Chapter 14 – The Human Eye

Subject content

Content
- Receptors – Eye

Learning outcomes
(a) describe the structure of the eye as seen in front view and in horizontal section
(b) state the principal functions of component parts of the eye in producing a focused image of near and distant objects on the retina
(c) describe the pupil reflex in response to bright and dim light

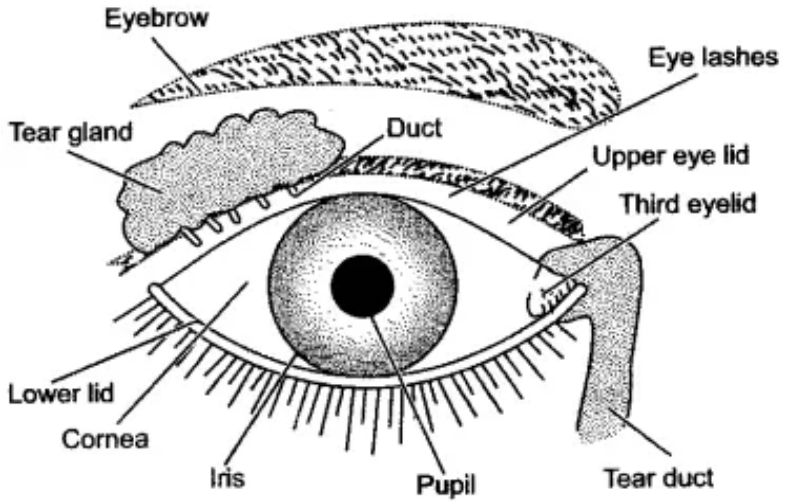
Use the knowledge gained in this section in new situations or to solve related problems.

Definition

Phrase	Definition
Focusing / accommodation	Adjustment of lens of the eye → clear images of objects at different distances are formed on retina

14.1 Sense Organs

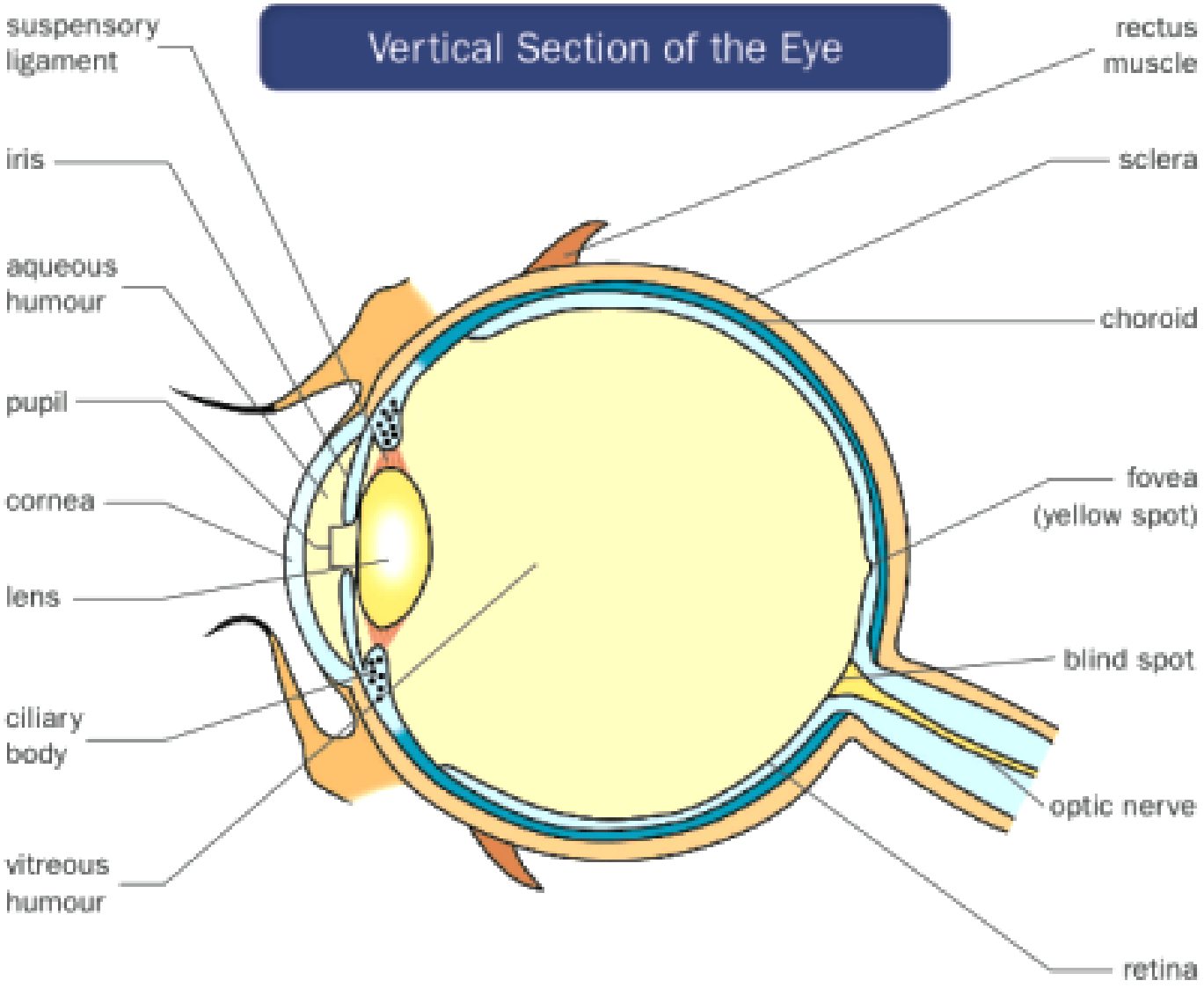
The human eye



Structure	Description	Function
1. **pupil**	hole in centre of iris	allow light to enter eye
2. **iris**	● circular sheet of muscles ● contain pigment → colour	control amount of light entering eye 1) **circular muscles** 2) **radial muscles**
3. **sclera**	● tough, white covering ● continuous with cornea	protect eyeball from mechanical damage
4. **conjunctiva**	● thin transparent membrane ● continuous with skin of eyelids	**mucous membrane**: secrete mucus → keep front of eyeball moist

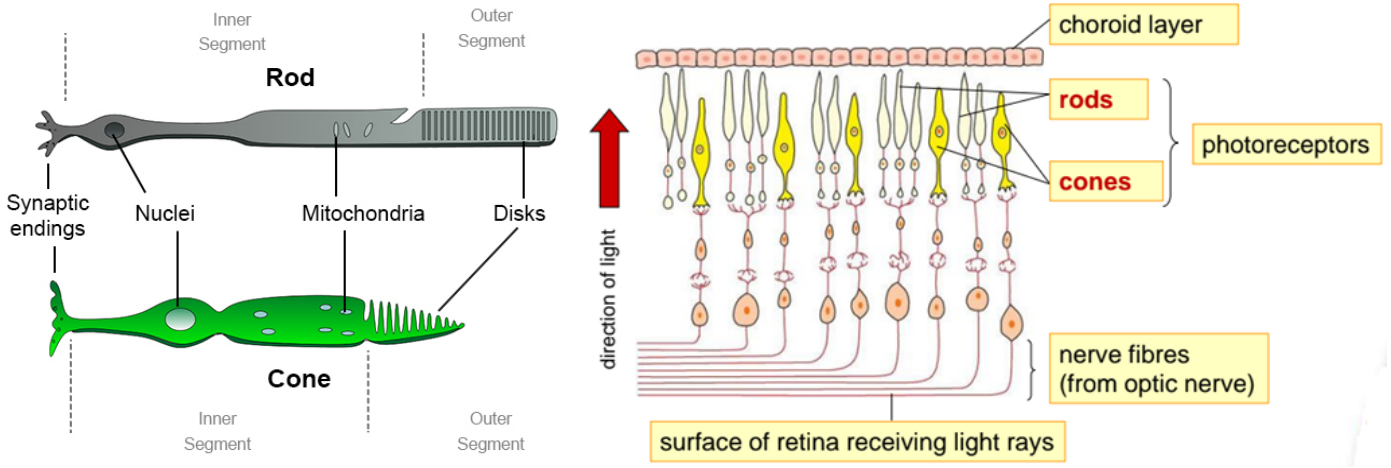
5. **eyelid**	consist of 1) upper eyelid 2) lower eyelid	● protect cornea from mechanical damage ● **squinting** (partially closed) ○ prevent excessive light from entering eye and damaging retina ● **blinking** ○ spread tears over cornea & conjunctiva ○ wipe dust particles off cornea
6. **eyelash**		shield eye from dust particles
7. **tear gland**	corner of upper eyelid	secrete **tears** ● wash away dust particles ● keep cornea moist for atmospheric oxygen to dissolve → diffuse into cornea ● lubricate conjunctiva → reduce friction when eyelids move

Internal structure of eye



Structure	Description	Function
1. **rectus muscle**	muscles attached to skull	
2. **sclera**	thick fibrous coat	
3. **choroid**	dark layer, rich in blood capillaries	1) pigmented black → prevent internal reflection of light 2) blood capillaries (a) transport oxygen + nutrients → eyeball (b) remove metabolic waste products
4. **retina**	contains photoreceptors (light sensitive cells) 1) **rods** → black and white (dim) 2) **cones** → colours (bright)	light-sensitive layer where images are formed
5. **yellow spot** (**fovea**)	directly behind lens, where images are normally focused	detailed colour vision (bright) ● greatest concentration of cones ● no rods
6. **blind spot**	region where optic nerve leaves eye	not sensitive to light ● no cones ● no rods
7. **optic nerve**	bundle of nerves that connect eye → brain	photoreceptors in retina stimulated + transmit nerve impulses → brain
8. **cornea**	transparent layer continuous with sclera	refract light rays into eye (most)
9. **lens**	elastic, crystalline structure	refract light rays into eye (change shape / thickness to focus light onto retina)
10. **iris**	coloured, muscular disc	
11. **pupil**	hole in centre of iris	
12. **ciliary body**		**ciliary muscles**: control **curvature** of lens
13. **suspensory ligaments**	connective tissue	attach edge of lens to ciliary body
14. **aqueous chamber**	filled with aqueous humour	1) keep front of eyeball firm 2) refract light into pupil
15. **vitreous chamber**	filled with vitreous humour	1) keep eyeball firm 2) refract light onto retina

Photoreceptors in retina

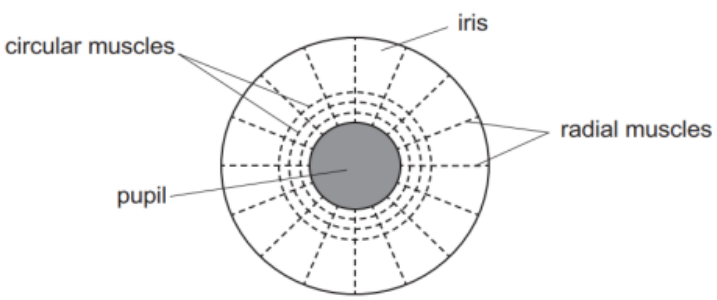


Types	Function	Features
1. **cone**	colours (bright light)	• 3 types 1) **red** 2) **blue** 3) **green** • contain different pigment → absorb light of different wavelengths • work together → see a wide variety of colours (bright) • do not work well in dim light
2. **rod**	black & white (dim light)	• **more sensitive** to light than cones • **visual purple**: sensitive to light in low intensity ○ exposed to bright light: ■ all bleached ■ nerve impulses cannot be transmitted → brain ○ bright → dim: cannot see objects (take time for visual purple to be re-formed in rods) ○ formation: requires vitamin A ■ lack vitamin A → night-blindness • densely located at the outer sides → <u>peripheral vision</u>

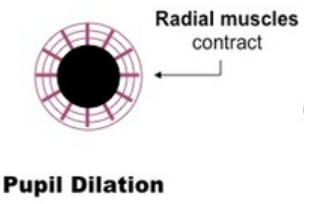
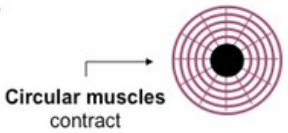
Control of amount of light entering eye

Size of pupil

- determine amount of light entering eye
- controlled by 2 sets of involuntary muscles in iris (antagonistic)
  1. **circular muscles**: arranged in a circle around pupil
  2. **radial muscles**: arranged radially

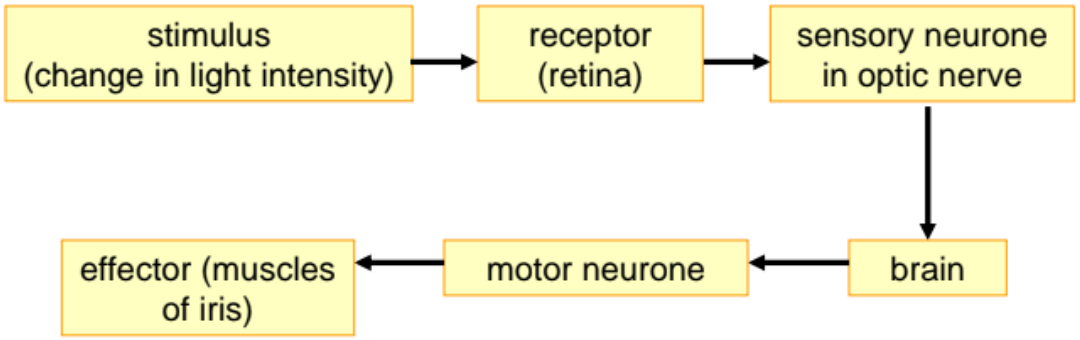


Pupil reflex:

Light intensity	high	low
Circular muscles	contract (shorten)	relax (lengthen)
Radial muscles	relax	contract
Pupil	constrict	dilate
Amount of light entering eye	decrease	increase
Figure	 Pupil Dilation	 Pupil Contraction

Pupil reflex (reflex action)

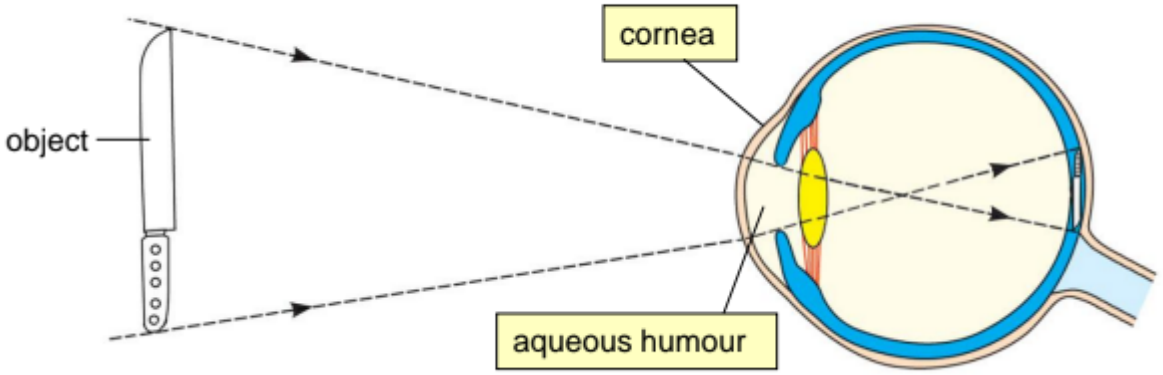
- stimulus: changes (increase / decrease) in light intensity
- protect eye from excessive light exposure → damage retina



Answering technique:

Stimulus	Change in light intensity	increase	decrease
Receptor	Photoreceptors in retina	detect stimulus, stimulated, generate nerve impulses	
SN	Pathway of nerve impulse transmission	Nerve impulses transmitted to brain via SN in optic nerve	
CNS + RN		Within brain, nerve impulses transmitted across 2 synapses from SN → RN → MN	
MN		Nerve impulses transmitted from brain to circular + radial muscles of iris along MN	
Effector	Circular muscles in iris	contract	relax
	Radial muscles in iris	relax	contract
Effect	Size of pupil	constricted	dilated

14.2 Vision



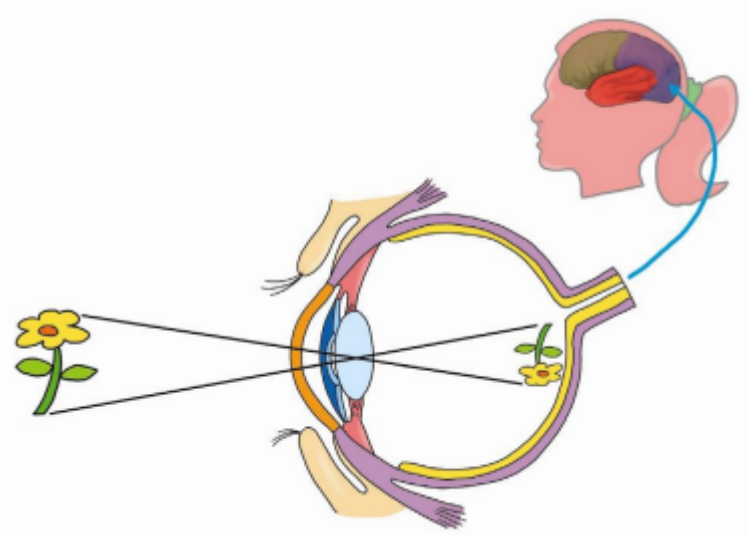
Formation of image on retina

1. light rays refracted through cornea → aqueous humour → lens → vitreous humour
2. light rays focus on retina → form image
    1) upside down (inverted)
    2) laterally inverted
    3) diminished
3. image on retina stimulates cones / rods (depend on light intensity) → generate nerve impulses
4. nerve impulses transmitted via optic nerve → brain
5. brain interprets nerve impulses → see object right way up, front to back, right size

Nature of image formed:

1. **Vertically inverted**
2. **Laterally inverted**
3. **Diminished**

Role of brain in vision

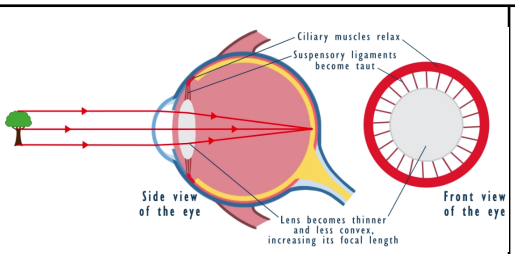
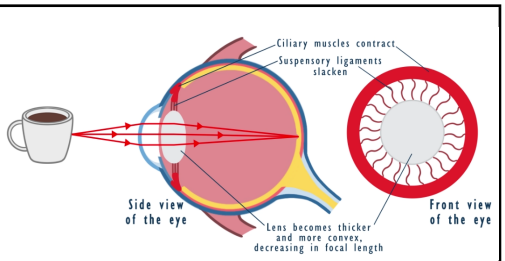


1. Inverted image formed on retina
2. Photoreceptors (rods & cones) are stimulated
3. Nerve impulses generated → transmitted through optic nerve
4. Nerve impulses reach optic centre of brain
5. Brain interprets information → form upright image
    - Brain has corrective function
    - Image **upside down** within retina → brain makes it **upright**

Focusing → adjust **curvature & thickness** of lens to allow light rays to be focused on retina

Focusing:

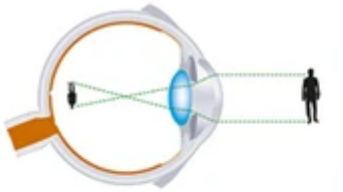
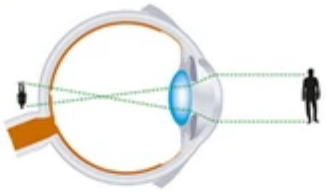
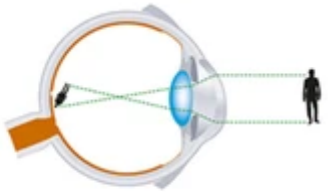
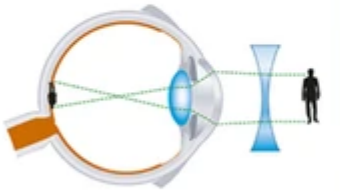
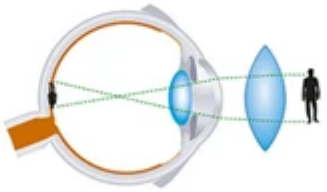
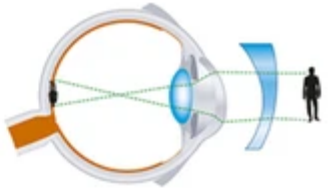
Object	distant	near
ciliary muscles	relax	contract
pull on suspensory ligaments	tightened	relaxed
suspensory ligaments	become taut	slacken
pull on edge of lens	tightened	relaxed
lens	thinner less convex	thicker more convex
focal length	increase	decrease
light rays from object	sharply focused on retina	
photoreceptors	stimulated, generate nerve impulses	
nerve impulses	transmitted along optic nerve → brain	
brain	interpret nerve impulses	
human vision	sees object	

Figure		

Vision conditions

Conditions:

1. **myopia** (shortsightedness)
2. **hyperopia** (longsightedness)
3. **astigmatism**

Condition	**myopia**	**hyperopia**	**astigmatism**
Figure			
Reason	• eye too long • cornea more curved than usual	• eye too short • cornea less curved than usual	• abnormal curve of the cornea
Outcome	focal point of image falls in front of retina	focal point of image falls behind retina	two different images overlap or combine
Treatment			

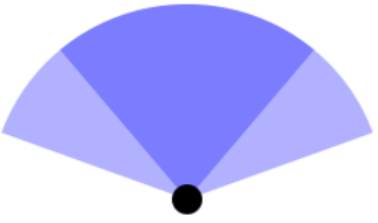
Common treatment methods:

- spectacles
- contact lenses
- surgery (laser-assisted in situ keratomileusis / LASIK)

Stereoscopic vision

Stereoscopic field: region where images from both eyes overlap

- see objects in 3D
- better judgement of distance of object



Typical questions

Multiple choice questions

1 The diagrams show two sections through the eye of the same person.

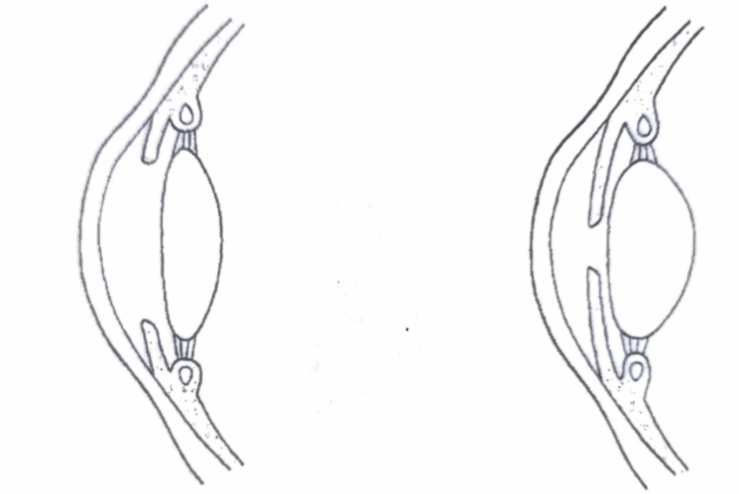


diagram 1
focusing on an object
sixty metres away
in dim light

diagram 2
focusing on an object
one metre away
in bright light

What happens to achieve the changes from the eye in diagram 1 to the eye in diagram 2 under the different conditions? (N2013/P1/Q26)

	ciliary muscles	iris radial muscles	iris circular muscles
A	contract	contract	relax
B	contract	relax	contract
C	relax	contract	relax
D	relax	relax	contract

2 When the eye adapts to view a distant object, what are the receptors and effectors? (N2014/P1/Q25)

	receptors	effectors
A	ciliary muscles	iris muscles
B	iris muscles	retinal cells
C	retinal cells	ciliary muscles
D	retinal cells	iris muscles

3 An eye detects an object flying towards it. Receptors send the information to the brain which causes the muscles in the eyelids to close the eyelids.
Which row is correct for this response? (N2018/P1/Q24)

	location of receptor	neurone to brain	neurone from brain
A	lens	motor	sensory
B	lens	sensoy	motor
C	retina	motor	sensory
D	retina	sensory	motor

4 On a bright, sunny day a man watches a friend walk away from him.
Which row describes the state of component parts of his eye as he keeps his friend in focus? (N2019/P1/Q25)

	ciliary muscle	radial muscle
A	contracting	contracted
B	contracting	relaxed
C	relaxing	contracted
D	relaxing	relaxed

Structured questions

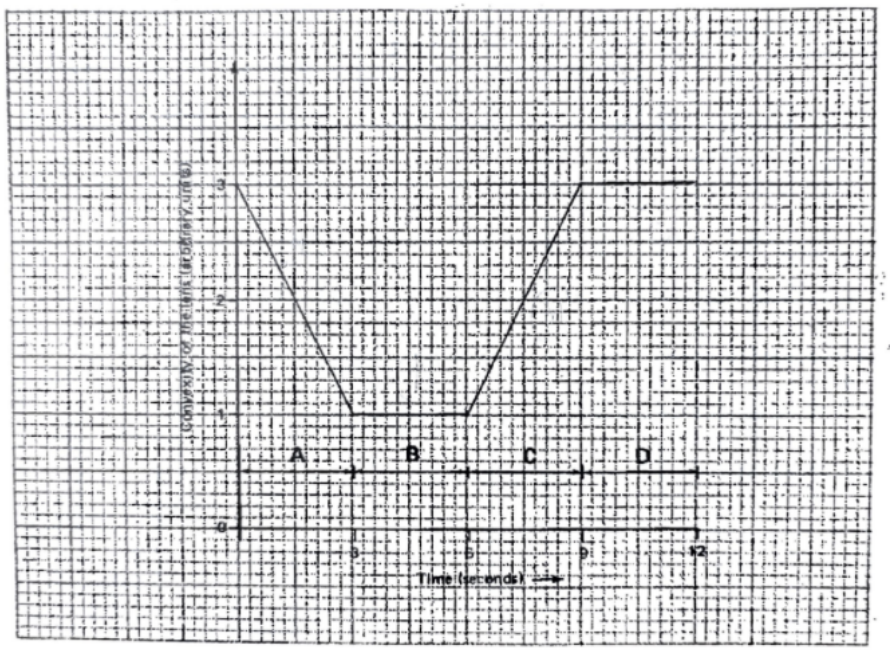
1 Identifying the stimulus, describe the pathway of nerve impulses in a reflex arc that will result in a constriction of the iris. [7]

Answering technique:

1. stimulus	When there is an increase in light intensity,
2. receptor	this increase is detected by photoreceptors in the retina. The photoreceptors in the retina are stimulated and generate nerve impulses.
3. SN	The nerve impulses are transmitted to the brain via sensory neurones in the optic nerve.
4. CNS + relay	Within the brain, nerve impulses are transmitted across two synapses from sensory neurone to relay neurone to motor neurone.
5. MN	Nerve impulses are transmitted from the brain to circular and radial muscles of iris along motor neurones.
6. effector	Circular muscles of the iris contract and radial muscles of the iris relax.
7. effect	This causes the pupil to be constricted.

2 The figure shows the change in the convexity of the lens of a boy who watched four different objects at four periods of time within 12 seconds:

M: a boy walking towards him
N: a cat running away from him
O: a book on the desk 20 cm from his eyes
P: a clock hanging on the wall



(a) Using the letters (**M**, **N**, **O** and **P**), indicate on the diagram which objects are watched by the body during periods **A**, **B**, **C** and **D**. [2]

(b) Give reasons to explain your answer. [4]

M: lens continue to thicken until a maximum

N: lens continue to be less and less convex until a minimum

O: stationary near object - lens is very convex, does not change in convexity

P: stationary distant object - lens is least convex

(c) Name two structures of the eyeball that bring about the change in the lens convexity during period A. [2]

Ciliary muscles, suspensory ligaments

(d) What changes occur in the above two structures when the eyes are in period C? [2]

- In period C, the object is approaching the boy.
- Ciliary muscles contract to relax their pull on the suspensory ligaments. Suspensory ligaments slacken to relax their pull on the edges of the lens.
- This causes the elastic lens to become more and more convex until it reaches its maximum convexity.

3 The lens of the eye is naturally transparent. Cataracts are a gradual, painless clouding of this clear lens.
Suggest how cataracts may affect vision. [3]
(N2006/A/Q1)

- The clouding on the lens reduces the amount of light passing through the lens and falling on the retina.
- This impairs the person's ability to focus light onto the retina.
- thus resulting in a blurred vision.

4 A person is sitting in the shade reading a book when he looks at the bright sky to see an aeroplane flying past. Explain the changes in: (N2005/2/Q6)

(a) the lens [6]

Answering technique:

1. action	The accommodation reflex action will be initiated
2. stimulus	when there is an increase in distance of objects to focus on.
3. receptor	Light from the object is no longer focused on the retina. The photoreceptors in the retina are stimulated and generate nerve impulses.
4. SN	(optional) Nerve impulses transmitted via reflex arc to ciliary muscles.
5. CNS + relay	
6. MN	
7. effector	Ciliary muscles relax + tighten their pull on suspensory ligaments. Suspensory ligaments become taut, tightening their pull on the edge of the lens.
8. effect	The elastic lens becomes thinner and less convex, increasing focal length and thus focusing light rays from objects on the retina.

(b) the pupil [4]

Answering technique:

1. action	The pupil reflex will be initiated
2. stimulus	when there is an increase in light intensity.
3. receptor	This increase is detected by photoreceptors in the retina, which are stimulated and generate nerve impulses.
4. SN	(optional) Nerve impulses transmitted via reflex arc to circular and radial muscles of the iris.
5. CNS + relay	
6. MN	
7. effector	Circular muscles of the iris contract, radial muscles of the iris relax.
8. effect	This causes the pupil to be constricted.

5 (N2015/P2/B10 OR)

(a) Describe and explain how the pupil of the eye responds to an increase in light intensity. [4]

When there is an increase in light intensity, the pupil of the eye carries out the pupil reflex. The reflex arc for the pupil reflex is retina (receptor) → sensory neurone in optic nerve → relay neurone in brain → motor neurone → iris (effector).

During this reflex action, the pupil changes size according to the changes in light intensity. When light intensity increases, too much light enters the eye through the pupil and stimulates the photoreceptors in the retina. Nerve impulses are produced and travel along the sensory neurone in the optic nerve to the relay neurone in the brain. The nerve impulses then travel along the motor neurone to the muscles of the iris. The circular muscles of the iris contract while the radial muscles of the iris relax to make the pupil smaller. Thus, the pupil constricts and less light enters the eye.

(b) Describe how a focused image is produced on the retina of the eye. [6]

The cornea and lens of the eye refract light rays and focus them on the retina to form a clear image. The curvature of the lens is controlled by the action of ciliary muscles. The changes in curvature alter the focal length of the lens and enable objects at varying distances to be seen clearly. For example, the light rays that reflect from a distant object reach the eye as almost parallel rays. The cornea and aqueous humour refract the light rays.

Fine focusing is then carried out by the lens to form a sharp image on the retina. The ciliary muscles relax and tighten the suspensory ligaments. The lens becomes thinner and less convex to refract the rays reflected by the object so that the rays can converge and focus sharply on the yellow spot.

The photoreceptors in the retina are stimulated and the electrical impulses produced are conducted by the optic nerve to the brain to be converted to visual images.

Thus, the eye is able to see the distant object clearly.

6 In an experiment, a person was kept in complete darkness for 30 minutes.
After that time the sensitivity of the person's retina to different wavelengths of light was measured.
The table below shows the results of the experiment.

wavelength of light / nm	420	440	460	480	500	520	540	560	580	600
sensitivity of retina / arbitrary units	5	15	35	65	100	65	40	25	15	5

During the investigation, the diameter of the pupils of the eyes decreased.
Describe how the decrease in the diameter of the pupils was brought about. [3]
(N2018/P2/B8)

At first, the person was kept in complete darkness for 30 minutes, thus his eyes were accustomed to seeing in the dark and the pupils of his eyes were large so that more light could enter his eyes. However, when light of different wavelengths was shone on his eyes, too much light entered his eyes through the pupils and stimulated the photoreceptors in the retina. Nerve impulses were produced and travelled along the sensory neurone in the optic nerve to the relay neurone in the brain. The nerve impulses then travelled along the motor neurone to the muscles of the iris. The circular muscles of the iris contracted while the radial muscles of the iris related to make the pupil smaller. This decreased the diameter of the pupils and reduced the amount of light entering the eyes.