Unit 22 · Sense Organs

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Human Biology (Units 17–24 together): 16 of 75 marks; 4 MCQs (knowledge, understanding, application, higher ability), 1 short question (4 marks: knowledge 1, application 2, higher ability 1) and 1 long question (8 marks: understanding 2, application 2, higher ability 4)
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **Our model papers:** Paper 1 MCQ (past 45, holds the newspaper far: lens lost elasticity, presbyopia); Paper 2's short OR question (Dawa's defect, why distant things blur and the lens for it; his grandmother's defect, not the same); Paper 3's short question (the ossicles in order; ears blocked on a descent, swallowing clears them; still turning after the ride stops)
- **MCQ (1 mark)**
  - eye: photoreceptor; simple, binocular, stereoscopic
  - nictitating membrane vestigial; six extraocular muscles
  - iris controls the pupil; cones: iodopsin; retina sensory
  - cornea → pupil → lens → retina; night blindness: rods
  - myopia without glasses: image in front of the retina
  - Eustachian tube: middle ear–pharynx; malleus → incus → stapes in the tympanic cavity
  - cristae: balance; cochlea, organ of Corti (scala media) hearing
  - helicotrema joins the scalae; ear: hearing and balance
- **Short and long (in parts)**
  - main structures of the eye
  - label the eye from the front and in section, with functions
  - defects of the eye
  - external, middle, internal ear; membranous labyrinth
  - working of the ear, illustrated; label the ear, functions
  - eye, structure and function with diagrams (long); ear (long)

Key terms

Receptor: cell or nerve ending turning one kind of stimulus into an electrical change → impulses.

Sense organ: receptors plus tissues that protect them and bring the stimulus.

Exteroceptors: stimuli from outside; **teloreceptors**: from far (sight, hearing, smell).

Interoceptors: from inside (gut, vessels, bladder); **proprioceptors**: the body's own position (muscles, joints, inner ear).

Special senses: receptors in a head organ; **general senses**: scattered (touch, pain, temperature).

Stato-acoustic organ: the ear, for balance and hearing.

Accommodation: focusing near or far by changing the lens's curvature.

Near point ~25 cm (adult); **far point**: infinity.

Dark adaptation: rods rebuilding rhodopsin in the dark, ~30 min.

Static equilibrium: head's position to gravity (maculae); **dynamic**: turning (cristae).

Receptor	Responds to	Where
photoreceptor	light	rods, cones (eye)
phonoreceptor	sound	cochlea's hair cells
statoreceptor	gravity, tilt, movement	vestibule, semicircular canals
chemoreceptor	chemicals (olfacto-, gustato-)	nose, tongue
thigmoreceptor	touch, pressure	skin
thermoreceptor	heat, cold	skin

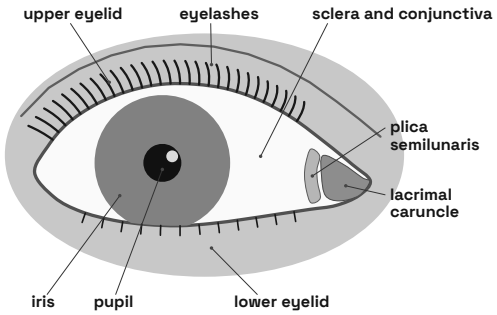
The eye

- **~2.5 cm**, **~7.5 g**, ~6.5 mL; in the **orbit**, cushioned in fat
- vision: **simple** (one lens) · **binocular** · **stereoscopic** (eyes 6–7 cm apart → depth) · **trichromatic** · acute (fovea)
- three groups of parts: accessory structures · wall (3 coats) · contents

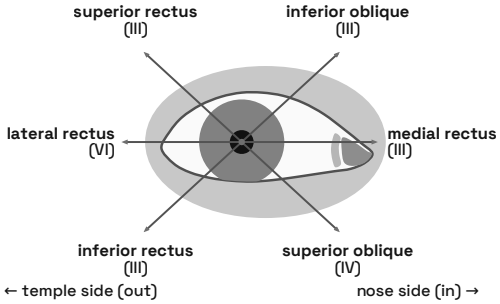
Accessory structures

- **eyebrows**: turn sweat, dust away

- **eyelids** (palpebrae): blink 15–20/min, moisten, protect; **plica semilunaris** = vestigial **nictitating membrane**
- **eyelashes**: keep out dust, insects
- **conjunctiva**: transparent mucous membrane lining the lids, over the white to the cornea's edge; **conjunctivitis** ("eye flu")
- **adipose tissue**: cushion
- **extraocular muscles** (6): superior, inferior, **medial**, **lateral rectus**; **superior oblique** (through the **trochlea**), **inferior oblique**; + levator palpebrae superioris (lid)
- nerves: **III** (superior, inferior, medial rectus, inferior oblique, levator) · **IV** (superior oblique) · **VI** (lateral rectus): **LR_6 SO_4, the rest 3**
- **optic nerve** (II), sensory, from **its own eye**; at the **optic chiasma** the **nose-side** fibers cross → left field seen by the right brain
- glands: **lacrimal** (tears, **lysozyme**; drain to the nose) · **Meibomian** (tarsal; oil on the tear film) · **Zeis** (eyelash roots; **stye**) · **Moll** (modified sweat)

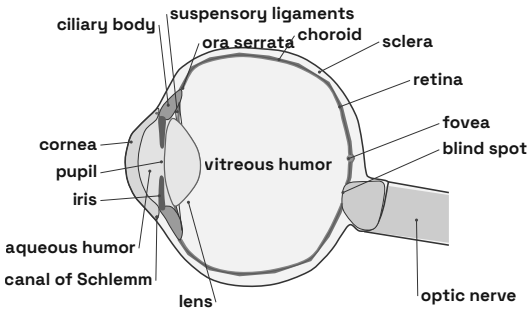


A right eye from the front.



The six extraocular muscles of the right eye.

Wall of the eyeball: three tunics; retina and lens from **ectoderm**



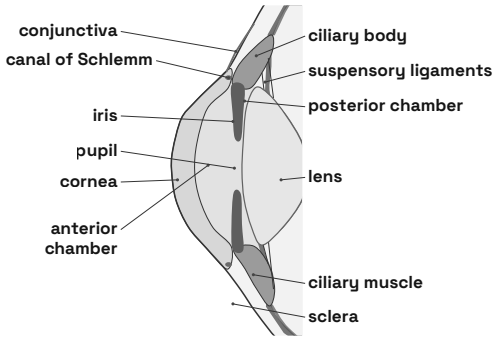
The eyeball cut from front to back.

Fibrous tunic (outer)

- **sclera**: white, ~⅚; dense **collagen**; protects, keeps shape; muscles attached
- **cornea**: front ~⅙; transparent, bulges; **~⅔ of the focusing**; **avascular** (O_2 from air, food from aqueous) → donor corneas rarely rejected (Tilganga eye bank)
- **canal of Schlemm** at the limbus: aqueous drains to veins

Vascular tunic (uvea; middle)

- **choroid**: dark, **pigment absorbs** stray light; vessels feed the retina's outer layers
- **ciliary body**: **ciliary processes** (**secrete aqueous**) + **ciliary muscle** (smooth; circular, meridional)
- **suspensory ligaments** (zonules) + capsule hold the lens
- **iris**: **melanin** (brown); **pupil**; **sphincter pupillae** (circular, **narrows**; parasympathetic, CN III) · **dilator pupillae** (radial, **widens**; sympathetic); pupil 2–8 mm
- iris splits the aqueous space: **anterior chamber** (cornea–iris), **posterior chamber** (iris–lens)

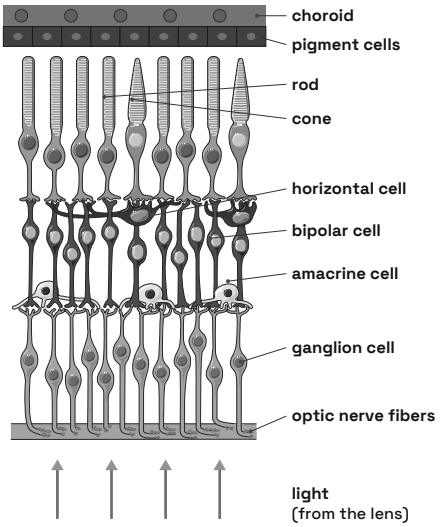


The front of the eye.

Nervous tunic: the retina (a sheet of brain)

- **macula lutea** (yellow spot) with the **fovea centralis**: **only cones**, sharpest vision
- **blind spot** (optic disc): optic nerve leaves; **no rods or cones**
- **ora serrata**: wavy front edge
- light passes all the nerve layers to reach rods and cones (outermost); signal back: **rod/cone** → **bipolar** → **ganglion** → **optic nerve**; horizontal, amacrine cells sideways

	Layer (outside in)	What is in it
A	**pigment cell layer**	dark pigment, next to the choroid
B	**rods and cones layer**	their light-sensitive outer parts
C	**external limiting membrane**	boundary
D	**external nuclear layer**	rods' and cones' cell bodies
E	**external plexiform layer**	rods, cones synapse with bipolar, horizontal cells
F	**internal nuclear layer**	bipolar, horizontal, amacrine cells
G	**internal plexiform layer**	bipolar synapse with ganglion, amacrine cells
H	**ganglion cell layer**	ganglion cell bodies
I	**optic nerve fiber layer**	ganglion axons
J	**internal limiting membrane**	boundary with the vitreous



The cells of the retina, light from below.

	Rods	Cones
number per eye	**90–120 million**	**5–6 million**
where	all but the fovea; edges	packed in the **fovea**
pigment	**rhodopsin** (visual purple)	**iodopsin** (3 photopsins)
light	**dim**: night	**bright**: day
color	no	**yes**
detail	coarse (many rods per ganglion cell)	fine (1 : 1 in fovea)

- **rhodopsin = opsin + retinal** (from **vitamin A**); light bleaches it → signal; rebuilding takes time → **dark adaptation**; lack of vitamin A → **night blindness**
- cones: **red** (~564 nm), **green** (~534), **blue** (~420): erythrolabe, chlorolabe, cyanolabe; brain compares → **trichromatic** vision

Contents

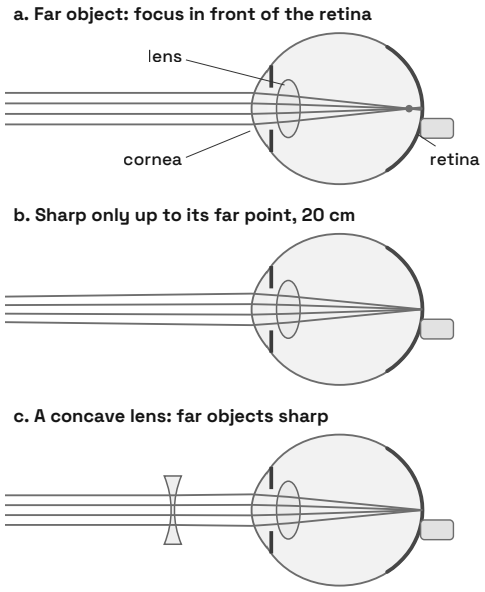
- **lens**: transparent, **biconvex**, **elastic**; ~9 mm × 4 mm, back more curved; **lens fibers** (crystallins, no nuclei); cuboidal epithelium in front; **capsule**; no vessels; **fine-tunes focus**
- **aqueous humor**: watery; **made by ciliary processes** → posterior chamber → pupil → anterior chamber → **canal of Schlemm**; feeds cornea, lens; **intraocular pressure**; can't drain → **glaucoma**
- **vitreous humor**: jelly, ⅘ of the volume; keeps shape, holds retina on choroid; formed before birth, **not replaced**; clumps → **floaters**

How the eye sees

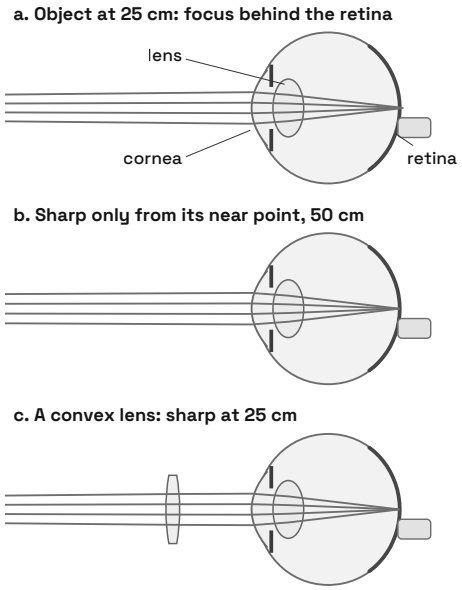
1. light **bent at the cornea** → aqueous → pupil → **lens** → vitreous → **retina**: small, **real, inverted** image
2. **iris** sets the light let in (narrow pupil also sharpens)
3. **accommodation**:
   - **far**: **ciliary muscle relaxes** → ring widens → **ligaments tight** → lens **thin, flat**
   - **near**: **ciliary muscle contracts** → ring narrows → **ligaments slack** → lens **thick, round**
4. pigment bleached → **potential difference** → bipolar → **ganglion cells fire** → optic nerve → chiasma → **visual cortex** (**occipital lobe**): shape, color, movement, depth; image set upright

Defects of the eye

Defect	Sees	Cause	Corrected by
myopia (short-sight)	near clear, **far blurred**	eyeball **too long** or too curved; focus **in front of** retina	**concave** lens
hypermetropia (long-sight)	far clear, **near blurred**	eyeball **too short**; focus **behind** retina	**convex** lens
astigmatism	blurred at **all distances**	cornea curved more one way	**cylindrical** lens
presbyopia (age 40–45+)	near blurred	lens **loses elasticity**; near point recedes	**convex**; bifocal (upper concave, lower convex) if also myopic

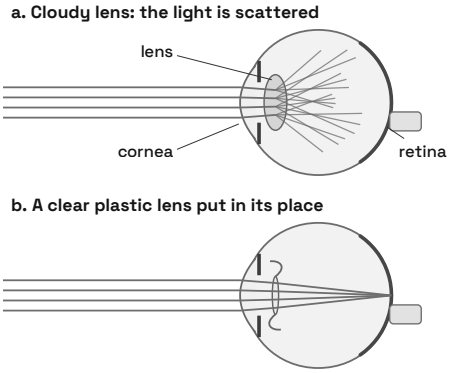


Myopia and its correction.



Hypermetropia and its correction.

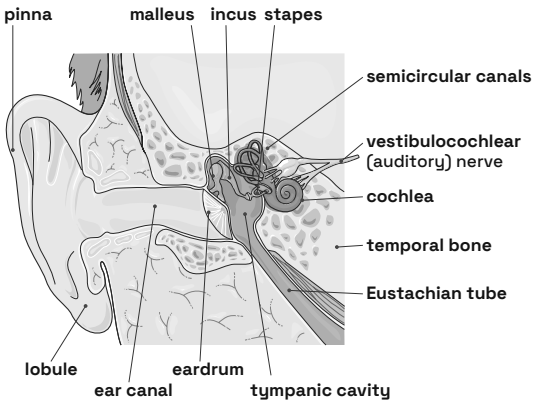
- myopia starts in school years; time outdoors in daylight seems to protect
- **cataract**: **cloudy lens**; age, UV, smoking, diabetes, injury; **surgery**, **intraocular lens**; **first cause of blindness in Nepal** (65% in people 50+, 2018–21)
- **macular degeneration**: central vision lost
- **floaters**: shadows of clumps in the vitreous; a sudden shower with flashes: retina tearing
- **corneal opacity**: scars, ulcer, vitamin A lack; **second cause** in Nepal; corneal transplant
- **glaucoma**: **raised intraocular pressure** damages the **optic nerve**; sides of view first; **permanent**; drops, surgery; **third cause** in Nepal
- **diabetic retinopathy**: retina's vessels damaged by high blood sugar; yearly checks
- **retinal detachment**: retina peels off the choroid; flashes, floaters, dark curtain; urgent surgery
- **dry eye**: too few tears or fast evaporation; screens; artificial tears
- **diplopia**: double vision; eyes not aligned (squint, muscle, nerve); alcohol
- **color blindness**: mostly **red–green**; gene on the **X** → men (1 in 12) ≫ women (1 in 200)
- **amblyopia** (lazy eye): brain didn't learn to use one eye; patch the good eye early (before ~8)



A cloudy lens and the intraocular lens that replaces it.

The ear

- **stato-acoustic**; **statoreceptors** + **phonoreceptors**; exteroceptor, teloreceptor, special sense; balance part also proprioceptor
- in the **temporal bone** (auditory capsule); **CN VIII** (vestibulocochlear), sensory: **cochlear** (hearing) + **vestibular** (balance)



The ear cut through.

External ear

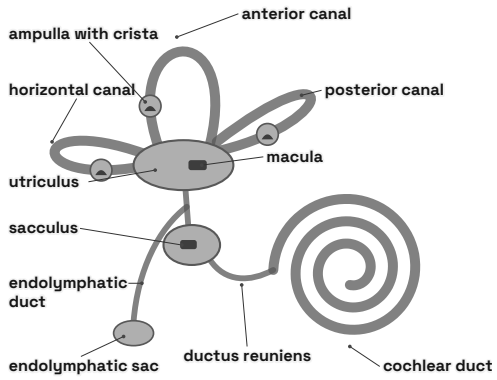
- **pinna** (auricle): **elastic cartilage**; **helix**; **lobule** (no cartilage); collects sound, helps tell direction; muscles **vestigial**
- **external auditory meatus**: **~2.5 cm**, S-shaped; cartilage outer third, bone inside; hairs + **ceruminous glands** (**cerumen**, earwax) trap dust, germs
- **tympanum** (eardrum): thin, semi-transparent, ~1 cm; **umbo**; separates external and middle ear
- no impulse made here; eardrum vibrates at the sound's frequency
- leave earwax alone: buds push it deeper, can tear the drum

Middle ear (in the temporal bone)

- **tympanic cavity**: pea-sized, **air**
- ossicles: **malleus** (hammer; largest; handle on the eardrum) → **incus** (anvil) → **stapes** (stirrup; **smallest bone**, ~3 mm; footplate in the **oval window**)
- muscles (acoustic reflex): **tensor tympani** (malleus) · **stapedius** (stapes; **smallest skeletal muscle**); **tensor veli palatini** is at the throat, opens the Eustachian tube
- **Eustachian tube**: 3.5–4 cm to the **nasopharynx**; opens on swallowing, yawning → **equal air pressure** on the eardrum
- **fenestra ovalis** (oval window): **stapes footplate** → vibrations into the fluid
- **fenestra rotunda** (round window): **secondary tympanic membrane** bulges, lets fluid move
- **pressure gain ~20 ×**: eardrum **~17 ×** the footplate's area × ossicle lever **1.3** (air → fluid, else 99.9% reflected)
- plane descending (Lukla): outside pressure rises, middle-ear air lower → drum pushed in, ears blocked; swallowing opens the tube, air in, pressure equal

Internal ear (labyrinth, in the petrous bone)

- **bony labyrinth**: channels in bone; **perilymph** (like CSF, Na^+-rich)
- **membranous labyrinth** inside it: **endolymph** (K^+-rich); the real stato-acoustic organ: **vestibule**, **semicircular canals**, **cochlea**



The membranous labyrinth, as a plan.

Vestibule

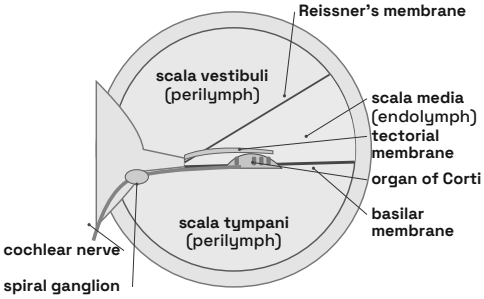
- **utriculus** (larger, upper; **all three canals open into it**) + **sacculus** (smaller, lower; joined to the cochlea)
- **utriculosaccular duct** → **ductus endolymphaticus** → **saccus endolymphaticus** (absorbs endolymph)
- each sac a **macula**: **hair cells** (stereocilia + a **kinocilium**) in a gel with **otoliths** ($CaCO_3$); tilt or straight movement → otoliths lag → hairs bend → vestibular nerve
- utricle's macula flat (tilt, horizontal); saccule's upright (up and down)

Semicircular canals

- three, at **right angles**: **anterior** vertical, **posterior** vertical, **horizontal**
- both ends open into the **utriculus**; one end an **ampulla** with a **crista ampullaris**; hairs in a jelly **cupula**, **no otoliths**
- head **turns** → endolymph lags → cupula pushed → hairs bend; senses **rotation**, its start and stop
- after a spinning ride stops, endolymph keeps moving → feels still turning

Cochlea

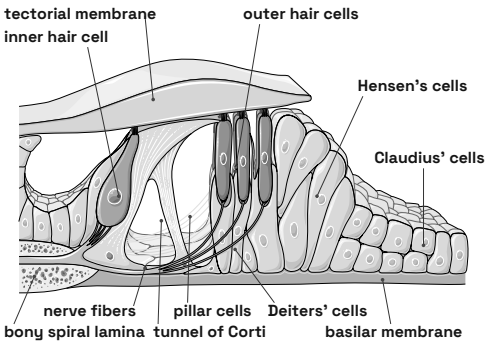
- **2¾ turns**, snail shell; ~3.5 cm uncoiled; **cochlear duct** joined to the sacculus by the **ductus reuniens**
- **scala vestibuli** (upper; perilymph; from the **oval window**; floor **Reissner's membrane**)
- **scala tympani** (lower; perilymph; to the **round window**; roof **basilar membrane**)
- join at the tip by the **helicotrema**
- **scala media** (cochlear duct; **endolymph**): **organ of Corti** on the basilar membrane



One turn of the cochlea cut across.

Organ of Corti (spiral organ)

- **inner hair cells**: 1 row, ~3,500 (send the signals heard)
- **outer hair cells**: 3 rows, ~12,000 (amplify)
- **pillar cells** (rods of Corti) arch over the **tunnel of Corti**; **Deiters'** (phalangeal), **Hensen's**, **Claudius'** cells
- **tectorial membrane** over the hair cells
- fibers → **cochlear nerve**



The organ of Corti.

Balance and hearing

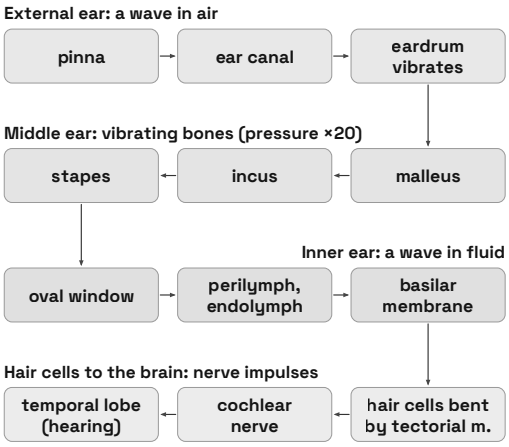
Mechanism of equilibrium (vestibular apparatus)

1. tilt, start or stop → otoliths slide, endolymph lags → maculae's gel, cristae's cupula move
2. **hair cells** bend → signal more or less

3. **vestibular nerve** → **vestibular nuclei** (medulla, pons) and **cerebellum**
4. compared with eyes, muscles, joints → orders to neck, body, limb and eye muscles: position corrected, gaze steady

Mechanism of hearing (**~20 Hz–20 kHz**, top falls with age)

1. **pinna** collects → canal → **eardrum** vibrates
2. **malleus** → **incus** → **stapes**: ~20 × pressure
3. stapes rocks in the **oval window** → waves in **scala vestibuli** perilymph
4. through **Reissner's membrane** to the endolymph → **basilar membrane** vibrates; **round window** bulges
5. hair cells move against the **tectorial membrane** → hairs bent → channels open → **impulses**
6. **cochlear nerve** → **auditory area**, **temporal lobe**



A sound's path: air, bone, fluid, nerve.

- **pitch by place** (von **Békésy**, Nobel 1961): base **narrow, stiff** → **high** notes; tip **wide, floppy** → **low** notes; loudness = how many cells fire, how fast
- loud sound kills hair cells (no regrowth), high-pitch ones first; earphones below ~60%

COMMON MISTAKES

✗ The left optic nerve supplies the right eye
✓ each optic nerve comes from **its own eye**; only the nose-side half of its fibers cross at the chiasma.

✗ The lens does most of the focusing
✓ the **cornea** does ~⅔; the lens fine-tunes.

✗ For near vision the ciliary muscle relaxes
✓ it **contracts**; ligaments slacken, lens rounds.

✗ Myopia is corrected by a convex lens
✓ **concave**; hypermetropia and presbyopia by **convex**.

✗ Presbyopia is a too-short eyeball
✓ the lens **loses elasticity** with age.

✗ Cones hold rhodopsin
✓ **rods**: rhodopsin; **cones**: iodopsin (red, green, blue).

✗ The blind spot is the fovea
✓ the fovea is the sharpest point; the **blind spot** is where the optic nerve leaves.

✗ The oval window is closed by the secondary tympanic membrane
✓ by the **stapes footplate**; the **round** window has the membrane.

✗ The round window equalizes air pressure
✓ the **Eustachian tube** does.

✗ The semicircular canals arise from the sacculus
✓ from the **utriculus**; the cochlea joins the sacculus.

✗ Cristae have otoliths
✓ **maculae** have otoliths (tilt); cristae a cupula (rotation).

✗ High notes are heard at the cochlea's tip
✓ at the **base**; low notes at the tip.