Visual apparatus
Visual pathway
Cortical visual fields

Institute of Anatomy

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Brain regions

cortex
basal ganglia
thalamus
hypothalamus
epithalamus - pineal gland
pretectum
metathalamus

cerebral cortex
basal ganglia
thalamus
hypothalamus
epithalamus - pineal gland
pretectum
metathalamus

Telencephalon

Prosencephalon (forebrain)

Diencephalon

Mesencephalon (midbrain)

Metencephalon

Rhombencephalon (hindbrain)

Myelencephalon

Spinal cord
Obr. 157. Postup diferenciacie neurální trubice v jednotlivé oddíly CNS v průběhu 3.–6. týdne embryonálního vývoje člověka
33 & 48 h chick embryo

- Prosencephalon
- Mesencephalon
- Rhombencephalon
- Optic vesicle
- Infundibulum
- Head fold
- Heart
- Vitelline vein
- AIP
- Spinal cord
- Somites
- Segmental plate mesoderm
- Primitive streak
- Area vasculosa
- Area pellucida
- Eye
- Cranial flexure of 5 part brain
- Heart tube twisted upon itself
- Anterior intestinal portal
- Lateral body folds
- Tail bud
- Tail fold
The development of the eye

- optic stalk
- lens placode
- lens pit
- surface ectoderm
- early stage of optic cup

- Lumen of optic stalk
- Optic fissure
- Hyaloid artery & hyaloid vein in optic fissure

- Retinal Rudiment from Inner layer of optic cup
- Pigment layer rudiment from optic cup

- sinus
- venousus sclerae
- iris
- cornea
- suspensory ligament
- central artery of the retina
- hyaloid canal
- ciliary body
The image shows a histological section of an eye. The labeled structures are:

- **Corneal epithelium**
- **Retina**
- **Pigmented epithelium**
- **Lens**
- **Optic nerve**
Lens development

http://www.dogstuff.info/lens_development_kral.html
1. Tunica fibrosa sclera; cornea
2. Tunica vasculosa choroidea; corpus ciliare; iris
3. Tunica interna pars optica retinae pars ciliaris et iridica retinae

Vitreous humour, lens, chambers, extraocular muscles, eyelids, lacrimal apparatus
The Fibrous Tunic

• Most **EXTERNAL layer** of the eyeball
  • Composed of two regions of connective tissue
    • **Sclera** – posterior five-sixths of the tunic
      • White, opaque region
      • Provides shape and an anchor for 6 eye muscles
    • **Cornea** – anterior one-sixth of the fibrous tunic
  • **Limbus** – junction between sclera and cornea (stem cells)
  • Scleral venous sinus – allows aqueous humor to drain (**Glaucoma! High eyeball pressure**)
The Vascular Tunic

- The **MIDDLE layer** of the eyeball
- Composed of **choroid, ciliary body, and iris**
- **1. Choroid** – vascular, darkly pigmented membrane
  - Forms posterior five-sixths of the vascular tunic
  - Brown color – from melanocytes
  - Prevents scattering of light rays within the eye
- Choroid corresponds to the arachnoid and pia materas (therefore sclera corresponds to …)
Eyelid development

Eyelids fused by 9 weeks of development.
Week 20 – opening begins.

1., 2., 3. N – rods and cones, bipolar cells, ganglion cells (+ horizontal and amacrine).

4. N – corpus geniculatum laterale, tr. geniculo-corticalis (radiatio optica) to area 17

5. N – cell in area 17 ($V_1$)
The Sensory Tunic - RETINA

- the **DEEPEST** layer
- Composed of two layers
  - Pigmented layer – single layer of melanocytes
  - Neural layer – sheet of nervous tissue
    - Contains three main types of neurons
      - Photoreceptor cells
      - Bipolar cells
      - Ganglion cells
RETINA - Photoreceptors

- **Rod cells** – more sensitive to light
  - vision in dim light
  - 120 million/eye
- **Cone cells** – operate best in bright light
  - high-acuity color vision
  - 7 million/eye
Normal Ophthalmoscopic View of Eye
Macula lutea

a. + v. centralis retinae

- nerve fiber layer
- ganglion cell layer
- inner plexiform layer
- inner nuclear layer
- outer plexiform layer
- outer nuclear layer
- receptor layer
- pigmented epithelium
- choroid
- sclera
- blood vessel
- ganglion cell
- bipolar cell
- photoreceptor cell
RETINA – macula lutea

- **Macula lutea** – very few blood vessels, contains *mostly* cones
- Its center - **fovea centralis** – contains only cones
  - Region of highest visual acuity
- **Optic disc** – blind spot, where optic nerve leaves.
BLIND SPOT
400-700nm
Defect of one or more types of cones - COLOURBLINDNESS

Trichromatic theory - the comparison begins in the retina ((optic nerve has only 1 million axons)), where signals from “red” and “green” cones are compared by specialized red-green cells “opponent-process theory”.
- compute the balance between red and green light coming from a particular part of the visual field

Cones – colour vision
“red” or “L” cones long wavelength light
“green” or “M” medium wavelength light
“blue” or “S” cones short wavelength light
• *Lateral inhibition* is the reduction of activity in one neuron by activity in neighboring neurons.
• responsible for heightening contrast in vision
The Photoreceptors: PHOTOTRANSDUCTION

- Rods and cones contain photopigments—chemicals that release energy when struck by light.

  Photopigments consist of 11-cis-retinal (derivative of Vitamin A) which is bound to opsin (a protein).

  Light converts 11-cis-retinal to all-trans-retinal, which ultimately activates 2\textsuperscript{nd} messenger systems that work to close Na\textsuperscript{+} channels, hyperpolarizing the receptor.

  More light = hyperpolarization.
The Photoreceptors: PHOTOTRANSDUCTION

Photoreceptors input to retinal bipolar cells, which input to retinal ganglion cells.

Photoreceptors and bipolar cells do not produce action potentials. They produce graded potentials.

Retinal ganglion cells produce action potentials.
The Photoreceptors:

PHOTOTRANSDUCTION

At rest, (i.e. in the dark) photoreceptors continuously release neurotransmitter (glutamate).

Glutamate hyperpolarizes some bipolar cells, and depolarizes other bipolar cells.

Some bipolar cells provide hyperpolarizing input to ganglion cells, and some bipolar cells provide depolarizing input.
Processing in the Retinal Ganglion Cell

Each ganglion cell ONLY responds to the presence or absence of light in its receptive field.

Receptive field is the area of visual space to which a given cell responds. Ganglion cell receptive fields are circular.

Ganglion cell receptive fields have a concentric antagonistic surround.

_on-center_ cells → mostly excited by light falling on the center of the receptive field

_off-center_ cell → mostly excited by light in the surround.
Geometric illusions

Müller-Lyer Illusion

ARROW JUNCTIONS

FORK JUNCTIONS
Visual Pathways to the Cerebral Cortex

- Light activates **photoreceptors**
- Photoreceptors signal **bipolar cells**
- Bipolar cells signal **ganglion cells**
- Axons of ganglion cells exit eye as the **optic nerve**
- Optic nerve **decussates at chiasma**
- **Optic tract** goes to **lateral geniculate nucleus** of the thalamus (but some fibers to midbrain for pupillary reflex, position and movements of the eye – unconscious)
- **Optic radiation** reaches the primary visual cortex (conscious seeing)
The primary visual cortex (area V1) receives information from the lateral geniculate nucleus and is the area responsible for the first stage of visual processing.

Some people with damage to V1 show blindsight, an ability to respond to visual stimuli that they report not seeing.
Visual fields

1 – amaurosis

2 – nasal hemianopia (a.carotis interna)

3 – bitemporal hemianopia (hypophysis)

4 – homonymous hemianopia

Cortex - quadrantanopia (ischaemia in a.cerebri post.), cortical blindness, optical agnosia, dysmorphopsia, fosfens, hallucinations
Corpus geniculatum lateral

http://radiopaedia.org/articles/corpora-quadreigemina
4. N, section of corpus geniculatum laterale

Crossed fibers to 1., 4., 6.
Uncrossed fibres to 2., 3., 5.
Lateral Geniculate Nucleus

• (LGN) in the thalamus is the **major target** of the retinal ganglion cells.

• It receives inputs from both eyes and **relays** these messages to the primary visual cortex via the optic radiation.

• Topographically organised.
Analysis of vision **shape, colours, movement and position in space**. Occipital, temporal and parietal lobes. Ca. 20 retinotopical maps.

**System of magnocellular tracts** for analysis of movement in space, rough shape and contrast. Not colour sensitive.

**System of parvocellular tracts** specializes on detection of details and exact shape and colours.
MST – V5, movement of objects, stereovision (binocular + monocular – decreasing size, loss of detail) … movement of eyes

V1(Br17) – primary visual cortex, simple, retinotopic, perception of object orientation and movement
MST – V5, movement of objects, stereovision (binocular + monocular – decreasing size, loss of detail) … movement of eyes

V2 - orientation, spatial frequency, and colour

V4 – colour perception
Central Projections of the Retina

The retina projects to *four subcortical regions in the brain:*
1) Lateral Geniculate nucleus
2) Superior Colliculus
3) Hypothalamus
4) Pretectum
Branches of the visual pathway (all start from the 3.N.)

~ To hypothalamus: optical input to vegetative system (circadian, season cycle)

~ Pupillary reflexes:

Miosis: via area pretectalis (AP=pretectum) to n. III (EW) - ganglion ciliare - nn. ciliares breves - m. ciliaris et m. sphincter pupillae (accommodation = same, but from AP via ncl. interstitialis Cajali)

Mydriasis: via AP to reticular formation: tractus reticulospinalis - centrum ciliospinale C8-Th1 - ganglion cervicale superius - plexus caroticus internus et ophtalmicus - nn. ciliares breves - m. dilatator pupillae

Convergence: via AP to ncl. Cajali - FLM - nuclei of extraocular muscles nerves

~ Tectal visual circuit — tr. tectospin., - nuclearis, - interstitialis, crbl (coordination of the movements of the eye, head, neck (body) towards a visual stimulus)

~ To pulvinar Th: coordination of visual and sensory inputs
Pupillary reflex

Obr. 104.: Schema drah pupillárního reflexu.

AP – area pretectalis,
E-W – Edinger-Westphalovo jádro (III.),
flm – fasc. longitudinalis medialis,
H – hypothalamus,
IC – ncl. interstitialis Cajalı,
ob – ncl. opticus basalis,
RF – retikulární formace,
roh – radix optica hypothalamica,
rom – radix optica mesencephalica,
TH – thalamus.

Petrovický et al.: Anatomie, IX
Centrální nervový systém, Karolinum, Praha, 1995
Odbočky ze zrakové dráhy

Dráhy pupilárního reflexu, dráhy pro akomodaci a konvergenci

nn. ciliares breves

* akomodace

gangl. cervicale superius

C8 – Th1

Ncl Cajali → fasc.longit.med., konvergence
Corneal reflex

Nasociliary branch of the ophthalmic branch (V1) of the 5th cranial nerve (trigeminal nerve) sensing the stimulus on the cornea, lid, or conjunctiva

7th cranial nerve (Facial nerve) initiating the motor response (i.e. it is the efferent)

Onion and contact lenses
Pupillary light reflex + accommodation reflex

And accommodation
The Vascular Tunic - IRIS

• Visible colored part of the eye
• Attached to the ciliary body
• Composed of smooth muscle
• Pupil – the round, central opening
  • Sphincter pupillae muscle (constrictor or circular)
    PARASYMPATHETIC
  • Dilator pupillae muscle (dilator or radial)
    SYMPATHETIC (atropin – atropa bella-donna – mandragora)
Pupillary dilation and constriction
The Eye as an Optical Device

- Structures in the eye (lens, cornea, and humors) bend light rays
- Light rays converge on the retina at a single focal point
- Accommodation – curvature of the lens is adjustable - for focusing on nearby objects (blur-driven)
oculocarpal reflex - the Extraocular muscles

Superior oblique muscle
Superior rectus muscle
Superior orbital fissure
Trochlear nerve
Lateral rectus muscle
Inferior rectus muscle
Inferior oblique muscle

3 cranial nerves...
smooth pursuit - track image
saccadic - not apparent; move image to different receptors
Vestibulo-ocular reflex - the Extraocular muscles
Extraocular muscles

Strabismus
Senile macular degeneration

http://www.medrounds.org

http://www.lowvisionclub.com
Glaucoma

http://137.222.110.150/calnet/Visual1/image/glaucoma-opthalmoscopic%20photo.jpg

http://www.lowvisionclub.com
Retinal amotion

Eyelid and conjunctiva

Lacrimal apparatus

Sjögrenův syndrom

http://www.dgrh.de

http://edoc.hu-berlin.de