OUTWARD CURRENT OF POTASSIUM. THE NET BALANCE OF CATIONS RESULTS IN A MEMBRANE POTENTIAL OF -40 mV

THE ABSORPTION OF LIGHT REDUCES THE cGMP CONTENT IN THE PHOTORECEPTOR LEADING TO THE CLOSURE OF OUTER SEGMENT CATION CHANNELS. ACCORDINGLY, THE EFFLUX OF POTASSIUM IONS BECOMES DOMINANT, THE POSITIVE CHARGE DECREASES AND HYPERPOLARIZATION DEVELOPS

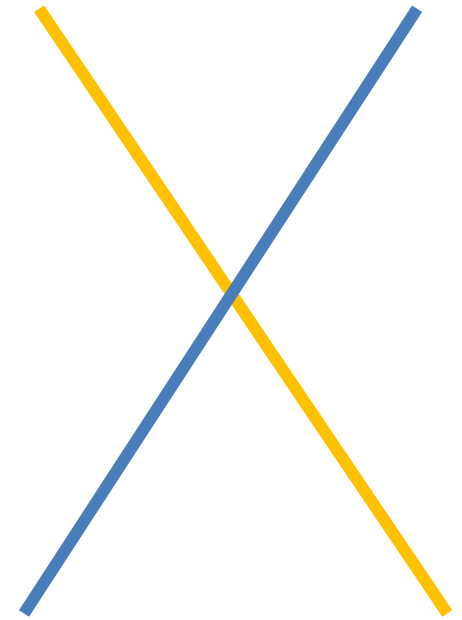
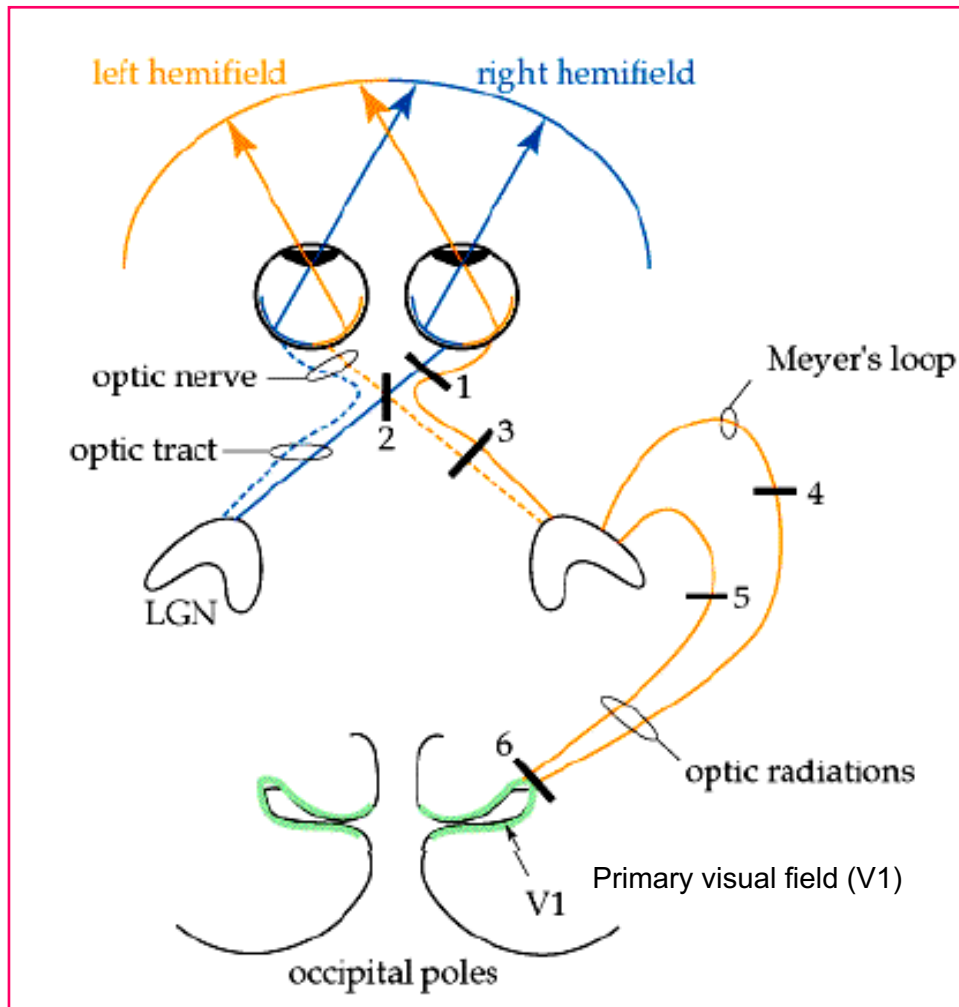


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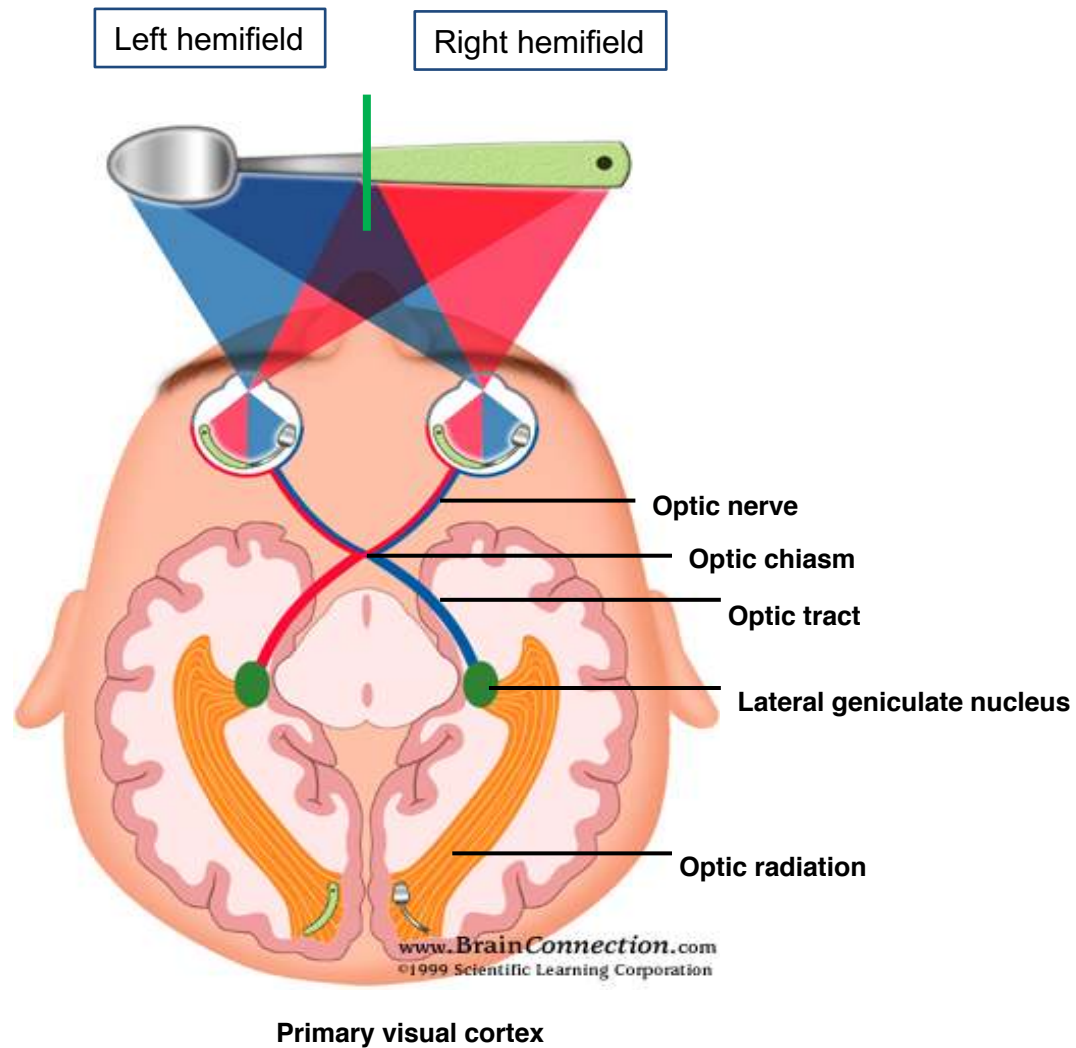
ON AND OFF CENTERS OF THE RETINA



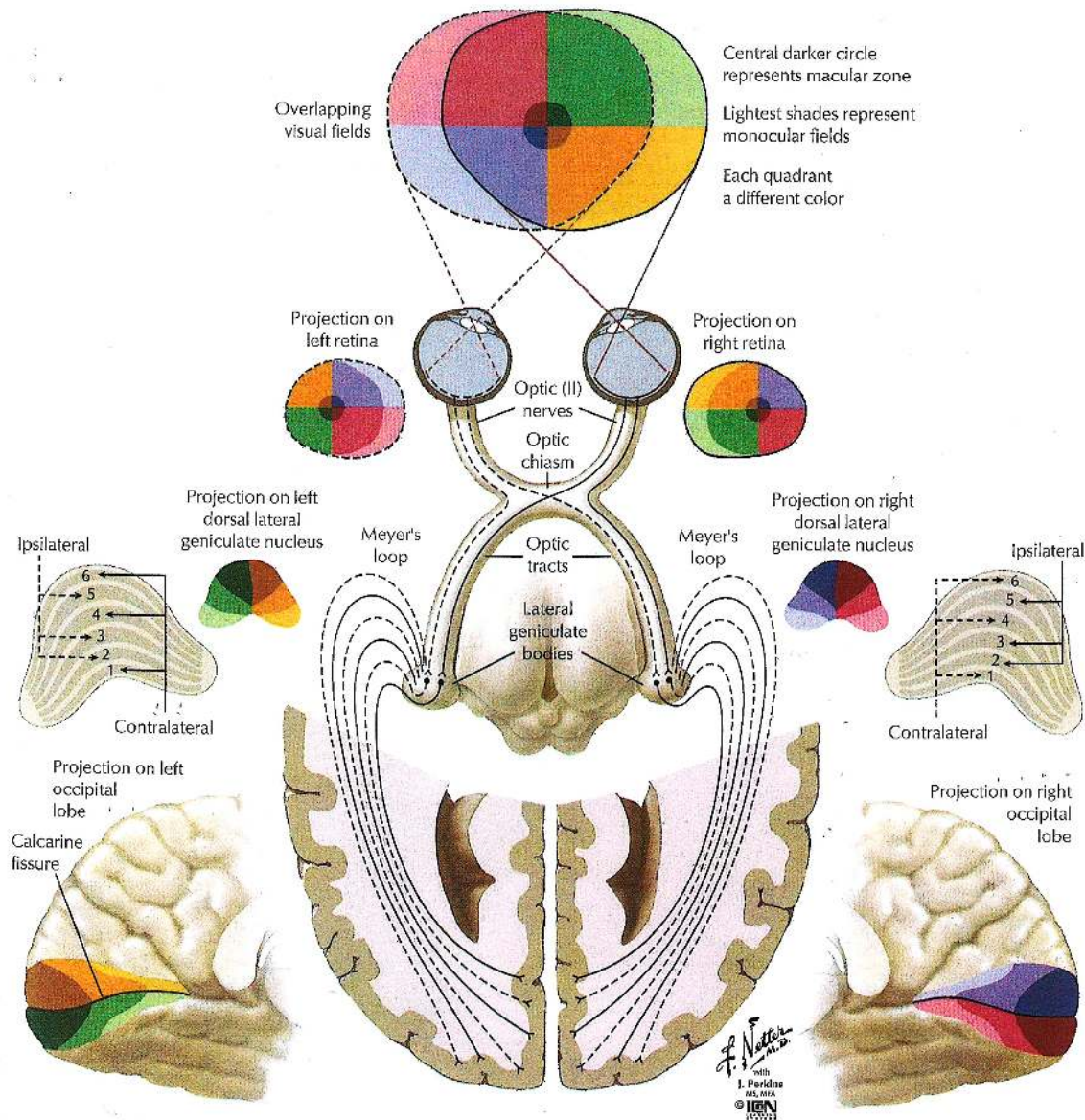
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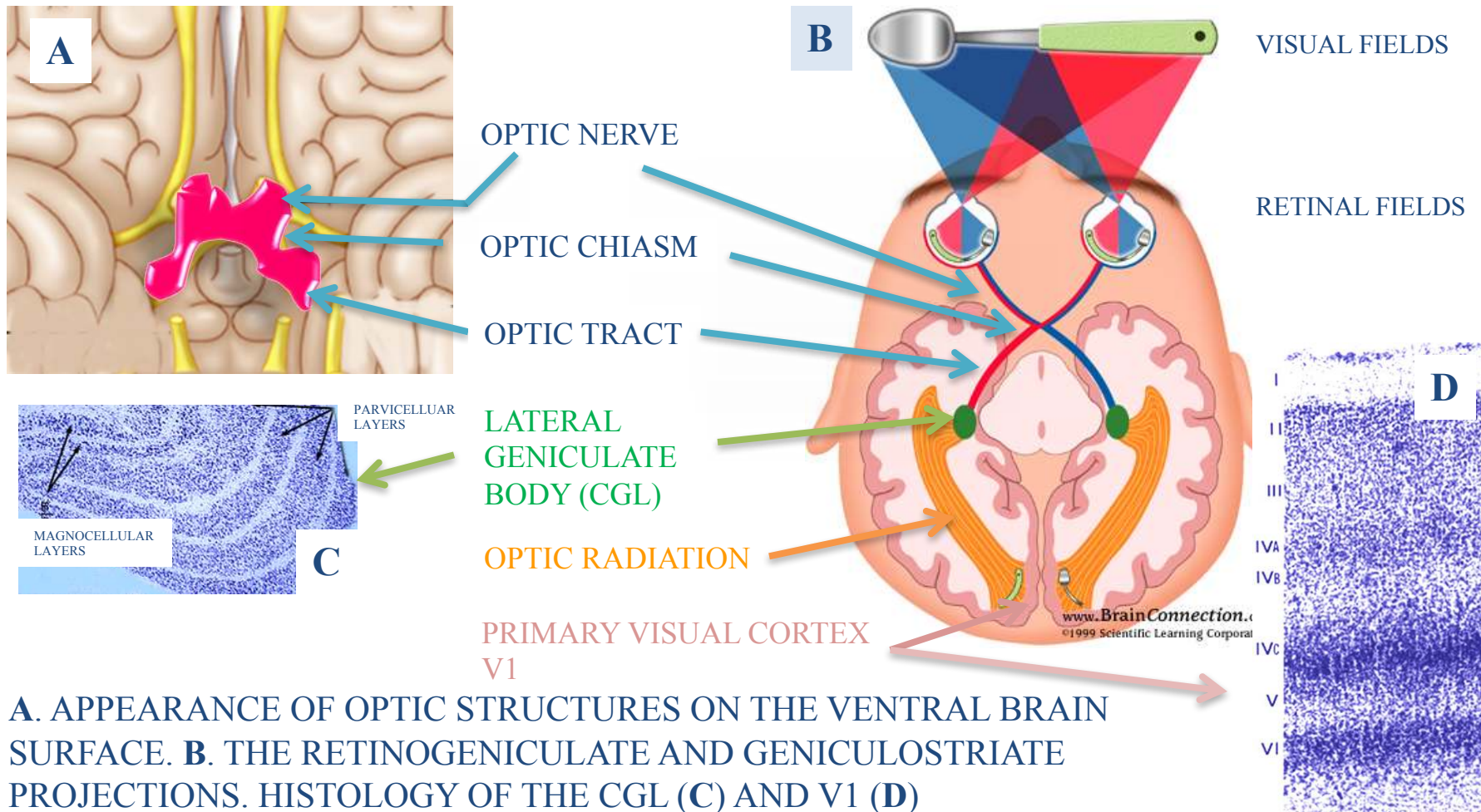


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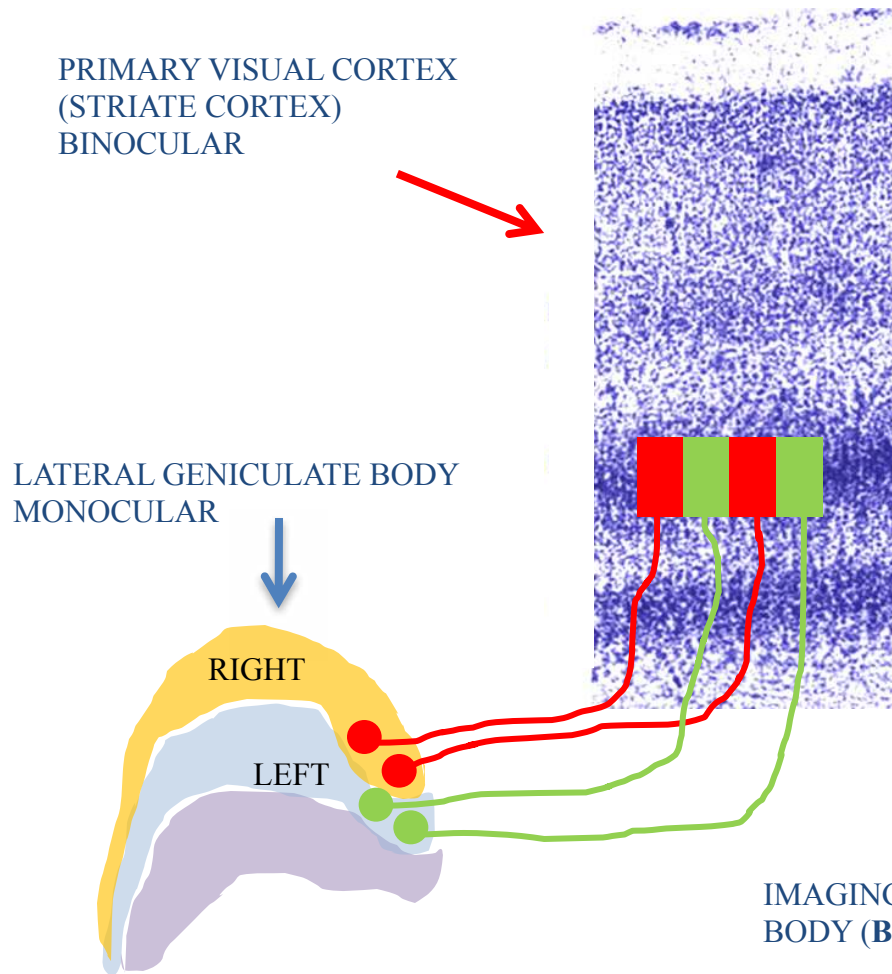
MAIN COMPONENTS AND PROJECTIONS OF THE VISUAL SYSTEM



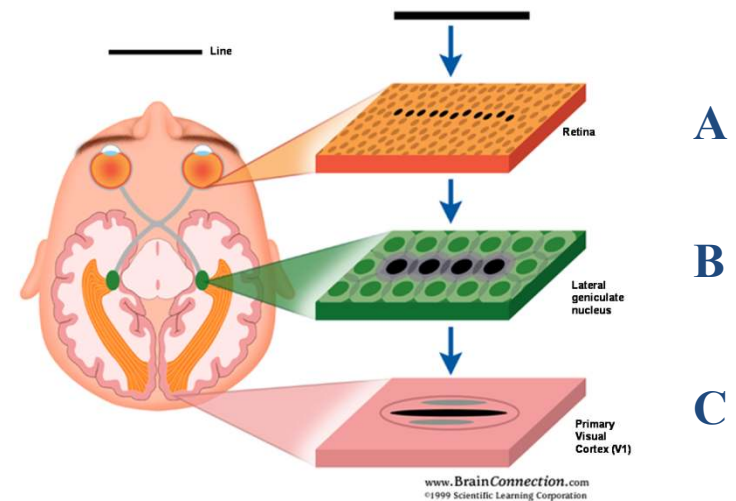
A. APPEARANCE OF OPTIC STRUCTURES ON THE VENTRAL BRAIN SURFACE. **B.** THE RETINOGENICULATE AND GENICULOSTRIATE PROJECTIONS. HISTOLOGY OF THE CGL (**C**) AND V1 (**D**)

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THE GENICULO-STRIATE PROJECTION. OCULAR DOMINANCE COLUMNS

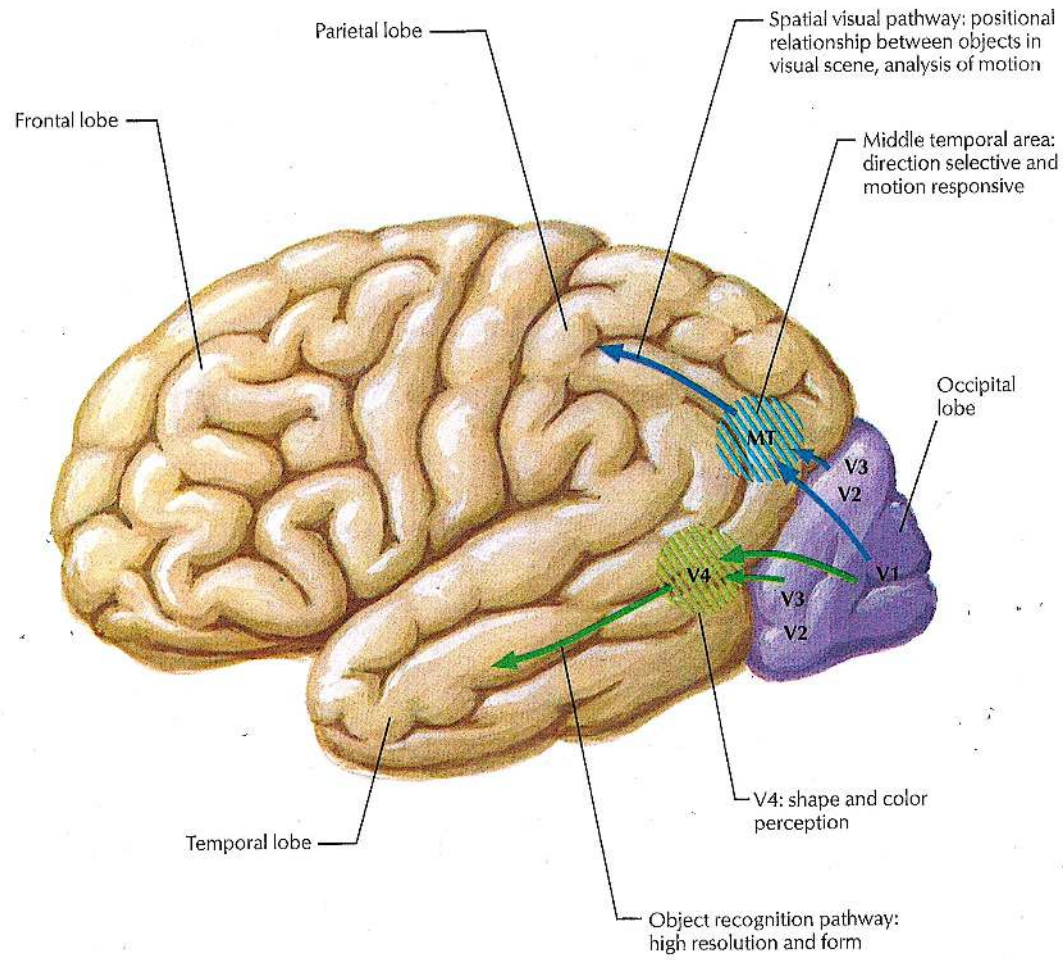


OCULAR DOMINANCE COLUMNS IN THE VISUAL CORTX



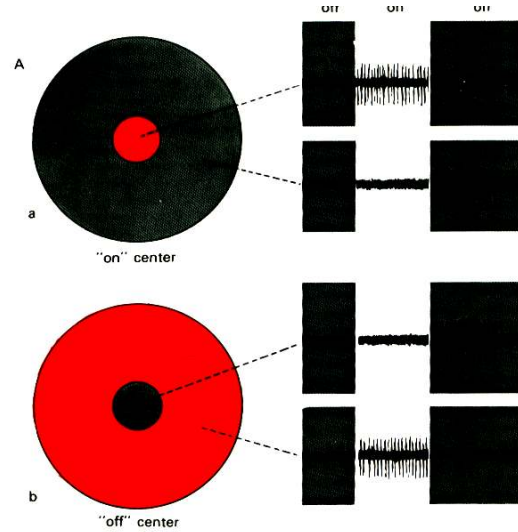
IMAGING AT RETINAL (A), LATERAL GENICULATE BODY (B) AND PRIMARY VISUAL CORTX (C) LEVELS

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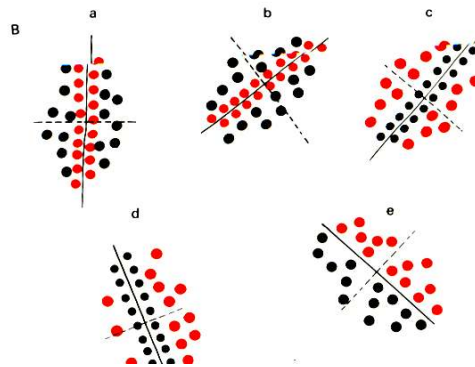
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RETINA
CGL



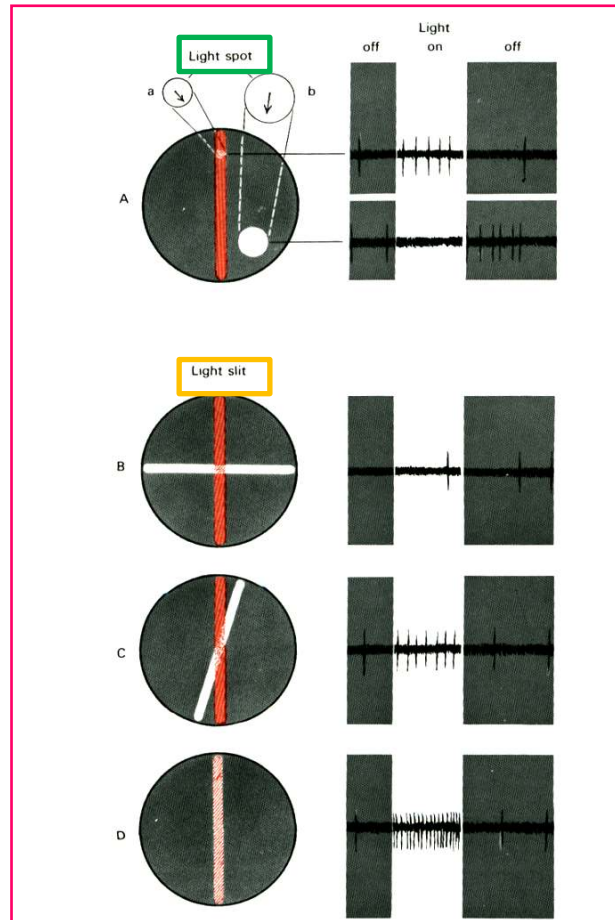
RECEPTIVE
FIELDS

V1
Simple cells



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FUNCTIONAL CHARACTERISTICS OF SIMPLE CELLS IN V1



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Organization of ocular dominance and orientation columns

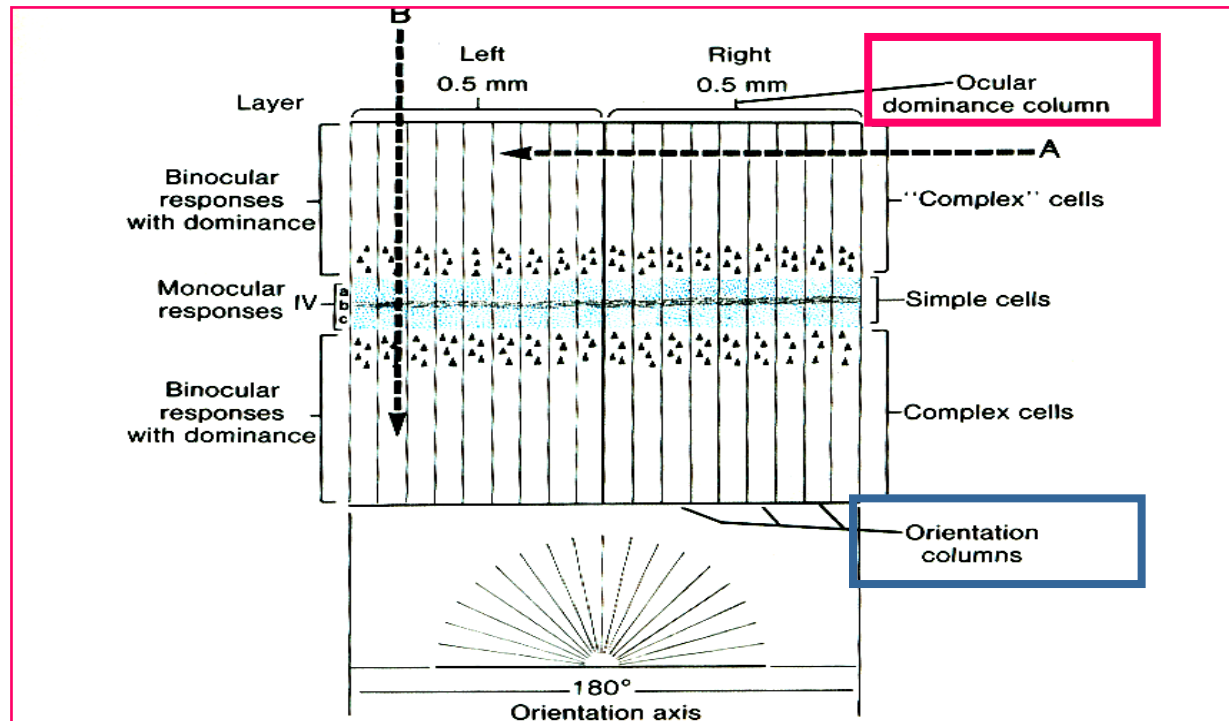
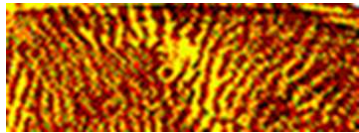
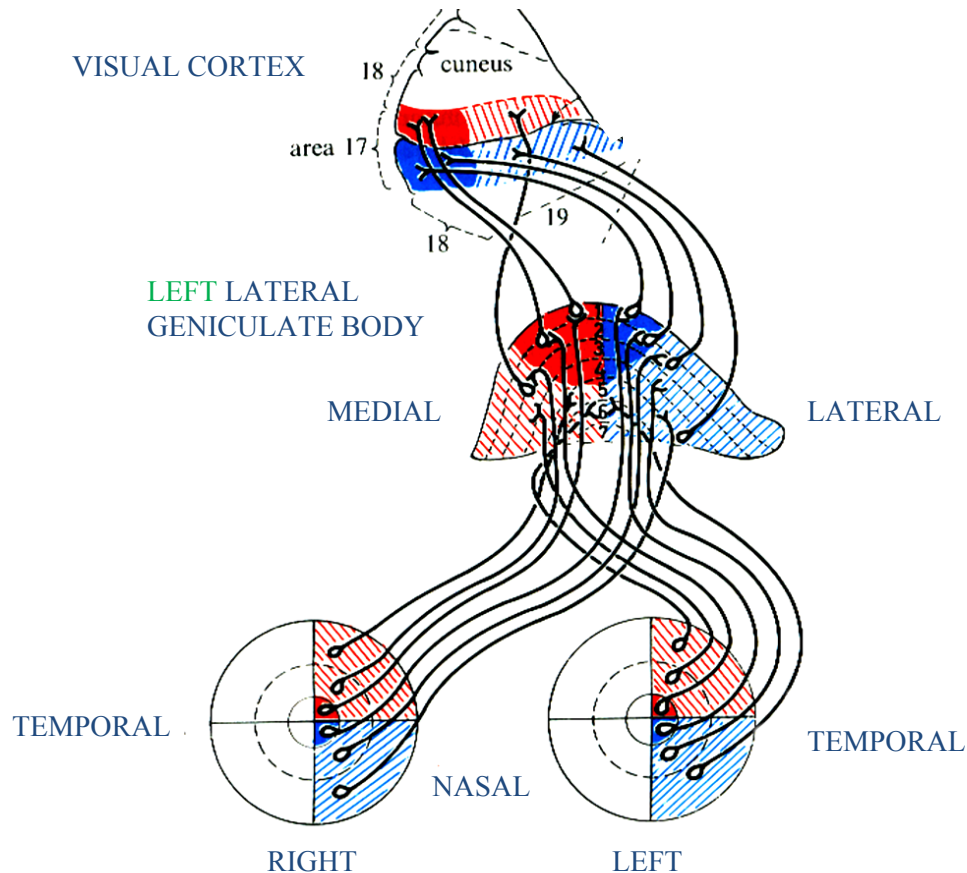


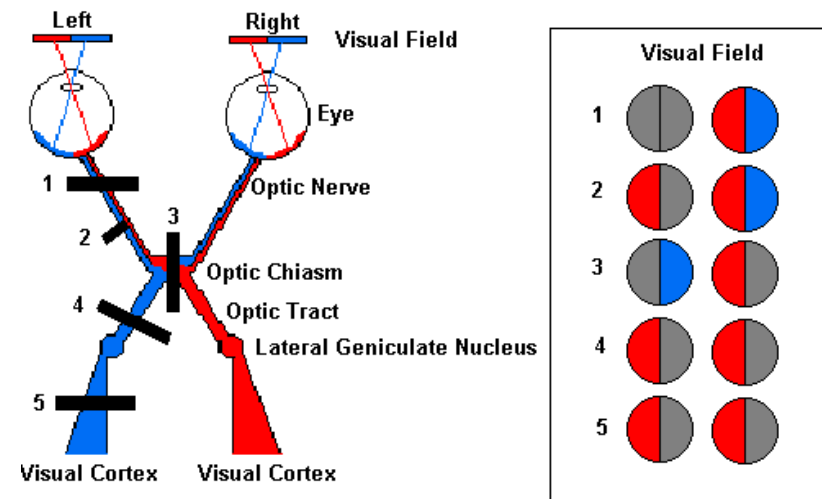
Figure 13-12. Schematic representation of the organization of ocular dominance and orientation columns in the striate cortex. Ocular dominance columns (0.25 to 0.5 mm) are an order of magnitude larger than orientation columns and a pair of left-right ocular dominance columns (0.5 to 1 mm) are roughly equal to a set of orientation columns representing a complete cycle of orientations through 180°. Input from the lateral geniculate to layer IV is strictly monocular and consists of a series of parallel and alternating stripes—one for the left eye and one for the right eye. Most of the cells in layer IV (blue) are "simple" cells. Binocularly influenced cells are predominantly "complex" cells in layers above and below layer IV. A recording electrode inserted tangential to the pial surface, as in arrow A, will detect responses to successive stimuli with different orientations, first with right eye dominance and then with left eye dominance. A recording electrode inserted vertically, as in B, will indicate responses only to stimuli presented in one axis of orientation. About 50% of the cell above and below layer IV (blue) will respond to binocular stimuli, but with consistent left ocular dominance. When the electrode is in layer IV, monocular responses will be recorded (based on Hubel and Wiesel, '74; Hubel et al., '77).

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REPRESENTATION OF THE RETINA IN LATERAL GENICULATE NUCLEUS AND VISUAL CORTEX

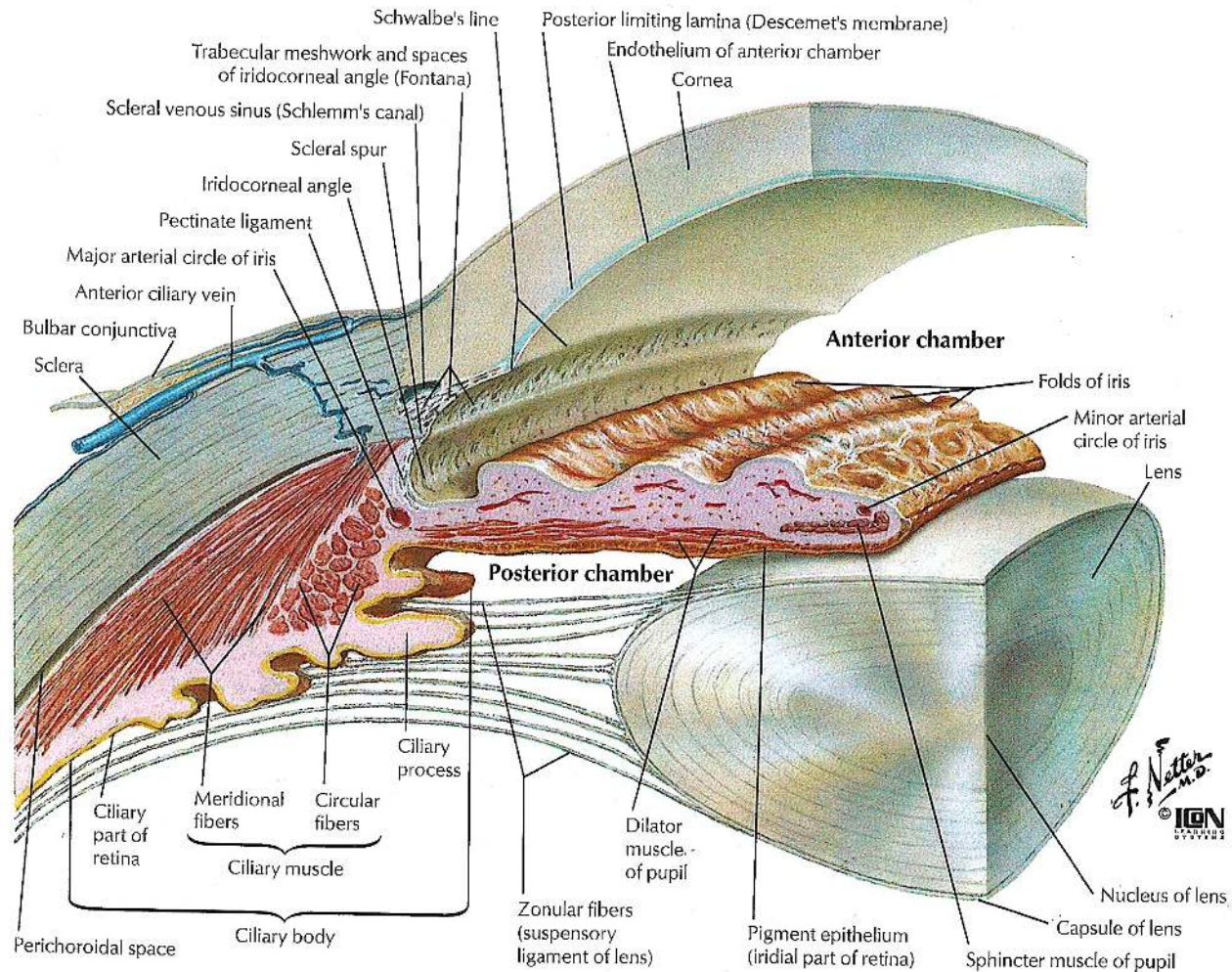


LOSS OF VISUAL FIELD DUE TO DAMAGE OF THE VISUAL STRUCTURES



1. BLINDNESS OF LEFT EYE
3. BITEMPORAL HETERONYM HEMIANOPSIA
4. HOMONYM HEMIANOPSIA

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Note: For clarity, only single plane of zonular fibers shown; actually, fibers surround entire circumference of lens

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