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Multiple Choice Questions in Ophthalmic and Neurophysiology

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Preface

This book of MCQs was written as a sister text to O. J. Lehmann's *Multiple Choice Questions in Ophthalmic and Neuroanatomy*. I hope the two books together will give candidates for the part one FCOphth a greater understanding of the range and standard required, and ultimately a better chance of passing.

I have tried hard to eliminate errors and ambiguity in the questions and am grateful to Victor Chong and Tariq Amin for their helpful comments and suggestions, to Mr Condon for making my first 6 months in ophthalmology so enjoyable, and finally to my friends and parents for their encouragement and support, my father in particular for typing out the first ten questions.

R. H. Caesar

Abbreviations

The following abbreviations are used in the text:

III	Oculomotor nerve
V	Trigeminal nerve
VII	Facial nerve
VIII	Vestibulocochlear nerve
ACh	Acetylcholinesterase
ATP	Adenosine triphosphate
GABA	Gamma-aminobutyric acid
GAG	Glycosaminoglycan
GMP	Guanosine monophosphate
GDP	Guanosine diphosphate
GTP	Guanosine triphosphate
GSH	Reduced glutathione
5-HT	Serotonin
LGN	Lateral geniculate nucleus
MLF	Medial longitudinal fasciculus
NA	Noradrenaline
NADPH	Nicotinamide-adenine dinucleotide phosphate (reduced form)

The eyelids, lacrimal apparatus and cornea

1 The eyelids

- A Are not covered with fine lanugo hairs
- B Have three protective functions
- C Contain three rows of cilia
- D Contain medial and lateral tarsal plates
- E Contain both the glands of Zeis and the Meibomian glands

2 Regarding eyelid movement

- A Levator palpebrae superioris is innervated by VII
- B Levator palpebrae superioris has skeletal muscle fibres only
- C In blinking, the eyelid and globe move in opposite directions
- D A tactile blink reflex involves V and VII
- E The rate of blinking is independent of retinal stimulation

The eyelids, lacrimal apparatus and cornea: Answers

- 1 A False
B True
C False
D False
E True

The eyelids have an extremely thin epidermis, covered with fine lanugo hairs. Protection of the eye involves direct protection through closure, the glandular secretions, and the sweeping movement to remove dust and other particles. There are two rows of cilia, the sebaceous glands of Zeis at their base. The upper and lower tarsal plates attach to the medial and lateral palpebral ligaments. Approximately 30 Meibomian glands are arranged vertically in each tarsus, their ostia open posterior to the cilia.

- 2 A False
B False
C True
D True
E True

Levator palpebrae superioris has both smooth and skeletal muscle fibres. It is innervated by III, with sympathetic supply from the superior cervical ganglion. Reflex blinking can be tactile, optic, auditory or percussive. A tactile blink involves input via V and output via VII. The eyelid and orbit move in opposite directions when blinking. The average rate of blinking is approximately 15/min. It is independent of retinal stimulation.

The eyelids, lacrimal apparatus and cornea: Questions

3 The tear film

- A Has three layers
- B The middle layer is from the Meibomian glands
- C Is predominantly aqueous
- D Suffers evaporative loss of 25%
- E Becomes hypotonic with evaporation

4 The tears contain

- A A glucose level that correlates with plasma glucose
- B 60% Albumin
- C 15% Locally produced immunoglobulin
- D Less lysozyme in old age
- E A pH of 6.3–6.7

5 Tear secretion

- A Is always bilateral
- B Ranges from 0.5 to 1.25 g during the day
- C Can be measured using the Schirmer test
- D Is normally equal in both eyes
- E Has basic and reflex components

The eyelids, lacrimal apparatus and cornea: Answers

- 3 A True
B False
C True
D True
E False

The tear film has an outer oily layer from the Meibomian glands and glands of Zeis, an aqueous middle layer from the lacrimal gland and accessory glands of Krause and Wolfring, and an inner mucous layer from the goblet cells of the conjunctiva. The aqueous layer is the largest. 25% of tears are lost by evaporation, this increases the salt concentration and thus the tonicity of the tear film.

- 4 A True
B True
C True
D True
E False

The glucose content of tears mirrors that of the plasma. The protein in tears is 60% albumin, 25% lysozyme and beta lysin, 15% IgA and traces of other enzymes. IgA is locally produced. Lysozyme is decreased in Sjögren's syndrome, corticosteroid therapy and old age. The pH of tears is 7.3–7.7

- 5 A False
B True
C True
D True
E True

Tear secretion has basic and reflex components. The average basic range is 0.5–1.25 g over the day. Secretion is normally equal in both eyes with up to 27% difference, but is not always bilateral due to the reflex component. The Schirmer test is a common test of tear secretion.

The eyelids, lacrimal apparatus and cornea: Questions

6 Regarding tear secretion

- A The commonest cause of hypersecretion is psychogenic
- B Both hypothyroidism and hyperthyroidism can cause hypersecretion
- C Sarcoidosis can cause hyposecretion
- D Sensory input to the semilunar ganglion can cause hypersecretion
- E Hyposecretion is always equal in both eyes

7 Tear elimination

- A Is totally dependent on blinking
- B Blinking moves tears nasally
- C The nasolacrimal duct has an important role in active transport
- D The Jones test can be used to investigate outflow failure
- E Dacryocystography is used to investigate the lacrimal gland

8 The cornea

- A Has a refractive index of 1.336
- B Has a curvature that changes with age
- C Becomes thinner with age
- D Has a comparatively high temperature
- E Is the most powerful refracting surface in the eye

The eyelids, lacrimal apparatus and cornea: Answers

- 6 A False
B True
C True
D True
E False

The commonest cause of hypersecretion is corneal irritation. Stimuli pass via Va or Vb to the semilunar (Gasserian) ganglion, and then to the sensory nucleus V. Both hypothyroidism and hyperthyroidism are capable of causing hypersecretion. Hyposecretion has many causes including congenital, local inflammation and sarcoid. It need not affect both eyes.

- 7 A False
B True
C False
D True
E False

Tear elimination involves evaporation, the nasolacrimal system, and, in excess, overflow. Blinking moves the tears nasally towards the lacrimal puncta, canaliculi and sac. All outflow through the nasolacrimal duct is passive. Outflow failure can be investigated using the Jones test, fluorescein dye disappearance test, or with dacryocystography to see the lacrimal sac and nasolacrimal duct.

- 8 A False
B True
C False
D False
E True

The cornea has a refractive index of 1.376, providing 70% of the refractive power of the eye. The curvature changes with age, most commonly from spherical to astigmatic with the rule, and then back through spherical to astigmatic against the rule. Corneal thickness increases with age. The temperature is comparatively low as the cornea is avascular and exposed to constant evaporative heat loss.

The eyelids, lacrimal apparatus and cornea: Questions

9 Regarding the corneal stroma

- A It is composed of 75–80% water
- B Dehydration is actively maintained
- C It is high in enzymatic activity
- D It contains 10% glycosaminoglycans
- E Chondroitin is the most prevalent glycosaminoglycan

10 The corneal epithelium

- A Contains 90% water
- B Has low levels of Na^+/K^+ ATPase
- C Has high levels of metabolic enzymes
- D Contains enzymes of the pentose pathway
- E Can store glucose

11 In corneal metabolism

- A Oxygen enters the epithelium direct from the air
- B The pentose shunt generates 2 ATP
- C Metabolic energy is essential for transparency
- D Oxygen can reach the cornea from the aqueous
- E The pentose shunt generates NADPH

The eyelids, lacrimal apparatus and cornea: Answers

- 9 A True
B True
C False
D False
E False

The corneal stroma's dehydration of 75–80% water is actively maintained. Glycosaminoglycans (GAGs) make up 4.0–4.5% of the cornea and are essential for transparency. Keratan sulphate at 50% is the most prevalent GAG, with 25% chondroitin and 25% chondroitin sulphate. The stroma is low in enzymatic activity.

- 10 A False
B False
C True
D True
E True

The epithelium contains 70% water with the rest nucleic acids, lipids, and proteins. There are high enzyme levels for glycolysis, the Krebs cycle, the pentose shunt, and high levels of Na^+/K^+ ATPase. Glucose can be stored in the epithelium as a substrate for metabolism.

- 11 A False
B False
C True
D True
E True

Oxygen in the air must dissolve into the precorneal tear film before entering the epithelium. In the absence of oxygen and metabolism the cornea swells and loses its transparency. Oxygen can also enter the cornea through the endothelium via the aqueous. The pentose shunt generates no ATP but is essential for the production of NADPH.

The eyelids, lacrimal apparatus and cornea: Questions

12 Regarding corneal dehydration

- A Endothelial damage leads to greater corneal swelling than epithelial
- B The epithelium regenerates more rapidly than the endothelium
- C GAGs have marked osmotic potential
- D The maintenance of corneal dehydration requires the maintenance of intraocular pressure
- E The endothelium provides a barrier to influx of aqueous

13 Regarding corneal electrolyte composition

- A The sum of anions is greater than cations
- B Acidic GAGs may bind anions
- C The epithelium has a high Na^+ concentration
- D The stroma has a high K^+ concentration
- E The stroma and aqueous have comparable Cl^- concentrations

14 Which of the following statements are correct

- A The epithelium and endothelium are impermeable to water
- B Na^+ moves faster across the endothelium than the epithelium
- C The epithelium is a perfect semipermeable membrane
- D The epithelium has strong zonulae occludentes
- E The endothelium is rich in organelles

The eyelids, lacrimal apparatus and cornea: Answers

- 12 A True
B True
C True
D True
E True

Corneal dehydration needs an equilibrium between anatomical integrity, metabolism, evaporation, intraocular pressure and electrolyte and osmotic balance.

- 13 A False
B False
C False
D False
E True

The stroma has a raised Na^+ concentration, decreased K^+ concentration, with Cl^- comparable to aqueous (Na^+ 176, K^+ 2.1, Cl^- 108 mmol/l). In contrast the epithelium has a raised K^+ , and decreased Na^+ concentration. The sum of cations (Na^+ K^+) is greater than anions (Cl^-). Acidic GAGs may act as anions and bind Na^+ and K^+ .

- 14 A False
B True
C True
D False
E True

The epithelium is a perfect semipermeable membrane. Both the epithelium and endothelium are permeable to water, but the endothelium has half the resistance to water flow and is 100 times faster in moving Na^+ . The endothelium has strong zonulae occludentes and is rich in organelles.

The eyelids, lacrimal apparatus and cornea: Questions

15 The following will cause corneal swelling

- A Intraocular pressure increased to 30 mmHg
- B A hypotonic tear film
- C Topical application of glycerine to the cornea
- D Poor fitting contact lens
- E Damage to Descemet's membrane

16 Drug penetration of the cornea

- A Is more effective in low concentration
- B The epithelium is more permeable to polar drugs
- C Is decreased by high molecular weight
- D Can be increased by wetting agents
- E A weak acid would best cross the stroma in its ionized form

17 Corneal transparency

- A Requires a regular orientation of collagen lamellae
- B Requires the collagen fibrils to be closely packed
- C Is decreased if fibres separate by one wavelength
- D Raised intraocular pressure causes a reversible decrease in transparency
- E GAGs are essential for transparency

The eyelids, lacrimal apparatus and cornea: Answers

- 15 A False
B True
C False
D True
E True

The cornea will swell if the epithelium or endothelium are damaged, especially if Descemet's membrane is breached. It will swell if the intraocular pressure is increased above 50 mmHg, with a hypotonic tear film, if metabolism is inhibited, or if epithelial oxygen availability is limited, e.g. with a tight-fitting contact lens.

- 16 A False
B False
C True
D True
E True

The epithelium and endothelium are lipid barriers and are therefore most easily penetrated by non-polar lipid-soluble drugs. The more aqueous stroma is better penetrated by a polar, ionized drug. Corneal penetration is increased by using a wetting agent to decrease the surface tension, by high drug concentration, and by low molecular weight.

- 17 A False
B True
C True
D True
E True

The transparent stroma contains a lamellar arrangement of collagen in random orientation. The fibrils must remain closer than one wavelength to ensure elimination of scattered rays of light by mutual interference. The transparency, in common with hydration, requires anatomical integrity, metabolic function, GAGs, and normal intraocular pressure. The decreased transparency associated with increased intraocular pressure is reversible.

18 Which of the following statements are correct?

- A Corneal vascularization can be induced by a low partial pressure of oxygen
- B The normal cornea is never avascular
- C Corneal wounds heal by epithelial cell mitosis and inward slide
- D The corneal epithelium has a turnover rate of about 7 days
- E Corneal tissue prevents polymorphonuclear leucocyte migration in response to injury

19 Which of the following statements are true?

- A The cornea swells on cooling
- B In the epithelium two thirds of aerobic metabolism is via the pentose shunt
- C In the stroma all aerobic metabolism is via the Krebs cycle
- D The stroma swells from anterior to posterior
- E Anaerobic metabolism is predominant throughout the cornea

20 Regarding corneal sensation

- A The cornea is innervated by C fibres only
- B Stimuli can be localized on the cornea
- C The nasal half is more sensitive than the temporal half
- D C fibres provide an immediate pricking sensation
- E Sensitivity decreases with age

The eyelids, lacrimal apparatus and cornea: Answers

- 18 A True
B False
C True
D True
E False

The normal cornea is always avascular. Vascularization implies pathology of some form, and can be induced by decreased partial pressure of oxygen. The cornea responds to injury with oedema, epithelial cell mitosis and sliding, migration of polymorphonuclear leucocytes, and appearance of fibroblasts. Normal turnover is about 7 days.

- 19 A True
B True
C True
D True
E True
All true.

- 20 A False
B True
C False
D False
E True

The cornea is innervated with more than 1000 small C and A δ fibres. Innervation is maximal centrally and there is evidence that stimuli can be localized, the temporal half being more sensitive than the nasal half. A δ fibres provide immediate pricking sensation, followed by a burning sensation from C fibres. Sensitivity decreases with age and with contact lens use.

The lens and vitreous

1 The lens

- A Is avascular
- B Reaches full size at age 18
- C Absorbs UV light
- D Receives all its nutrition from the aqueous
- E Is commonly dislocated in homocysteinuria

2 Regarding the lens

- A The lens is 33% protein
- B The lens contains more protein than muscle
- C The proteins are 55% albumin
- D Alpha crystallin is the commonest crystallin
- E Gamma crystallin is the largest crystallin

3 The lens

- A Will swell if placed in a hypertonic solution
- B Has an osmolarity greater than aqueous
- C Has an electronegative potential
- D Contains a high level of Na^+
- E Contains a low level of K^+

The lens and vitreous: Answers

- 1 A True
B False
C True
D False
E True

The crystalline lens is avascular and continues growing throughout life. It functions to maintain its clarity, absorb UV light, and provide refractive power and accommodation. Its nutrition is from the aqueous and vitreous. It is attached to the ciliary body by cysteine-containing zonules. In homocysteinuria, the zonules are poorly formed and the lens may dislocate.

- 2 A True
B True
C False
D False
E False

The dehydrated lens, with 33% protein, contains more protein than muscle. The proteins are 85% soluble crystallins, with beta crystallin the commonest at 55%. Alpha crystallin is the largest at one million daltons.

- 3 A False
B False
C True
D False
E False

The lens has the same osmolarity as aqueous and will swell if placed in a hypotonic solution. It has an electronegative potential of -64 to -78 mV. The lens Na^+/K^+ ATPase pumps Na^+ out and K^+ in.

4 Regarding lens proteins

- A Lens proteins are normally immunologically isolated
- B Exposure leads to type II sensitivity
- C Antigenic membrane material alone is sufficient to initiate sensitivity
- D The second eye is always affected if proteins from the first are exposed
- E Chemically denatured lens protein can initiate sensitivity

5 Glutathione

- A Is synthesized in the lens
- B Is in increased levels in the lens nucleus
- C Is a polypeptide of glycine, lysine and glutamic acid
- D Requires NADPH, if it is to be maintained in a reduced state (GSH)
- E A decrease in the level of GSH precedes disruption of lens fibre membranes

6 Regarding lipids in the lens

- A The lens contains 10% lipids by dry weight
- B The majority of lipids are glycosphingolipids
- C Cholesterol is locally produced
- D 50% of cholesterol is in the ester form
- E The lipids are the major component of lens fibre membranes

The lens and vitreous: Answers

- 4 A True
B False
C True
D False
E True

The lens proteins are immunologically protected by the membrane of the lens fibres and by the capsule. Exposure of antigenic membrane material, chemically denatured lens protein, or large amounts of lens protein can lead to lens-induced uveitis, a type IV hypersensitivity reaction. If not treated swiftly, the hypersensitivity can cross and damage the second eye.

- 5 A True
B False
C False
D True
E True

Glutathione is a polypeptide of glycine, cysteine and glutamic acid. It is synthesized in the lens and kept in a reduced state by NADPH from the pentose shunt. It is in highest levels in the cortex. It functions to preserve the physicochemical equilibrium of the lens proteins. A decrease in GSH precedes disruption of lens fibre membranes.

- 6 A False
B False
C True
D False
E True

The lens lipids are unique and comprise 3.0–5.0% of the lens by dry weight. 50% are cholesterol, locally produced from acetate synthesis. 25% of the cholesterol is in the ester form. Of the remaining lipids, 45% are phospholipids, and 5% glycosphingolipids. Lipids are the major component of membranes.

7 Lens fibres

- A Are hexagonal in cross-section
- B Attach to the lens capsule
- C Have small nuclei
- D Interlock with each other
- E Have small extracellular spaces

8 Lens metabolism

- A Uses glucose from the aqueous and vitreous
- B Is predominantly anaerobic
- C Is 15% from the pentose shunt
- D Has its rate regulated by hexokinase
- E Is essential to maintain transparency

9 Cataract

- A 90% of people over the age of 65 have some change in lens transparency
- B Includes vacuoles and water clefts
- C When mature involves complete disruption of lens chemistry
- D Is not produced by viruses
- E Is associated with increased lens inositol

The lens and vitreous: Answers

- 7 A True
B False
C False
D True
E True

Lens fibres make up the bulk of the nucleus and cortex, and are continually formed throughout life. Hexagonal in cross-section, they meet anteriorly and posteriorly at sutures and lose their nuclei when mature. To maintain transparency the fibres interlock and the extracellular space is very small.

- 8 A True
B True
C True
D True
E True

Lens metabolism is 80% glycolysis, 15% pentose shunt and 5% Krebs. The ATP is essential for transport, protein synthesis GSH synthesis, and to maintain transparency. The rate-limiting steps are regulated by hexokinase and phosphofructokinase.

- 9 A False
B True
C True
D False
E False

60% of people over 65 have some change in lens transparency including vacuoles, water clefts, dense areas and microscopic dots. A mature cataract involves complete disruption of lens chemistry, with increased Na^+ , water, and Ca^{2+} , and decreased K^+ , amino acids and inositol. Cataract can be produced by viruses.

10 In diabetic cataract

- A There is decreased glucose in the lens
- B Glucose is converted to sorbitol and fructose
- C The rate of progression is independent of the plasma glucose level
- D The cataract changes start in the pre-equatorial region
- E The Na^+ concentration in the lens is decreased

11 The vitreous

- A Is a clear hydrogel
- B Is a product of the neuroretina
- C Has a density greater than water
- D Transmits 90% of visible light
- E Has a refractive index of 1.3145

12 The embryology of the vitreous

- A Has five stages
- B The hyaloid artery develops in the secondary vitreous at 6 weeks
- C The hyaloid artery is no longer functional at 7 months and is reabsorbed at 9 months
- D The zonules extend as products of the ciliary epithelium
- E The vitreous continues to develop until birth

The lens and vitreous: Answers

- 10** A False
B True
C False
D True
E False

In diabetes increased plasma glucose leads to increased aqueous and lens glucose, hexokinase is saturated and excess glucose is converted to sorbitol and fructose. Increased sorbitol leads to increased Na^+ and water in the lens with associated swelling. The progression begins with pre-equatorial vacuolation and continues to full nuclear opacity, with the rate dependent on the glucose level.

- 11** A True
B True
C True
D True
E False

The clear vitreous is physically a hydrogel filling the posterior cavity of the eye. It is produced by the neuroretina and is 99% water, has a volume of 3.9 ml, a density less than water, a pH of 7.5, and a refractive index of 1.3345. It transmits 90% of light between 300 and 1600 nm.

- 12** A False
B False
C True
D True
E False

The embryology of the vitreous is divided into three stages, primary hyaloid secondary definitive hyaloid, and tertiary zonula. The hyaloid artery develops in the primary vitreous and lasts until 7 months, it is finally reabsorbed at 9 months. The zonules extend at 6 months from the ciliary epithelium to the lens. The vitreous continues to develop until adult.

13 Hyaluronic acid

- A Synthesis begins at 2 months
- B Is a glycosaminoglycan
- C Is made of repeating trisaccharide units
- D Is negatively charged
- E Is hydrophobic

14 Which of the following statements are true?

- A Oxygen enters the vitreous from the aqueous only
- B There is a high flux of water through the vitreous
- C The phosphate level is lower in the vitreous than in the aqueous
- D The pyruvate concentration is lower in the vitreous than in the aqueous
- E The vitreous contains a higher concentration of bicarbonate than the aqueous

The lens and vitreous: Answers

- 13 A False
B True
C False
D True
E False

Isolated from vitreous as the predominant glycosaminoglycan, hyaluronic acid synthesis begins at 5 months. It is made of repeating disaccharides of *N* acetyl glucosamine and glucuronic acid. It is negatively charged and hydrophilic, and responsible for the viscosity of the vitreous.

- 14 A False
B True
C True
D False
E False

Oxygen enters the vitreous from the vessels of the central artery of the retina, as well as through the aqueous. There is therefore a high rate of aerobic glucose metabolism and a high pyruvate concentration. The rapid flux of water through the vitreous is due to outflow across the choroid. Phosphate is metabolized by the retina and levels are therefore lower in the vitreous than aqueous; bicarbonate levels are also lower as a more acidic pH pushes to the unionized form.

Extraocular muscles and control of eye movements

1 Which of the following statements are true?

- A The fascia of the orbit acts as a fluid brake
- B The eyeball has a fixed centre of rotation
- C Movement can be analysed with Fick's axes
- D Each extraocular muscle has two layers of fibres with the larger fibres orbital
- E The perimesium has a large number of elastic fibres

2 Regarding Fick's axes

- A The X axis passes through the pupil
- B Depression occurs around the Z axis
- C Incycloduction occurs around the Y axis
- D Adduction occurs around the X axis
- E Accommodation involves the Z axis

Extraocular muscles and control of eye movements: Answers

- 1 A True
B False
C True
D False
E True

The eyeball is suspended in the pyramidal orbit. Fascia resists initiation of movement and acts as a fluid brake. There is no true fixed centre of rotation, rather a body centroid. Movement can be analysed with Fick's axes. Each ocular muscle has two layers of fibres, with the larger fibres central. The perimesium and septa have an unusually high number of elastic fibres.

- 2 A False
B False
C True
D False
E True

Fick's axes are the horizontal X axis, about which vertical rotation takes place, the anteroposterior Y axis, about which torsional movements take place, and the vertical Z axis, about which horizontal rotation takes place.

Extraocular muscles and control of eye movements: Questions

3 Of the extraocular muscles

- A The secondary function of the superior oblique is intorsion
- B The primary function of the inferior oblique is extorsion
- C The medial rectus has minimal secondary function
- D The superior rectus will not elevate an adducted eye
- E The vertical recti together can apply significant adduction

4 In extraocular muscle

- A The thick filaments comprise myosin and tropomyosin
- B The thin filaments contain actin alone
- C The size of the A band is consistent in contraction
- D The H band is between A bands
- E The Z line is at the centre of the I band

5 At the neuromuscular junction

- A There is always a large single motor end plate
- B An action potential is always conducted through the muscle
- C The motor nerve terminals are unmyelinated
- D The synaptic cleft measures 1.0–5.0 nm
- E A single nerve action potential is able to generate an action potential in the muscle

Extraocular muscles and control of eye movements: Answers

- 3 A False
B True
C True
D False
E True

The extraocular muscles all work together, any other description is a simplification. Within such a simplified framework, the vertical recti cause primary elevation and depression, with secondary adduction and torsion. The superior and inferior obliques cause primary intorsion and extorsion, with secondary depression and elevation respectively. The horizontal recti cause primary adduction and abduction, with minimal secondary action.

- 4 A False
B False
C True
D False
E True

Extraocular muscle is skeletal muscle. The thick filaments are myosin alone, the thin filaments comprise actin with tropomyosin. The A band represents the length of the thick filament and is consistent throughout contraction. The I band between thick filaments and H band between thin filaments both decrease in size during contraction as the filaments overlap. At the centre of the I band is the Z line. At the centre of both A and H bands is the M line. A sarcomere runs from Z line to Z line.

- 5 A False
B False
C True
D False
E True

Extraocular muscle fibres have three subtypes; a fast, action potential conducting twitch fibre with a single *en plaque* motor end plate, an intermediate, action potential conducting fibre with multiple *en grappe* innervation, and a slow, non-conducting fibre with multiple *en grappe* innervation. At the neuromuscular junction the synaptic cleft is 10–50 nm wide, the motor nerve is unmyelinated, and a single action potential is sufficient to induce an action potential in the muscle.

Extraocular muscles and control of eye movements: Questions

6 Regarding calcium

- A Calcium concentration below 10^{-7} M inhibits muscle contraction
- B Spread of excitation down the t-tubule leads to calcium release from the sarcoplasmic reticulum
- C Calcium uptake involves secondary active transport
- D Calcium binds tropomyosin to trigger contraction
- E Calcium is protein bound within the terminal cisternae

7 Muscle ATP

- A Provides energy for cross-bridge movement
- B Provides energy for calcium release
- C Production can be by oxidative phosphorylation in the mitochondria
- D Binds myosin to allow dissociation of actin and myosin
- E Can be formed by substrate phosphorylation in glycolysis

8 Muscle tension

- A Has active and passive components
- B Always increases as muscle length increases
- C Is maximal at normal muscle length during contraction
- D Isometric contraction involves a change in muscle length
- E Always involves ATP hydrolysis

Extraocular muscles and control of eye movements: Answers

- 6 A True
B True
C False
D False
E True

Calcium is stored bound to proteins in the terminal cisternae of the sarcoplasmic reticulum. Spread of depolarization down the t-tubule leads to its release, elevating the calcium concentration from 10^{-7} M to 10^{-5} M, it then binds to troponin inducing a conformational change in tropomyosin, exposing the myosin binding sites, and initiating contraction. It is then taken back into the terminal cisternae by primary active transport.

- 7 A True
B False
C True
D True
E True

Hydrolysis of ATP provides the energy for skeletal muscle contraction, and for the active reuptake of calcium to end contraction. Binding of ATP to myosin causes dissociation of actin and myosin. ATP can be produced by oxidative phosphorylation or by substrate phosphorylation by glycolysis in the absence of oxygen.

- 8 A True
B False
C True
D False
E False

Muscle tension is generated by active contraction of muscle fibres or by passive stretch of the elastic connective tissue. In isometric contraction the muscle length is constant, in isotonic it changes. During stimulus to contract, maximal tension is developed at maximal actin/myosin overlap, this is at the normal resting length.

Extraocular muscles and control of eye movements: Questions

9 The extraocular muscles

- A Have a low ratio of motor fibres to muscle fibres
- B Contain both Golgi tendon organs and muscle spindles
- C Activation of gamma fibres causes intrafusal muscle fibre contraction
- D Golgi tendon organs are supplied by Ia afferents
- E < 0.1 g force will signal stretch

10 Which of the following statements are true?

- A Golgi tendon organs are not involved in the stretch reflex
- B Intrafusal muscle contraction stimulates flower spray endings
- C The gamma loop contributes to the initiation of movement
- D The gamma loop contributes to maintenance of muscle tone
- E Firing of Golgi tendon afferents inhibits the same muscle

11 In the control of eye movements

- A Separate groups can be defined by the stimuli that evoke contraction
- B The control mechanisms are supranuclear
- C Loss of control mechanisms always lead to diplopia
- D Extraocular motor units recruit more slowly than skeletal muscle
- E The muscles maintain constant tone

Extraocular muscles and control of eye movements: Answers

- 9 A False
B True
C True
D False
E True

The extraocular muscles have the highest ratio of motor fibres to muscle fibres, essential for fine control. Muscle spindles have intrafusal fibres with gamma efferent to stimulate contraction, and type Ia and II afferent signalling stretch and rate of stretch. Golgi tendon organs have type Ib afferent, signalling force. Less than 0.1 g is sufficient to signal stretch.

- 10 A True
B True
C True
D True
E True
All true.

- 11 A True
B True
C False
D False
E True

The control of eye movement involves five distinct groups, defined by the stimuli that evoke contraction, saccadic, smooth pursuit, vestibular, vergence and position maintenance. The control is supranuclear, loss leads to loss of gaze function, but not necessarily diplopia. The extraocular muscles differ to skeletal in that they are able to recruit more rapidly, and maintain constant tone.

12 Saccades

- A Are reflex only
- B Can be tested using a rotating drum
- C Are the fastest movement
- D Have a short latency of < 20 ms
- E Have cortical drive from Brodmann's area 19

13 Vergence eye movements

- A Function to maintain foveal fixation in accommodation
- B Are stimulated by retinal blur and diplopia
- C Have a latency of < 15 ms
- D Have a velocity of < 20° of arc per ms
- E Divergence is faster than convergence

14 Pursuit

- A Has occipitoparietal drive
- B Can function smoothly up to 40° of arc per ms
- C Is stimulated by retinal error slip
- D Involves the internal sagittal striatum
- E Has a latency of < 50 ms

Extraocular muscles and control of eye movements: Answers

- 12 A False
B True
C True
D False
E False

Saccades can be voluntary, refixation, or reflex, and function to bring an object of interest onto the fovea. Cortical drive comes from area eight of the frontal cortex. Latency is long, 200–250 ms. Velocity can be very rapid, up to 700° of arc per ms. Saccades can be tested with refixation, optokinetics and calorics.

- 13 A True
B True
C False
D True
E False

Vergence eye movements are stimulated by retinal blur and diplopia, and function to maintain foveal fixation on accommodation with movement of target along the Z axis. Latency is 160 ms. Velocity is $< 20^\circ$ of arc per ms with convergence faster than divergence.

- 14 A True
B True
C True
D True
E False

Pursuit functions to hold the image on the fovea. The cortical drive is from the occipitoparietal cortex, Brodmann's area 19. The pathway involves the internal sagittal striatum. Pursuit is stimulated by retinal error slip. The latency is 125 ms, with velocity up to 90° of arc per ms. A saccade will foveate more rapidly if the target is moving too fast for pursuit.

Extraocular muscles and control of eye movements: Questions

15 Vestibulo-ocular eye movements

- A Have the minimum latency, < 15 ms
- B Involve the frontal cortex
- C Involve the VII nuclei
- D Can be tested using calorics
- E Are independent of the MLF

16 Optokinetic nystagmus

- A Is stimulated by the semicircular canals
- B Can be tested using a rotating drum
- C Can be tested using calorics
- D Has a latency of 100 ms
- E Is a reflex

17 In the control of eye movement

- A The superior colliculus has motor activity
- B The superior colliculus has sensory input
- C The ocular motor nuclei are linked by the lateral lemniscus
- D Rapid movement involves the larger muscle fibres
- E Accuracy of refixation is independent of amplitude

Extraocular muscles and control of eye movements: Answers

- 15** A True
B False
C False
D True
E False

Vestibular eye movements integrate eye and body movements to allow continuous fixation of a target despite body movement. The stimulus is from the semicircular canals via the VIII nerve and vestibular nuclei, connecting to the ocular motor nuclei via the MLF. The latency is very fast at < 15 ms, with a velocity up to 400° of arc per ms. The movement can be tested with rotation, 'dolls head' or calorics.

- 16** A False
B True
C False
D True
E True

Optokinetic nystagmus compensates as a reflex when vestibulo-ocular movements fail, for example in low velocity movement. The stimulus is movement of the surrounds, and can be tested using a rotating drum. The semicircular canals are not involved. The latency is 100 ms.

- 17** A True
B True
C False
D True
E False

The superior colliculus has an important role in orientating responses, especially foveation. It has sensory and motor activity with point to point association between the motor and sensory maps. The superior colliculus, ocular motor nuclei, and vestibular nuclei are linked by the MLF. Rapid movement involves the larger fibres first, followed by correctional movement from the smaller fibres.

Extraocular muscles and control of eye movements: Questions

18 Which of the following statements are correct?

- A In vestibulo-ocular movement the eyes move in the opposite direction as the endolymph
- B In caloric testing warm water in the right ear will cause nystagmus to the left
- C Vergence eye movements do not involve the MLF
- D With perfect fixation the eye is totally still
- E Damage to the MLF leads to internuclear ophthalmoplegia

Extraocular muscles and control of eye movements: Answers

- 18** A False
B False
C True
D False
E True

In vestibulo-ocular movement the eyes move in the same direction as the endolymph. In caloric testing the rule for the direction of the nystagmus is 'cold opposite warm same' (COWS). Damage to the MLF leads to internuclear ophthalmoplegia, vergence movements are spared as they do not involve the MLF (although some recent literature has suggested that vergence movements are not spared if the lesion is at a lower level). The eye is never totally still as the image would be lost through adaptation.

The ciliary body, aqueous and intraocular pressure

1 In ocular circulation

- A The foveola is avascular
- B The intraocular pressure is independent of the blood pressure
- C The venous pressure is less than the intraocular pressure
- D The choroid capillary pressure is greater than retinal capillary pressure
- E The total oxygen extraction is greatest from the choroid

2 The intraocular pressure

- A Averages 15.5 mmHg
- B Is lower than tissue pressure elsewhere in the body
- C Depends only on the rate of aqueous formation
- D Depends only on the resistance to aqueous drainage
- E Is controlled within a narrow range

The ciliary body, aqueous and intraocular pressure: Answers

- 1 A True
B False
C False
D True
E True

The fovea is avascular to minimize vascular interference of light reaching the cones. The intraocular pressure varies with the blood pressure. The venous pressure is greater than the intraocular pressure to avoid venous collapse. The capillary pressure is greater in the choroidal capillaries, and the total oxygen extraction is greatest from the choroid.

- 2 A True
B False
C False
D False
E True

The intraocular pressure averages 15.5 mmHg within a normal range of 10.0–22.0 mmHg. This is greater than tissue pressure elsewhere in the body. The pressure depends on both the rate of aqueous formation and resistance to drainage.

The ciliary body, aqueous and intraocular pressure: Questions

3 Regarding intraocular blood flow

- A Intraocular arterial pressure is the same as peripheral blood pressure
- B Blood flow in the eye may have a temperature-regulating function
- C The mean circulation time is 4.7 s
- D Precapillary sphincters help control choroidal blood pressure
- E Choroidal blood flow is independent of intraocular pressure

4 Blood flow in the choroid

- A Is increased by decreased partial pressure of oxygen
- B Is increased by increased partial pressure of carbon dioxide
- C Is increased by decreased hydrogen ion concentration
- D Is decreased by alpha receptor stimulation
- E Remains constant throughout a rollercoaster ride

5 The formation of tissue fluid in the ciliary body

- A Is controlled by tight junctions in the capillaries
- B Is affected by local tissue protein concentration
- C Is balanced by removal through the ciliary lymphatics
- D Is increased by decreased arterial blood pressure
- E Is decreased in inflammation

The ciliary body, aqueous and intraocular pressure: Answers

- 3 A False
B True
C True
D False
E False

Intraocular arterial pressure is 65–70 mmHg, about half the peripheral blood pressure. The mean circulation time is 4.7 s and the circulation may protect against hyperthermia and hypothermia in the eye. There are no precapillary sphincters in either the choroid or the retina. Choroidal blood pressure is directly proportional to intraocular pressure and perfusion pressure.

- 4 A True
B True
C False
D True
E False

Metabolic autoregulation leads to increased blood flow with decreased partial pressure of oxygen, increased partial pressure of carbon dioxide, or acidosis. Alpha receptors prevent over-perfusion of the eye via vasoconstriction. The gravitational forces exerted during a fairground ride will be transmitted to the choroid and retina. At the most extreme there are reported cases of retinal bleeds associated with bungy jumping.

- 5 A False
B True
C False
D False
E False

In the ciliary body the capillary walls are thin with large fenestrations. Tissue fluid formation depends on hydrostatic pressure, and colloid osmotic pressure. It is increased in inflammation. There are no ciliary lymphatics.

The ciliary body, aqueous and intraocular pressure: Questions

6 Regarding the retinal circulation

- A The retinal capillary endothelium is thick and fenestrated
- B The choroid has a higher protein concentration than the retina
- C The osmotic pressure difference between the choroid and retina may assist in retinal attachment
- D Retinal glucose transport is carrier mediated
- E Retinal pigment epithelium has zonulae occludentes

7 The ciliary body

- A Secretes hyaluronic acid
- B Has a dominant role in accommodation
- C Contains a rich capillary network
- D Secretes aqueous into the anterior chamber
- E Has an inner pigmented layer in contact with the aqueous

8 The aqueous

- A Has a total volume of 2.5 ml
- B Has an index of refraction greater than the cornea
- C Is less dense than water
- D Has an osmotic pressure less than plasma
- E Is formed at a rate of 0.2 μ l per min

The ciliary body, aqueous and intraocular pressure: Answers

- 6 A False
B True
C True
D True
E True

In contrast to the choroid, the retinal capillaries have a thick non-fenestrated endothelium held together by tight junctions. The endothelium is impermeable to proteins and glucose transport is carrier mediated. The second blood–retinal barrier is the retinal pigment epithelium, also with tight junctions (zonulae occludentes). Water flows down the osmotic gradient from the retina to the choroid, and may assist in retinal attachment.

- 7 A True
B True
C True
D False
E False

The ciliary body has important anatomical and physiological functions. It secretes hyaluronic acid of the vitreous, has a dominant role in accommodation, secretes aqueous into the posterior chamber and has extensive arterial and neuronal input. The inner non-pigmented layer is in contact with the continuation of the internal limiting membrane of the retina.

- 8 A False
B False
C False
D False
E False

The aqueous fills the anterior and posterior chambers. It has a volume of 0.25 ml, 0.19 ml in the anterior and 0.06 ml in the posterior chamber. The index of refraction is 1.336, less than that of the cornea. It has greater density and viscosity than water. The osmotic pressure is 3.5 mOsm/l, greater than that of the plasma, and the rate of formation is 2.0 μ l/min.

The ciliary body, aqueous and intraocular pressure: Questions

9 The following factors influence the composition of aqueous

- A The blood–ocular barrier
- B Haemodynamics
- C The rate of drainage
- D Metabolism
- E Diffusional exchange across the iris

10 Which of the following statements are true?

- A Excess protein in the aqueous is visible with the slit lamp
- B The aqueous and plasma contain similar amounts of protein
- C The iris vessels have tight junctions
- D The aqueous is actively secreted
- E The composition of aqueous differs from posterior to anterior chamber

11 Which of the following statements are true?

- A The ciliary epithelium is rich in mitochondria
- B Aqueous formation has a diurnal rhythm
- C The outer pigmented layer has greater metabolic activity than the inner non-pigmented layer
- D Cyclic AMP is involved in the control of aqueous secretion
- E The Na^+ component of aqueous is secreted by primary active transport

The ciliary body, aqueous and intraocular pressure: Answers

- 9 A True
B True
C True
D True
E True
All true.

- 10 A True
B False
C True
D True
E True

In inflammation, vasodilatation leads to increased protein in the aqueous, visible as a flare of scattering of light with the slit lamp. The aqueous has much less protein than the plasma. The iris vessels have tight junctions. The aqueous is actively secreted and differs in composition during its flow due to diffusional exchange and metabolism.

- 11 A True
B True
C False
D True
E True

The aqueous is formed by active secretion. ATP is formed by oxidative phosphorylation, predominantly in mitochondria in the inner non-pigmented layer. The secretion of Na^+ is primary active. There is a diurnal rhythm of formation and both beta adrenoceptors and cyclic AMP activated phosphokinases are thought to be involved.

The ciliary body, aqueous and intraocular pressure: Questions

12 Regarding intraocular pressure

- A The normal distribution of intraocular pressure is a perfect Gaussian curve
- B The uveoscleral outflow of aqueous is 0.2–0.5 $\mu\text{l}/\text{min}$
- C The major outflow into the canal of Schlemm is 5.0–8.0 $\mu\text{l}/\text{min}$
- D Increased intraocular pressure leads to increased outflow resistance
- E Increased intraocular pressure leads to increased aqueous outflow

13 Regarding intraocular pressure

- A Increased pressure leads to decreased aqueous formation
- B The pressure is greater in the anterior than posterior chamber
- C If the zonules are broken the lens may be extruded through the pupil
- D The ciliary body and choroid are distended against the sclera by the intraocular pressure
- E The pressure in the suprachoroidal space is 2 mmHg greater than the intraocular pressure

14 Factors affecting the intraocular pressure include

- A Coughing
- B Valsalva manoeuvre
- C Co-contraction of the extraocular muscles
- D Tumour growth within the eye
- E Intraocular haemorrhage

The ciliary body, aqueous and intraocular pressure: Answers

- 12 A False
B True
C False
D True
E True

The normal range of intraocular pressure is not a perfect Gaussian curve, as it is skewed to the right with an extended upper range. The outflow has two components, the major outflow via the trabecular meshwork of 1.8–2.5 $\mu\text{l}/\text{min}$, and the minor uveoscleral outflow of 0.2–0.5 $\mu\text{l}/\text{min}$. Increased intraocular pressure leads to increased outflow of aqueous despite an increasing outflow resistance.

- 13 A True
B False
C True
D True
E False

An increased intraocular pressure leads to decreased aqueous formation by decreasing the pressure difference for ultrafiltration in the ciliary body. The pressure in the posterior chamber is greater than that in the anterior, and may push the lens through the pupil should the zonules be broken. The ciliary body and choroid are distended against the sclera, and pressure in the suprachoroidal space is usually 2 mmHg less than the intraocular pressure.

- 14 A True
B True
C True
D False
E True

Intraocular pressure changes constantly over the short-term and is affected by coughing, the Valsalva manoeuvre, fluctuations of blood pressure, and position and co-contraction of extraocular muscles. Intraocular haemorrhage will cause increased intraocular pressure, tumour growth is normally far too slow to increase intraocular pressure.

The ciliary body, aqueous and intraocular pressure: Questions

15 Intraocular pressure

- A Shows diurnal variation
- B Is maximal in the evening
- C Transient increase will damage the peripheral visual field
- D Can be measured by applanation tonometry
- E Changes can give a measure of aqueous outflow

16 Intraocular pressure is unaffected by

- A Ciliary muscle contraction
- B Blood osmolarity
- C Topical steroids in the short-term
- D Carbonic anhydrase inhibitors
- E Cataract formation

The ciliary body, aqueous and intraocular pressure: Answers

- 15 A True
B False
C False
D True
E True

The intraocular pressure shows diurnal variation being maximal in the morning. Sustained raise in intraocular pressure compresses the retinal vasculature, with the smaller peripheral vessels affected first, leading to progressive visual field loss. Tonometry is used to measure intraocular pressure and can also give an index of aqueous outflow facility by measuring the rate of change of the initial slight increase in pressure due to the flattening of the cornea by the tonometer.

- 16 A False
B False
C True
D False
E True

The position of the ciliary muscle affects the degree to which the trabeculae are open and hence outflow resistance and intraocular pressure. Increased blood osmolality will decrease the formation of aqueous. Carbonic anhydrase inhibitors also decrease the formation of aqueous by inhibiting the formation of bicarbonate. Cataract formation does not affect the intraocular pressure, steroids do not usually increase the pressure in short-term use.

Accommodation and the pupil

1 Accommodation

- A Is necessary within 6 m
- B An increased depth of field increases the need for precise accommodation
- C A blur circle occurs at the cornea
- D Depth of focus is related to depth of field
- E Depth of focus is independent of the pupil diameter

2 Regarding accommodation

- A Minimal pupil size will minimize the depth of field
- B A high degree of blur is tolerated
- C Maximum depth of focus is influenced by illuminance
- D Diffraction disturbances become a problem at a pupil diameter of 1.5 mm
- E Retinal receptors have finite diameter

Accommodation and the pupil: Answers

- 1 A True
B False
C False
D True
E False

Accommodation is necessary within 6 m. The depth of field and depth of focus are related and depend upon pupil diameter. An increased depth of focus decreases the need for precise accommodation, as the blur circle produced at the retina can be kept within an acceptable range over a greater range of accommodation.

- 2 A False
B True
C True
D False
E True

The smallest pupil produces the largest depth of focus, within the limits of both the available light and diffraction, as with a smaller pupil less light enters the eye, and there is more diffraction, becoming a problem at pupil diameters of less than 0.75 mm. A high degree of blur can be tolerated, and can even exceed the finite diameter of the retinal receptors, while still producing a sharp image.

3 In accommodation

- A The pupil contracts by synkinesis
- B The posterior pole moves forward
- C The anterior pole moves backward
- D The anterior chamber becomes shallower
- E The posterior of the lens becomes more convex

4 In accommodation

- A The lens increases in diameter
- B There is increased tension in the lens capsule
- C The lens sinks in the direction of gravity
- D The lens thickens in the centre
- E There is increased tension on the zonules

5 Regarding the mechanism of accommodation

- A The intraocular pressure maintains tension on the zonular fibres
- B The lens capsule is thicker centrally
- C There is active contraction of ciliary muscle
- D There is active change in the shape of the lens
- E The choroid is stretched forward

Accommodation and the pupil: Answers

- 3 A True
B False
C False
D True
E True

In accommodation a number of changes take place as a result of ciliary muscle contraction. The pupil contracts by synkinesis, the posterior pole is predominantly stationary, the anterior pole moves forward, the anterior chamber becomes shallower, and both surfaces of the lens become more convex.

- 4 A False
B False
C True
D True
E False

In accommodation as the zonules slacken, the elastic lens capsule decreases in tension, the lens decreases in diameter, thickens in the centre and sinks in the direction of gravity.

- 5 A True
B False
C True
D False
E True

The tension on the zonular fibres when the ciliary muscle is relaxed is caused by the intraocular pressure. The lens capsule is thinner centrally and during active contraction of the ciliary muscle it contracts because of elasticity, passively bringing about the change in the shape of the lens. Some fibres of the ciliary muscle attach to the anterior choroid and pull the choroid forward during contraction.

6 The zonules

- A Become tighter with age
- B Prevent prolapse of the lens
- C Prevent the lens compressing the iris
- D Transmit the force of the ciliary muscle to the lens
- E Attach to the trabeculae

7 Which of the following statements are correct

- A The stimulus to accommodation is chromatic aberration
- B The reaction time for accommodation is 0.36 s
- C The maximum accommodative capacity is reached in adolescence
- D Nasal displacement of an image signals both accommodation and convergence
- E The amplitude of accommodation corresponds to the amplitude of convergence

8 Regarding accommodation

- A The physiological maximum can be produced by convergence
- B Accommodative convergence is a conditioned reflex
- C Presbyopia requires concave glasses
- D In myopia the near point becomes more distant
- E Presbyopia can be due to ciliary muscle weakness

Accommodation and the pupil: Answers

- 6 A False
B True
C True
D False
E False

The zonules slacken with age as the lens continues to grow, and although preventing prolapse of the lens, may no longer be able to prevent the lens compressing the iris and causing acute angle glaucoma. The zonules attach from the ciliary body to the capsule, and transmit the expansile force of intraocular pressure to the lens.

- 7 A False
B True
C False
D False
E True

The stimulus to accommodation is retinal blur. The reaction time is slower than to light alone at 0.36 seconds, and the maximum amplitude is reached as a child. Accommodation and convergence operate in unison, and correspond in amplitude. As an object approaches in the midline, temporal displacement of the image signals the reaction.

- 8 A True
B False
C False
D False
E True

Convergence can produce maximal accommodation, the accommodation is an unconditioned reflex. In presbyopia the near point becomes more distant, increasing with increasing age, until convex glasses are required. The cause is ciliary muscle weakness, a stiffer and larger lens nucleus, and possibly loss of capsular elasticity.

9 The ciliary muscle

- A Is inhibited by beta agonists
- B Is inhibited by alpha agonists
- C Contracts with pilocarpine
- D Increases the diameter of the lens with anticholinesterases
- E Is unaffected by cyclopentolate

10 The pupil

- A Dilator is formed prior to the sphincter
- B Muscles are mesodermal
- C Constriction is lost if a section of sphincter is cut
- D The sphincter can shorten to 55% of its length at maximum
- E The pupil size ranges from 1 to 9 mm

11 Regarding the pupil

- A The normal pupil is in the centre of the iris
- B The pupil is largest at birth
- C A healthy iris is in constant motion
- D Adrenaline will not cause dilatation in a premature infant
- E 25% of the population have anisocoria

12 Regarding the pupillary reaction to light

- A The threshold is equal to the scotopic visual threshold
- B There is a sudden increase in effect in the photopic range
- C The latency in the photopic range is 0.2 s
- D At 5.0 Hz a flicker leads to steady contraction
- E The reaction is affected by the reticular formation

Accommodation and the pupil: Answers

- 9** A True
B False
C True
D False
E False

The ciliary muscle is inhibited by beta agonists such as adrenaline. Pilocarpine and anticholinesterases cause accommodative spasm, and therefore decrease the diameter of the lens. Cyclopentolate has an antimuscarinic effect and therefore causes the ciliary muscle and pupillary sphincter to relax.

- 10** A False
B False
C False
D False
E True

The muscles in the pupil are formed from neuroectoderm, with the sphincter formed first. The pupil size can range from 1 to 9 mm, with the sphincter shortening up to 87% of its length. Constriction remains even if a section of the sphincter is cut.

- 11** A False
B False
C True
D True
E True

The normal pupil is slightly nasally placed in the iris, and reaches maximal size in adolescence. A healthy iris is in constant motion, and 25% of the population have anisocoria of 0.4 mm or more. Sympathetic innervation reaches the dilator at full term, adrenaline will therefore not cause dilatation in a premature infant.

- 12** A True
B True
C True
D True
E True
All true.

13 In afferent pupil defects

- A The pupil is fixed and dilated
- B The problem is sensory
- C The pupil responds to light shone into the second, normal eye
- D Both pupils constrict when light passes from the normal to the abnormal eye
- E The damage could be to the oculomotor nerve

14 The causes of efferent pupil defects include

- A Drugs such as atropine
- B Damage to the optic nerve
- C Adie's syndrome
- D Damage to the lateral geniculate nucleus
- E Damage to the iris

15 A tonic pupil is associated with

- A Poor reaction to light
- B Tonic response to near vision
- C Cholinergic insensitivity
- D Increased corneal sensation
- E Accommodative paresis

Accommodation and the pupil: Answers

- 13** A False
B True
C True
D False
E False

In afferent pupil defects the problem is sensory, and the pupil is still responsive to light input from the second eye. The damage could not be to the oculomotor nerve, and both pupils would constrict when light passed from the abnormal to the normal eye.

- 14** A True
B False
C True
D False
E True

Efferent pupil defects can be caused anywhere along the pathway from the parasympathetic nucleus to the iris, and include midbrain damage, damage to the oculomotor nerve, damage to the ciliary ganglion or iris, and by drugs such as atropine.

- 15** A True
B True
C False
D False
E True

A tonic pupil is due to postganglionic parasympathetic denervation, and is associated with a poor reaction to light, a strong and tonic response to near vision, cholinergic supersensitivity, accommodative paresis and decreased corneal sensation.

16 Light near dissociation can involve

- A Neurosyphilis
- B A lesion in the optic radiation
- C Diabetic neuropathy
- D A poor near reaction
- E A good light reflex

17 In Horner's syndrome

- A 1.0% hydroxyamphetamine will dilate a postganglionic lesion
- B 1.0% phenylephrine will dilate a preganglionic lesion
- C Cocaine will not dilate a postganglionic lesion
- D The ptosis only affects the upper lid
- E The miosis is most apparent in low light levels

Accommodation and the pupil: Answers

- 16** A True
B False
C True
D False
E False

Light near dissociation occurs with damage to the pupillary light reflex. It involves a good near reaction with no light reflex, and can be caused by a retinal lesion, a lesion in the anterior visual pathway, a lesion in the midbrain, neurosyphilis, and diabetic or alcoholic neuropathy.

- 17** A False
B False
C True
D False
E True

In Horner's syndrome ipsilateral interruption to sympathetic outflow leads to miosis, ptosis and anhydrosis. The ptosis affects both upper and lower lids, and the miosis is best seen in the dark. Hydroxyamphetamine releases noradrenaline from nerve endings and will supernormally dilate a preganglionic lesion. Phenylephrine stimulates alpha receptors and will supernormally dilate a postganglionic lesion. Cocaine, an uptake type one inhibitor, will cause dilatation with an intact pathway.

Basic neurophysiology

1 With respect to an action potential

- A The equilibrium potential for Na^+ is -60 mV in mammals
- B K^+ channels open more slowly and for a shorter period than Na^+ channels
- C An increase in the external Na^+ concentration decreases the size of the action potential
- D The total number of ions involved is minute
- E A decrease in the extracellular Ca^{2+} concentration increases the excitability of nerves

2 Conduction of a nerve impulse

- A Is slower in hypothermia
- B Is more sensitive to anoxia than synaptic transmission
- C Is at a steady rate in myelinated fibres
- D Can occur in both directions in a neuron
- E Is at an equivalent speed to electrical transmission

Basic neurophysiology: Answers

- 1 A False
B False
C False
D True
E True

An action potential is the result of movement of Na^+ and K^+ ions towards their equilibrium potentials following the opening of their respective channels. The equilibrium potential for Na^+ is +60 mV in mammals, a decrease in the external Na^+ concentration would therefore decrease the size of the action potential. The K^+ channels open more slowly than the Na^+ channels but remain open longer. The overall number of ions involved is minute. The extracellular Ca^{2+} concentration, if decreased, will increase the excitability of nerve fibres by moving the resting potential closer to threshold.

- 2 A True
B False
C False
D True
E False

The conduction of a nerve impulse along an axon requires energy, is slower in hypothermia, can occur in both directions, and is saltatory in myelinated fibres. Axonal conduction is less sensitive to anoxia than synaptic transmission. It is much, much, slower than electrical transmission.

3 The distal segment of a sectioned nerve

- A Becomes completely unexcitable within 24 hours
- B Changes more slowly in children than adults
- C Sensory fibres lose their excitability before motor fibres
- D Changes more slowly in hypothermia
- E Shows a decrease in conduction velocity

4 In myelinated nerve fibres

- A The Na^+ channels are evenly distributed along the axon
- B 70% of the energy is used by Na^+/K^+ ATPase
- C The metabolic rate of a nerve doubles during maximal activity
- D A threshold stimulus will excite all the axons in a neuron
- E A compound action potential reflects the different fibre diameters in a mixed nerve

5 Regarding nerve membranes

- A A fall in the resting potential can represent a net gain of Na^+
- B A fall in the resting potential can represent a net loss of protein
- C Permeability is greater to Cl^- than K^+
- D Permeability is greater to Na^+ than K^+
- E Permeability is greater to Cl^- than organic anions

Basic neurophysiology: Answers

- 3 A False
B False
C True
D True
E True

The distal segment of a sectioned nerve takes about 5 days to completely lose its excitability, with the smallest sensory fibres being lost first. The threshold for excitability rises, the conduction velocity decreases, and the amplitude of the action potential decreases. The changes are slower in adults than children, and due to decreased metabolic demand are slower in hypothermia.

- 4 A False
B True
C True
D False
E True

In myelinated nerve fibres the Na^+ channels are concentrated at the nodes of Ranvier. During maximal activity the metabolic rate doubles, with 70% of the energy used by the Na^+/K^+ ATPase pump. A threshold stimulus will only excite the most easily excitable axons in a nerve, the compound action potential reflecting the different fibre diameters in a mixed nerve.

- 5 A True
B False
C True
D False
E True

If the resting membrane potential of a nerve falls there can be net gain of Na^+ or Cl^- , or loss of K^+ . The nerve membrane is impermeable to protein. Permeability is greater to Cl^- than K^+ , and greater to K^+ than Na^+ .

6 With respect to different size nerve axons

- A The speed of conduction is inversely proportional to diameter
- B A fibres are smaller than C fibres
- C A gamma fibres are motor to muscle spindles
- D A alpha fibres have a diameter of 12–20 μm
- E The maximum conduction velocity is approximately 12 m/s

7 Regarding glial cells

- A There are as many glial cells as neurons
- B Oligodendrocytes are involved in myelin formation
- C Astrocytes form the blood–brain barrier
- D Astrocytes enter the nervous system from blood vessels
- E Microglia have a homeostatic function with respect to neurotransmitters

8 Which of the following statements are true

- A Nerve cells are secretory cells
- B Axons contain ribosomes
- C Axoplasmic flow can reach 400 mm/day
- D Viruses are transported to the cell body by retrograde transport
- E Axoplasmic flow is dependent on ATP

Basic neurophysiology: Answers

- 6 A False
B False
C True
D True
E False

Nerves can be classified according to their size into various groups. A fibres are the largest, reaching diameters of 12–20 μm . The speed of conduction is proportional to nerve diameter, A fibres can conduct at speeds of 120 m/s and are motor to muscle spindles via the gamma subgroup.

- 7 A False
B True
C True
D False
E False

There are up to 50 times as many glial cells as neurones. Oligodendrocytes are involved in myelin formation, astrocytes form the blood–brain barrier, and have a homeostatic function with respect to neurotransmitters, and microglia enter the nervous system from blood vessels.

- 8 A True
B False
C True
D True
E False

Nerve cells are secretory cells, with ribosomes and Golgi apparatus found in the cell body. Axons themselves contain no ribosomes. Axoplasmic flow is independent of ATP and can reach up to 400 mm/day. Retrograde transport is responsible for the transport of viruses to the cell body.

9 Synaptic transmission

- A Can occur in both directions
- B Involves presynaptic transmitter release
- C Requires local postsynaptic cell membrane hyperpolarization
- D Is slower in circuits involving several synapses
- E Cannot take place in the presence of inhibitory transmitters

10 The excitatory postsynaptic potential

- A Is transient
- B Is small
- C Is a depolarization towards threshold
- D May be recorded from a motor neuron in the anterior horn of the grey matter
- E Is not conducted

11 An inhibitory postsynaptic potential

- A Can be recorded from an autonomic ganglion cell
- B Is small
- C Is prolonged
- D Depolarizes
- E Can summate

Basic neurophysiology: Answers

- 9** A False
B True
C False
D True
E False

Synaptic transmission can only occur in one direction with pre-synaptic transmitter release causing local postsynaptic cell membrane depolarization. Synaptic transmission is slower than axonal conduction, and transmission is therefore slower in circuits involving several synapses. Transmission can take place in the presence of inhibitory transmitters so long as there are sufficient excitatory transmitters.

- 10** A True
B True
C True
D True
E True
All true.

- 11** A False
B True
C False
D False
E True

Inhibitory postsynaptic potentials are small, transient, able to summate and cause hyperpolarization. They are not recorded in autonomic ganglion cells.

12 When a nerve to muscle is divided

- A The overlying skin temperature falls
- B The electrical resistance of the overlying skin decreases
- C The muscle becomes less sensitive to acetylcholine
- D A needle electrode placed in the muscle will record action potentials
- E A smaller current is required to produce contraction

13 Skeletal muscle

- A Cannot generate spontaneous activity
- B Contracts on uptake of Ca^{2+}
- C Contracts when actin and myosin filaments shorten
- D Moderate stretch favours contraction
- E Can develop sustained contraction for less energy than smooth muscle

14 The muscle spindle is stimulated by

- A The antagonist muscle shortening
- B Relaxing the muscle under load
- C Shortening extrafusal fibres
- D The gamma efferent
- E Sympathetic denervation

Basic neurophysiology: Answers

- 12 A False
B False
C False
D False
E False

All false. When a nerve to a muscle is divided the overlying skin both increases in temperature and increases in its electrical resistance, due to increased vasomotor tone, and decreased sweating from loss of sympathetic fibres. The muscle becomes more sensitive to acetylcholine, with a needle electrode placed in the muscle recording fibrillation spike potentials. The strength duration curve shifts to the right, with a larger current required to produce contraction.

- 13 A True
B False
C False
D True
E False

Skeletal muscle is unable to generate spontaneous activity, instead it contracts when a motor nerve signal causes the release of Ca^{2+} from the sarcoplasmic reticulum. The actin and myosin filaments then pull over each other, neither filament actually shortens. Moderate stretch favours contraction. Smooth muscle is much more energy efficient in maintained contraction.

- 14 A True
B True
C True
D True
E False

The muscle spindle is stimulated by gamma efferents, shortening extrafusal fibres, antagonist muscle contraction and relaxing the muscle under load. Sympathetic denervation does not affect the muscle spindle.

15 The stretch reflex

- A Is the only human monosynaptic reflex
- B The efferent arc starts at the gamma motor neuron
- C Golgi tendon organs are inactivated by muscle contraction
- D The annulospiral receptor is excited on muscle contraction
- E Afferent stimulation may inhibit antagonistic muscles

16 Muscle fatigue involves

- A Normal nerve conduction
- B Normal transmission across the motor end plate
- C Abnormal initiation of action potentials in muscle
- D No increased gamma nerve stimulation to muscle spindles
- E Decreased stimulation of the same muscle group

17 Competitive neuromuscular blockers include

- A Neostigmine
- B Thiopentone
- C Neomycin
- D Halothane
- E Botulinus toxin

18 Which of the following can affect transmission at the neuromuscular junction

- A Carcinoma of the bronchus
- B Thiamine deficiency
- C Diabetes mellitus
- D Hypothyroidism
- E Hyperthyroidism

Basic neurophysiology: Answers

- 15** A True
B False
C False
D False
E True

The muscle stretch reflex is the only human monosynaptic reflex, the efferent arc starting at the alpha motor neuron. Muscle contraction activates the Golgi tendon organs and relaxes the annulospiral endings of the muscle spindles. The afferent stimulation may also inhibit the antagonistic muscles, facilitating movement around the involved joint.

- 16** A True
B True
C False
D True
E False

Fatigue occurs when there is repeated stimulation of the same muscle group. It occurs with normal nerve conduction, transmission, action potential initiation, and with no increased gamma nerve stimulation to the muscle spindles.

- 17** A False
B True
C True
D True
E False

Neostigmine is an anticholinesterase. Botulinus toxin blocks acetylcholine release. Neomycin, thiopentone and halothane are all competitive neuromuscular blockers.

- 18** A True
B True
C True
D True
E True

All true. The neuromuscular junction is sensitive to many different factors.

19 Muscle tone is

- A Resistant to active stretch
- B Increased by curare
- C Affected by the eighth cranial nerve
- D Increased following loss of cerebellar function
- E Decreased following a cerebrovascular accident

20 Atropine may

- A Blur vision
- B Cause diarrhoea
- C Cause difficulty with micturition
- D Cause bronchoconstriction
- E Decrease bronchial secretions

21 Smooth muscle

- A Has a well-developed sarcoplasmic reticulum
- B Does not contain troponin
- C Contains many mitochondria
- D Depends predominantly on glycolysis
- E In the iris has individual muscle units with interconnecting bridges

Basic neurophysiology: Answers

- 19** A False
B False
C True
D False
E False

Muscle tone is defined as resistance to passive stretch. It is decreased by curare-like drugs and after loss of cerebellar function. It is increased following stroke and is affected by the postural control component of the eighth cranial nerve.

- 20** A True
B False
C True
D False
E True

Atropine acts as an anticholinergic drug. It therefore dilates the pupil and can blur vision, causes constipation, difficulty with micturition, decreases bronchial and salivary secretions, and bronchodilation.

- 21** A False
B True
C False
D True
E False

Smooth muscle has specific differences to striated muscle. The sarcoplasmic reticulum is poorly developed, there are few mitochondria, glycolysis is predominant, and there is no troponin. The individual muscle units of the iris do not have interconnecting bridges.

22 In smooth muscle

- A Ca^{2+} binds to calmodulin
- B Myosin must be dephosphorylated to activate myosin ATPase
- C Ca^{2+} plus calmodulin activates myosin light chain kinase
- D There is usually a single nerve supply
- E Phenylephrine causes contraction

23 Pain sensation

- A Is a specific sense
- B Is less readily elicited in injured tissue
- C Is due to receptor excitation by local mediators
- D Shows poor adaptation
- E Is always stimulated by internal tissue damage

24 Hair cells in the semicircular canal respond to

- A Stretch
- B Inertia of perilymph
- C Rotational acceleration
- D Change in the temperature of the ear drum
- E Linear acceleration

Basic neurophysiology: Answers

- 22 A True
B False
C True
D False
E True

For smooth muscle to contract, Ca^{2+} binds calmodulin and the complex activates myosin light chain kinase. Myosin must be phosphorylated to activate myosin ATPase. There is usually a dual sympathetic and parasympathetic nerve supply. Phenylephrine is one of many drugs which can cause contraction.

- 23 A True
B False
C True
D True
E False

Pain sensation is a specific sense rather than overstimulation of other senses, and is due to the excitation of receptors by local mediators. Injured tissue shows hyperalgesia with a lowered threshold to pain. Pain shows poor adaptation as a self-protective response. Internal tissue damage need not always cause pain.

- 24 A True
B False
C True
D True
E False

Hair cells in the semicircular canal are connected to the cupulae. In rotational acceleration caused by body motion or local thermal change, the inertia of the endolymph causes displacement of the cupulae, with stretching of the hair cells. Linear acceleration is detected by the utricle and saccule.

Light and the photochemistry of vision

1 Regarding light

- A The optical spectrum is non-ionizing radiation
- B The visible spectrum is from 400 to 780 nm
- C Optical radiation can be described in radiometric or photometric terms
- D A lux is a lumen per steradian and is a measure of illuminance
- E Luminance can be measured in candelas

2 Regarding the measurement of light

- A Radiance measures the amount of light arriving at a given point
- B Irradiance and illuminance measure the amount of light leaving a source
- C A troland is a measure of retinal illuminance
- D One lumen per steradian per square metre is equal to 0.3142 millilamberts
- E The visible spectrum is larger in the aphakic eye

Light and the photochemistry of vision: Answers

- 1 A True
B True
C True
D False
E False

The visible spectrum is non-ionizing radiation from 400 to 780 nm. It can be described in radiometric or photometric terms, each with their own units of measurement. A lux is a lumen per square metre, and is a measure of illuminance. Luminance can be measured in millilamberts.

- 2 A False
B False
C True
D True
E True

Radiance measures the amount of light leaving a source, while irradiance and illuminance measure the amount of light arriving at a given point. Luminance is equivalent to radiance and can be measured in lumen per steradian per square metre, one of which is equal to 0.3142 millilamberts. A troland is a measure of retinal illuminance and is equal to luminance multiplied by pupil area. The lens absorbs a significant proportion of the visible light, especially at short wavelength; the visible spectrum of the aphakic eye is therefore larger.

3 Regarding light

- A Red has a shorter wavelength than blue
- B Photometric measurements are based on visual response
- C The measurement of luminance is independent of the distance from the source
- D A candela is a measure of luminous intensity
- E One lumen is 1/685 of a watt at 555 nm

4 Regarding vision

- A Vision can be divided into light sense, colour sense and form sense
- B Light sense is most accurately tested in a fully light adapted eye
- C Hue discrimination is maximum in the red–yellow range
- D All hues can be formed from two primaries
- E Form sense can be tested with a Landolt-C chart

5 Which of the following statements are true about light?

- A The frequency of radiation varies with the density of the medium
- B The index of refraction is the ratio of frequency of light in a vacuum to the velocity of light in the medium
- C The index of refraction is always greater than 1 for media more dense than a vacuum
- D Each medium has a constant index of refraction for each wavelength
- E Yellow light is brought to focus closer than green

Light and the photochemistry of vision: Answers

- 3 A False
B True
C True
D True
E True

Red light has a longer wavelength than blue and is consequently brought to focus at a greater distance than blue. Photometric measurements are based on visual response using volunteers as the measuring instrument and averaging the results. The measurement of luminance is independent of the distance from the source, a candela is a measure of luminous intensity, and 1 lumen, a measure of luminous flux, is equivalent to $1/685$ of a watt at 555 nm wavelength.

- 4 A True
B False
C False
D False
E True

Vision is commonly divided into three senses, light, colour and form. Light sense is most accurately tested in a fully dark adapted eye. Hue discrimination is maximum in the blue–yellow range, and all hues can be formed from three primaries. Form sense can be tested using the Landolt-C chart.

- 5 A False
B False
C True
D False
E False

The frequency of radiation of light does not vary with the density of the medium through which it passes. On entering a more dense medium, as the speed is reduced the wavelength is correspondingly affected. The index of refraction is the ratio of the speed of light in a vacuum to the speed of light in the medium, it is always greater than 1 for media more dense than a vacuum. Each medium has a different index of refraction for each wavelength. Shorter wavelength green light is brought to focus closer than longer wavelength yellow.

6 Regarding the energy of light

- A Electromagnetic radiation is emitted in quanta
- B A quanta of light equals a photon
- C The energy of light is directly proportional to wavelength
- D The energy of light is inversely proportional to frequency
- E A watt is 10 000 000 ergs per second

7 Regarding the eye

- A There is greater transmission of light of short wavelength than long
- B The radiant power per unit area of retinal image is independent of the distance of the eye from the source
- C The photopic luminous efficiency curve has a peak at a shorter wavelength than the scotopic curve
- D The lens absorbs more blue light than red
- E At best, 100% of the available light reaches the retina

8 Rhodopsin

- A Has a density spectrum equal to human scotopic sensitivity
- B Is found in rod and cone phospholipid membrane discs
- C Has 348 amino acids in seven helices
- D Has a retinal component attached to lysine residue no. 206 in helix V
- E Is formed from 11-*cis* retinal plus opsin

Light and the photochemistry of vision: Answers

- 6 A True
B True
C False
D False
E True

Electromagnetic radiation is emitted in quanta and 1 quanta of light is a photon. The energy of light is directly proportional to frequency and inversely proportional to wavelength. A watt is 10 000 000 ergs per second.

- 7 A False
B True
C False
D True
E False

The lens absorbs more blue light than red, due to this absorption there is greater transmission of light of longer wavelength, and at best some 50–60% of the available light reaches the retina. The radiant power per unit area of retinal image is independent of the distance of the eye from the source, as at greater distances the image is correspondingly smaller. The photopic luminous efficiency curve has a peak at a longer wavelength than the scotopic curve.

- 8 A True
B False
C True
D False
E True

Rhodopsin is the photopigment found in rods and therefore has a density spectrum equal to human scotopic sensitivity. It is formed from 11-*cis* retinal attached to the 348 amino acid, seven helix, protein opsin at lysine no. 206 in helix VII.

9 Phospholipid membrane discs

- A Are found in rods and cones
- B In rods are eventually engulfed by the retinal pigment cells
- C Are maximally shed from rods in the evening
- D Are continuous with the outer plasma membrane in cones
- E Contain proteins formed in the outer segment

10 In the presence of light

- A 11-*cis* retinal is isomerized to all *trans*
- B The first intermediate to be formed is pararhodopsin
- C The initial thermolysis of rhodopsin is reversible
- D Activated rhodopsin catalyses the activation of phosphodiesterase directly
- E Activated phosphodiesterase increases the concentration of cyclic guanosine monophosphate (GMP)

11 The regeneration of rhodopsin

- A Requires NADPH
- B Occurs in the presence of light
- C Involves the retinal pigment epithelium
- D Is not possible until all *trans* retinal is split from opsin
- E Involves retinal isomerase

Light and the photochemistry of vision: Answers

- 9 A True
B True
C False
D True
E False

Phospholipid discs are found in both rods and cones. In rods the discs are separate from the outer plasma membrane throughout the outer segment, and are engulfed by the retinal pigment cells with maximal shedding in the morning. In cones the discs are continuous with the outer plasma membrane and have a much lower rate of disc turnover, maximal in the evening. The proteins in the disc are formed in the inner segment.

- 10 A True
B False
C True
D False
E False

Light energy isomerizes 11-*cis* retinal to all *trans* via a series of intermediates, hypsorhodopsin or bathorhodopsin are the first to be formed, then lumirhodopsin and metarhodopsin I and II, and finally pararhodopsin. The initial steps to lumirhodopsin and metarhodopsin are reversible. The activated rhodopsin, via transducin, indirectly catalyses the activation of phosphodiesterase, which then in turn decreases the concentration of cyclic GMP.

- 11 A True
B False
C True
D True
E True

The regeneration of rhodopsin requires the dark, NADPH, the retinal pigment epithelium, retinal isomerase, and for the all *trans* retinal to be split from opsin.

12 Regarding the retinoids

- A Within the circulation they are free in the plasma
- B They are picked up by receptors in the retinal pigment epithelium
- C In the dark retinol is in increased concentration in the retinal pigment epithelium
- D They are protein bound in transport from the retina to the retinal pigment epithelium
- E Within the retinal pigment epithelium retinol is converted to retinal

13 In the dark

- A Na^+ enters the rod inner segment
- B Rods are depolarized
- C Na^+ is actively pumped out of the rod outer segment
- D Cyclic GMP maintains the Na^+ current
- E Ca^{2+} concentration within the rod outer segment is low

14 Sufficient quanta of light

- A Cause bipolar cell hyperpolarization
- B Decrease the permeability of the cone outer segment to Na^+
- C Inhibit the Na^+/K^+ ATPase in the inner segment
- D Undergo energetic amplification by the photoreceptors
- E Increase the intrarod ATP concentration

Light and the photochemistry of vision: Answers

- 12 A False
B True
C False
D True
E True

Retinoids are protein bound in the circulation, are picked up by protein receptors in the retinal pigment epithelium, and are protein bound in transport from the retina to the retinal pigment epithelium. In the light, retinol is transported into the retinal pigment epithelium and retinal is transported out. Retinol is converted to retinal in the retinal pigment epithelium.

- 13 A False
B True
C False
D True
E False

In the dark, a 'dark current' is caused by the active exit of Na^+ from the inner segment, and passive entry of Na^+ into the outer segment, thus depolarizing the photoreceptor. The current is maintained by cyclic GMP and high intrarod concentrations of Ca^{2+} .

- 14 A True
B True
C False
D True
E False

Sufficient light will hyperpolarize the photoreceptor, and in turn hyperpolarize the bipolar cell. The hyperpolarization is a result of a decreased permeability of the cone outer segment to Na^+ , the energy of the light having been amplified through an enzyme cascade. Light does not inhibit the inner segment Na^+/K^+ ATPase. The concentration of ATP decreases in the light as it is used to deactivate phosphodiesterase.

15 In transduction

- A Guanosine triphosphate (GTP) is formed
- B Guanosine diphosphate (GDP) is released from transducin by activated rhodopsin
- C Phosphodiesterase is inactivated by dephosphorylation
- D A decreased Ca^{2+} concentration increases the deactivation of activated phosphodiesterase
- E There is positive feedback

16 Regarding metabolism

- A The retina accumulates lactate even with an adequate oxygen supply
- B There is a dense accumulation of mitochondria in the ellipsoid region of photoreceptor cells
- C The retina has a large store of glycogen
- D Insulin is essential for retinal glucose uptake
- E Na^+/K^+ ATPase is absent in the outer segment

17 The following are used as neurotransmitters in the retina

- A ACh
- B 5HT
- C NA
- D Dopamine
- E GABA

Light and the photochemistry of vision: Answers

- 15 A False
B True
C False
D True
E False

In transduction GDP is formed from GTP, activated rhodopsin releasing GDP from transducin and allowing GTP to bind. Phosphodiesterase is deactivated by phosphorylation, the deactivation accelerated by a low Ca^{2+} concentration. There is negative feedback through the decreased Ca^{2+} concentration.

- 16 A True
B True
C False
D False
E True

In retinal metabolism the retina accumulates lactate even with an adequate oxygen supply due to the predominance of anaerobic metabolism. The photoreceptors have a dense accumulation of mitochondria in their ellipsoid region, the retina does not store glycogen, but insulin is not essential for retinal glucose uptake. The Na^+/K^+ ATPase is absent in the outer segment.

- 17 A True
B True
C False
D True
E True

Retinal neurotransmitters include acetylcholine, serotonin, dopamine and GABA. Noradrenaline is not a neurotransmitter in the retina.

18 Which of the following statements are true?

- A The photopic luminosity curve matches the composite spectrum of the three cone iodopsins
- B Peak rhodopsin sensitivity is at 450 nm
- C The cone absorption spectra are at 400, 475 and 525 nm
- D Once phagocytosed by the retinal pigment epithelium only a small proportion of the retinol is recycled
- E The retinal pigment epithelium is protected from degeneration by reducing agents

Light and the photochemistry of vision: Answers

- 18** A True
B True
C False
D False
E True

The peak rhodopsin sensitivity is at 500 nm. The photopic luminosity curve matches the composite spectrum of the three cone iodopsins at 450, 525 and 555 nm for blue green and red respectively. Most retinal is recycled when phagocytosed and is protected from degeneration by reducing agents such as vitamin E.

The retina, optic pathway and visual cortex

1 The retina

- A Contains unmyelinated optic fibres
- B At the vitreal face has the expanded feet of the glial cells of Müller
- C Has a clear physical barrier to diffusion from the vitreous to the retina
- D Has the photoreceptor cell body in the inner nuclear layer
- E Has an exclusive blood supply to the inner one-third

2 The retina

- A Can be divided into 10 layers
- B Develops from neuroendothelium
- C The retinal artery has tight endothelial junctions
- D The choroidal capillaries have no gap junctions
- E The glial cells of Müller extend to the inner nuclear layer

3 The photoreceptors

- A Are randomly orientated
- B Are related to ciliated ependymal cells
- C Have an inner and outer segment linked by a nine plus two arrangement of microtubules
- D Contain ribosomes and Golgi apparatus at the apex of the inner segment
- E Contain abundant melanosomes

The retina, optic pathway and visual cortex: Answers

- 1 A True
B True
C False
D False
E False

The retina contains only unmyelinated optic nerve fibres. The expanded feet of the glial cells of Müller are at the vitreal face, they provide no barrier to diffusion. The photoreceptor cell body is in the outer nuclear layer. The inner two thirds of the retina have exclusive arterial supply from the choroidal capillaries.

- 2 A True
B False
C True
D False
E False

The retina is best understood by division into 10 layers, all developed from neuroepithelium. The retinal artery has tight junctions whereas the choroidal capillaries are fenestrated. Müller's cells extend the full thickness of the retina.

- 3 A False
B True
C False
D True
E False

Photoreceptors are optimally orientated for interaction with light. They are related to ciliated ependymal cells and have an inner and outer segment linked by just nine microtubules. The large numbers of ribosomes and Golgi apparatus are at the apex of the inner segment. Melanosomes are abundant in the retinal pigment epithelium, not in the photoreceptors.

The retina, optic pathway and visual cortex: Questions

4 Photoreceptors

- A Reach the pigment epithelium at their apex
- B Cones have a conical inner segment
- C The outer segment contains flat saccules
- D The saccules are isolated from each other in cones
- E Show movement of insoluble proteins from the inner to the outer segment

5 Retinal attachment is due to

- A The distribution of photoreceptors
- B Melanosomes in the retinal pigment epithelium
- C Intraocular pressure
- D Factors regulating the fluid in the intraretinal space
- E Cohesive acid mucopolysaccharide in the ocular ventricle

6 Regarding the distribution of photoreceptors

- A The retina contains approximately 20 times more rods than cones
- B There are approximately 100 million cones
- C The maximum number of rods are found at the periphery
- D The blind spot contains more rods than cones
- E The central foveola contains only cones

The retina, optic pathway and visual cortex: Answers

- 4 A True
B False
C True
D False
E True

The photoreceptors reach the pigment epithelium at their apex. Cones are so named due to a conical outer segment. The outer segment of both rods and cones contains flat saccules, these are isolated from each other in the rods. Insoluble proteins are transported from the inner to the outer segment.

- 5 A False
B False
C True
D True
E True

The factors contributing to retinal attachment are believed to be the intraocular pressure, the regulation of fluid in the intraretinal space, and the action of cohesive acid mucopolysaccharides in the ocular ventricle.

- 6 A True
B False
C False
D False
E True

There are 20 times more rods than cones with approximately 6 million cones and 100 million rods. The maximum density of rods is at 20° from the foveola, which contains only cones. The blind spot contains neither rods nor cones.

The retina, optic pathway and visual cortex: Questions

- 7 Which of the following statements is true**
- A The maximum photoreceptor density is 160 000/mm²
 - B Beyond 20° there are no cones
 - C The parafovea surrounds the perifovea
 - D The foveola is avascular
 - E Trichromatic colour vision is restricted to a central area of 9 mm diameter
- 8 Regarding cells and their connections**
- A A photoreceptor is always connected to a bipolar cell
 - B There is greater convergence of rods than cones
 - C Amacrine cells have no morphologically definable axon
 - D Direct electrical synapses predominate in the retina
 - E In the macula the receptor to ganglion cell ratio is 2:1
- 9 Which of the following are postulated neurotransmitters**
- A Glutamate
 - B Aspartate
 - C Glycine
 - D Dopamine
 - E Asparagus

The retina, optic pathway and visual cortex: Answers

- 7 A True
B False
C False
D True
E True

In the avascular foveola the photoreceptors reach a maximum density of 160 000/mm². Cones extend beyond 20° in small numbers, but trichromatic colour vision is restricted to a central area of 9 mm diameter. The perifovea surrounds the parafovea.

- 8 A True
B True
C True
D False
E False

A photoreceptor is always connected to a bipolar cell. There is greater convergence of rods than cones, with the macular cones connected to ganglion cells in the ratio 1:1. Amacrine cells do not have any morphologically definable axon. Direct electrical synapses are found in the retina, but chemical transmission predominates.

- 9 A True
B True
C True
D True
E False

The asparagus is, indeed, a vegetable.
(Having reached this far you deserve a laugh.)

10 Within the retina

- A Both ganglion and amacrine cells have a full action potential
- B Photoreceptors have maximal transmission of neurotransmitter in the dark
- C Photoreceptors can show on-centre and off-centre properties
- D Ganglion cells can be classified according to their response to light
- E Amacrine cells can show response to the onset and termination of light

11 Regarding the optic nerve head

- A The optic disc contains 10% astrocytes
- B Fibres with information from the the temporal visual field are situated temporally
- C The nerve axons are in contact with the central retinal vessels
- D The nerve head is usually oval in the horizontal
- E The lamina cribrosa transmits myelinated nerve fibres

12 In normal subjects

- A The cup to disc ratio is 0.51
- B The cup to disc ratio differs significantly between the two eyes in 92%
- C 75% show an optic cup
- D 30% have a visible cribriform plate
- E The neuroretinal rim area is 1.75 mm^2

The retina, optic pathway and visual cortex: Answers

- 10** A False
B True
C False
D True
E True

Within the retina only ganglion cells have a full action potential. Maximal transmission of neurotransmitter occurs in the dark. On- and off-centre properties of transmission only occur at a higher level of processing than the photoreceptor, therefore amacrine cells can show response to the onset and termination of light, and ganglion cells are classified according to their response to light.

- 11** A True
B False
C False
D False
E False

At the optic nerve head there are 10% astrocytes, which separate the nerve axons from the retinal vessels. Temporal fibres are from the nasal field and vice versa, the fibres only becoming myelinated once beyond the lamina cribrosa. The head is normally round or oval in the vertical.

- 12** A True
B False
C True
D False
E True

In normal subjects the cup/disc ratio is < 0.3 , and does not differ significantly in 92%. 75% show an optic cup, 10% have a visible cribriform plate, and the average neuroretinal rim area is 1.75 mm^2

The retina, optic pathway and visual cortex: Questions

13 Within the retina

- A Amacrine cells are the most diverse
- B Bipolar cells establish centre surround characteristics
- C Glial cells pump excess K^+ into the vitreous
- D There are approximately three million optic nerve axons
- E Müller cells have a homeostatic function

14 Regarding interneural connections

- A Off bipolar cells are hyperpolarized by glutamate
- B Negative feedback to the rods and cones is frequently by GABA
- C Interplexiform cells modify centre surround characteristics
- D Amacrine cells feedback to bipolar cells
- E Positive feedback is more common than negative

15 Which of the following statements are true

- A There are more ganglion cells in the temporal retina
- B The optic nerve has 30 mm slack in the orbit
- C At the optic chiasm there is 60% decussation
- D 70% of fibres leave the optic tract prior to the lateral geniculate nucleus (LGN)
- E Fibres passing to the superior colliculus synapse in the LGN

The retina, optic pathway and visual cortex: Answers

- 13** A True
B False
C True
D False
E True

Within the retina the amacrine cells are the most diverse, with some 25 subclasses. Centre surround characteristics are established by the horizontal cells, and the glial cells of Müller have an important homeostatic role, involving glycogenolysis and electrolyte balance, pumping excess K^+ into the vitreous. There are about one million optic nerve axons.

- 14** A False
B True
C True
D True
E True

Within the retina (of the cat) off bipolars are depolarized by glutamate, negative feedback to the photoreceptors is frequently by GABA, interplexiform cells modify centre surround characteristics established by horizontal cells, amacrine cells feedback to bipolars, and negative feedback is by far the most common.

- 15** A False
B False
C True
D False
E False

There are more ganglion cells in the nasal retina, with, therefore, 60% decussation of nasal fibres at the chiasm. The optic nerve has 12 mm slack in the orbit to facilitate movement. 30% of optic nerve fibres leave the optic tract prior to the LGN, some of these passing to the superior colliculus.

16 Optic nerve fibres pass to

- A The Edinger–Westphal nucleus
- B The parvocellular reticular formation
- C The suprachiasmatic nucleus of the hypothalamus
- D The LGN
- E The superior colliculus

17 The LGN

- A Is retinotopic in structure
- B Is laminated
- C Has six layers
- D Has four dorsal magnocellular layers
- E The ventral two layers are parvocellular

18 Regarding the connections of the LGN

- A The ipsilateral eye passes to layers one, four and six
- B Layers one, two and three are retinotopic
- C Each layer is in register with the next
- D Synaptic connections are both intra- and inter-laminar
- E Triads are formed between interneurons, retinogeniculate and geniculocortical neurons

19 Regarding ganglion cells

- A The receptive field can be defined as on centre or off centre
- B The two opposite field types are antagonistic
- C The neurons can be divided into X, Y and W subtypes
- D X neurons have a phasic response
- E Y neurons have a tonic response

The retina, optic pathway and visual cortex: Answers

- 16** A True
B True
C True
D True
E True
All true.

- 17** A True
B True
C True
D False
E False

The LGN is laminated in six retinotopic layers, with four dorsal parvocellular, and two ventral magnocellular layers.

- 18** A False
B False
C True
D True
E True

Within the LGN the ipsilateral eye passes to layers two, three and five, and the contralateral eye passes to layers one, four and six. Every layer is retinotopic, and hence in register with the next. Synaptic connections are both intra- and inter-laminar, with triads between interneurons, retinogeniculate neurons and geniculocortical neurons a particular feature.

- 19** A True
B True
C True
D False
E False

Ganglion cells are divided into X, Y, and W neurons based on their response to a stimulus (X tonic and Y phasic), size, conduction, projection and function. All show antagonistic on-centre and off-centre receptive fields.

The retina, optic pathway and visual cortex: Questions

20 X ganglion cells

- A Have a large receptive field
- B Have a fast conduction time
- C Have a fast projection to the cortex
- D Are orientated to detect form
- E Show linear spatial summation

21 Y ganglion cells

- A Have a large field
- B Have a conduction of 30–40 m/s
- C Have action potentials that reach the LGN prior to those from X cells
- D Project to the superior colliculus
- E Are orientated to detect movement

22 Regarding the LGN

- A The laminae have functional specificity
- B Layers one and two are colour coded
- C Layers one and two have input from Y cells
- D The parvocellular layers with Y input are colour opponent
- E W ganglion cells project predominantly to the parvocellular layers

23 The striate cortex

- A Is on both sides of the calcarine fissure
- B Is divided into four layers
- C Geniculate afferents pass to layer IV
- D Layer IV C alpha is predominantly parvocellular
- E Layer V projects to the superior colliculus

The retina, optic pathway and visual cortex: Answers

- 20** A False
B False
C False
D True
E True

X ganglion cells have a small receptive field, slow conduction, slow projection, show linear spatial summation, and are therefore orientated to detect form.

- 21** A True
B True
C True
D True
E True

All true. The large rapid Y ganglion cells are optimally configured to detect movement, but carry little in the way of fine detail.

- 22** A True
B False
C True
D False
E True

The LGN laminae differ in their input and output and as such have functional specificity. Layers one and two, the magnocellular layers, have Y input and are therefore not colour coded. The parvocellular layers, layers three to six, have X and W input and are colour opponent.

- 23** A True
B False
C True
D False
E True

The striate cortex is situated on both sides of the calcarine fissure. It is divided into six layers, each with specific input and output. The magnocellular and parvocellular division is continued from the ganglion cells of the retina to the cortex. Geniculate afferents pass to layer IV, with subdivision IV C alpha predominantly magnocellular. Some of the output from layer V passes to the superior colliculus.

24 Regarding the arrangement of the visual cortex

- A The cortex shows columnar organization
- B The ocular dominance columns from each eye lie next to each other
- C The fields do not exactly correspond
- D The columns are arranged in a linear array
- E There are no dominance columns from the temporal crescent of the visual field

25 Projection from the visual cortex can be

- A To the LGN
- B Direct to the retina
- C Direct to the frontal eye field
- D To area 9 to recognize faces
- E To areas 20 and 21 for shape analysis

26 Which lesions would produce a homonymous hemianopia

- A To the optic radiation
- B To the optic tract
- C To the optic nerve
- D At the chiasm
- E At the retina

The retina, optic pathway and visual cortex: Answers

- 24 A True
B True
C False
D False
E True

The visual cortex shows columnar organization with exactly corresponding ocular dominance columns from each eye lying next to each other in a whorl-like array. The temporal crescent of the visual field is monocular and therefore has no dominance columns.

- 25 A True
B False
C True
D False
E True

The visual cortex projects to the LGN, the frontal eye field, area 37 to recognize faces, areas 20 and 21 for shape analysis, to areas 18 and 19 for 'feature extraction', and to the contralateral striate cortex. There is no direct projection to the retina.

- 26 A True
B True
C False
D False
E False

A homonymous hemianopia would be produced by a lesion posterior to the chiasm, in either the optic tract, optic radiation or visual cortex.

Visual acuity and colour sense

1 Regarding visibility

- A Visibility is best defined as the minimum size of target necessary to be seen in an otherwise empty field
- B The limit of visibility is 0.5 s of arc
- C Recognition is fundamental to resolution
- D The limit of recognition is 0.5 s of arc
- E Localization is more sensitive than resolution

2 Acuity may be affected by

- A Contrast
- B Colour
- C Pupil size
- D Familiarity
- E Exposure

3 With respect to the Snellen chart

- A Each character has five notional elements
- B At the specified distance each element subtends 1 minute of arc
- C 6/6 represents a subtended angle of 5 min of arc for the entire letter
- D All letters have the same discriminability
- E The scale directly represents the minimum angle of resolution

Visual acuity and colour sense: Answers

- 1 A True
B True
C False
D False
E True

Visibility is defined as the minimum size of target necessary to be seen in an otherwise empty field. The limit of visibility is 0.5 s of arc, the limit of recognition is 0.5 m of arc. Resolution is fundamental to recognition. Localization is more sensitive than resolution.

- 2 A True
B True
C True
D True
E True

All true. Acuity may be affected by physical, physiological and psychological factors, including illumination, motion, contrast, colour, age, drugs, pupil size, expectation, familiarity and motivation.

- 3 A True
B True
C True
D False
E False

In the Snellen chart each character has five notional elements, each subtending 1 min of arc at the specified distance, the entire letter then subtending 5 min of arc at that distance. The scale represents the reciprocal of the minimum angle of resolution, thus 6/6 subtends 1 min of arc, and 6/12 subtends 2 min of arc for the element to be discriminated.

4 Contrast sensitivity

- A Is directly proportional to contrast
- B Peaks at 2.5 spatial frequency cycles/degree of visual angle
- C Represents the visual system's sensitivity to light
- D Can be tested using the Snellen chart
- E May be abnormal in eyes with cataracts

5 Problems in determining sensory thresholds involve

- A Specification of the stimulus
- B Transduction in the sensory organ
- C Scales of measurement
- D Techniques of obtaining threshold values
- E Anatomical substrates

6 Factors affecting the spread of light entering the eye include

- A Diffraction, increased with a larger pupil
- B Aberration, increased with a smaller pupil
- C Scatter
- D Contrast
- E Focussing

7 Visual acuity is decreased by an increase in

- A Refractive error
- B Retinal eccentricity
- C Illuminance
- D Duration
- E Pupil size greater than 2.5 mm

Visual acuity and colour sense: Answers

- 4 A False
B True
C False
D False
E True

Contrast sensitivity is inversely proportional to contrast. It represents the visual system's sensitivity to spatial information and can be tested using sine wave gratings with a peak at 2.5 spatial frequency cycles/degree of visual angle. It is usually reduced in eyes with cataracts.

- 5 A True
B True
C True
D True
E True

Accurate sensory thresholds are very difficult to obtain.

- 6 A False
B False
C True
D False
E True

The spread of light entering the eye is affected by diffraction (worse with a smaller pupil), aberration, (worse with a larger pupil), scatter, absorption and focussing. It is not affected by contrast.

- 7 A True
B True
C False
D False
E True

Visual acuity is decreased by an increase in refractive error, retinal eccentricity and pupil size above 2.5 mm. It is decreased by a decrease in illumination or duration.

8 Regarding colour

- A Colour is perceived at the retinal level
- B Spectral sensitivity is a function of rates of absorption of photons
- C The three cones correspond to maximum absorbance at 425, 530 and 560 nm
- D Cone neuronal output is paired in an opponent manner
- E Cones detect colours

9 With respect to colour coding

- A The neutral point is detected at ganglion cell level
- B Ganglion cells have a wide distribution of neutral points
- C Only large differences in wavelength can be discriminated
- D The minimum detectable difference is dependent on the frequency distribution of amacrine cells
- E Colour discrimination is constant across the spectrum

10 Which of the following statements are true

- A Primary colours are those where one cannot be matched by a mix of the other two
- B There are only three possible primary colours
- C Trichromacy is the basis for normal colour vision
- D The colour perceived is independent of luminance
- E Chromatic contrast boundaries can change the appearance of a colour

Visual acuity and colour sense: Answers

- 8 A False
B True
C True
D True
E False

Colour is perceived at the cortical level, not before. Spectral sensitivity is a function of the rates of absorption of photons, with the three cone iodopsins having maximum absorbance at differing wavelength, namely 425, 530 and 560 nm. The cones detect contrast boundaries, with their output then paired in an opponent manner, red/green and blue/yellow (red + green).

- 9 A True
B True
C False
D False
E False

Colour coding requires the detection of a neutral point between opponent cone pairs. The neutral point is detected at ganglion cell level. Ganglion cells have a wide distribution of neutral points such that very small differences in wavelength can be discriminated. The minimum detectable difference is therefore dependent on the frequency distribution of ganglion cells, and varies across the spectrum.

- 10 A True
B False
C True
D False
E True

Primary colours are those where one cannot be matched by mixing the other two. There are many three primary triplets possible. Trichromacy is the basis for normal colour vision. The colour perceived is dependent on both luminance and chromatic contrast boundaries.

11 Colour discrimination

- A Is poorest at long wavelengths
- B Is maximal at mid-spectrum
- C Is maximal at the fovea
- D Varies across the visual field
- E Is affected by the distribution of rods

12 Regarding colour deficiency

- A Protanomalous trichromats have a decreased blue response
- B Deuteranopes are green colour-blind
- C Tritanomaly is the commonest deficiency
- D Monochromats see contrast only
- E The protan and deutan alleles are on the short arm of the X chromosome

Visual acuity and colour sense: Answers

- 11 A False
B True
C True
D True
E False

Colour discrimination varies across the spectrum and across the visual field according to the frequency distribution of the three cones, being poorest at short wavelengths, and maximal at mid-spectrum in the fovea. Blue cones are the most scarce and therefore have poorer spatial resolving power. The rods are not involved in colour vision.

- 12 A False
B True
C False
D True
E False

Protanomalous trichromats have decreased red response, but all three cone types. Deuteranopes are green blind, lacking the green cone type. Monochromats lack all cones and see contrast only. The protan and deutan alleles are on the long arm of the X chromosome, and X-linked red/green colour blindness is the most common.

Binocular vision and adaptation

1 Regarding binocular vision

- A Binocular vision has a temporal component
- B Binocular parallax is essential to see depth
- C Each eye views a near object from a different angle
- D Angular disparity decreases with the square of the viewing distance
- E Visual assessment of depth is best at a distance of approximately 5 metres

2 Monocular depth clues include

- A Object overlay
- B Linear perspective
- C Angular disparity
- D Texture density
- E Motion parallax

Binocular vision and adaptation: Answers

- 1 A True
B True
C True
D True
E False

Binocular vision involves the simultaneous vision with two seeing eyes of the same visual field, and therefore has a temporal component. Each eye views a near object from a slightly different angle; this angular disparity gives rise to the binocular parallax essential to see depth. The angular disparity decreases with the square of the viewing field, the best assessment of depth is therefore as close as possible.

- 2 A True
B True
C False
D True
E True

Monocular depth clues include object overlay, linear perspective, light and shadow, texture density gradient and motion parallax.

3 Stereoscopically presented random dot patterns test

- A Julesz theory
- B Monocular feature extraction
- C Global stereopsis
- D Recognition
- E Diplopia

4 Panum's area

- A Is the range of angular disparities over which vision is single and fused
- B Varies with the eccentricity of the target
- C Varies with the colour of the target
- D Varies with the size of the target
- E Varies with the form of the target

5 Vergence movements

- A Can be induced as a reflex by an induced disparity
- B Have a latency of 160 ms
- C Are phasic
- D Are of constant speed
- E Are always driven by the cortex

Binocular vision and adaptation: Answers

- 3 A True
B False
C True
D True
E False

Stereoscopically presented random dot patterns can only be made to fuse in the presence of global stereopsis, and test Julesz theory that the brain has a cooperative process whereby trial matches in one part of the image affect the likelihood of matches in another part. No feature need be visible monocularly, all the dots can be identical, and the binocular vision functions in the absence of any prior pattern or feature recognition.

- 4 A True
B True
C False
D False
E True

Panum's area covers the range of angular disparities over which vision is single and fused. Too large an angle of disparity results in diplopia. The area varies with the eccentricity and form of the target but is independent of colour and size.

- 5 A True
B True
C False
D False
E False

Stereopsis requires accurate vergence movements to foveate. Vergence is a disparity driven, tonic reflex of 160 ms latency, with a speed proportional to the size of the disparity. Voluntary cortical drive can be imposed.

6 Stereopsis

- A Is present at birth
- B Is fully developed by 4 months
- C Can be eliminated by an artificially induced squint
- D Requires a level of tonic vergence
- E Is easily disrupted in early life

7 Regarding adaptation

- A The eye detects light over a range of $10^9:1$
- B Adaptation is principally photochemical
- C The rod threshold is approximately 6 quanta of light close in time and space
- D Bipolar cells are thought to be principal in neural adaptation
- E Photoreceptors only respond to change

8 Which of the following statements are true

- A The fully dark adapted eye is three log units more sensitive than the light adapted eye
- B The time required for dark adaptation is dependent on the number of bleached rods
- C The threshold is inversely proportional to the fraction of bleached rhodopsin
- D The dynamic range of cones varies with the background intensity
- E Light adaptation is more rapid than dark adaptation

Binocular vision and adaptation: Answers

- 6 A False
B False
C True
D True
E True

Stereopsis is not present at birth. It appears suddenly at 4 months and requires both a sensitivity in the cortical neurons, and a level of tonic vergence. It can be easily disrupted in early life, for example by a squint, which eliminates the binocular sensitivity of the cortical neurons.

- 7 A True
B False
C True
D False
E True

The eye is able to detect light over a huge range of approximately $10^9:1$, principally through neural adaptation, believed to be at the horizontal cell level and above. The absolute threshold has been calculated to be 6 quanta of light close in time and space. Through adaptation a constant signal is eventually lost, photo-receptors therefore only ultimately respond to change.

- 8 A True
B True
C False
D False
E True

The fully dark adapted eye is approximately 1000 times (three log units) more sensitive. Following a pulse of light the bleached rhodopsin regenerates, the threshold is then proportional to the fraction of bleached rhodopsin and the duration before the eye is again fully dark adapted is dependent on the number of rods bleached. Neural light adaptation is much faster than photo-chemical dark adaptation.

9 Which of the following statements are true

- A The absolute threshold is best defined as the minimum stimulus to evoke the sensation of light in the fully light adapted state
- B A single rod is sufficient to cause a synaptic stimulus
- C A single cone can cause an action potential in a ganglion cell
- D The absolute threshold involves spatial summation
- E Temporal summation is essential for a stimulus to be seen

10 Regarding entopic phenomena

- A Opaque opacities usually cause more visual disturbance than diffuse opacities
- B Opacities in the lens do not always lead to imperfections in the retinal image
- C The closer to the retina the more likely an opacity will interfere with the retinal image
- D Blood vessels in the retina are not seen due to lateral inhibition
- E Phosphenes are due to inadequate retinal stimuli

Binocular vision and adaptation: Answers

- 9 A False
B False
C True
D True
E False

The absolute threshold is the minimum stimulus to evoke the sensation of light in the fully dark adapted eye. A single cone is sufficient to cause an action potential, but it appears that several rods must summate to achieve the same. The absolute threshold therefore involves spatial summation. If a stimulus is large enough temporal summation is not essential for that stimulus to be seen.

- 10 A False
B True
C True
D False
E True

Opaque opacities usually cause less visual disturbance than diffuse as they do not scatter light. An opacity is more likely to interfere with the retinal image the closer it is to the retina as further forward the umbral cone may not reach the retina, for example in the lens. The retinal blood vessels are not seen due to adaptation. Phosphenes are seen as blue bands or dark spots and are due to inadequate retinal stimuli.

Time-dependent functions of vision

1 Regarding photopic and scotopic conditions

- A In photopic conditions a changing pattern of stimulation is more important for visual function than in scotopic conditions
- B Some ganglion cells can transmit either rod or cone signals
- C Temporal separation of rod and cone transmission occurs in scotopic conditions
- D In mesopic conditions both rod and cone receptor potentials are discernible
- E Ganglion cells are refractive to rod signals in photopic conditions

2 W ganglion cells

- A Have a small field size
- B Have a small axon
- C Have slow transmission
- D Are least in number
- E Project to the parvocellular layers of the LGN

Time-dependent functions of vision: Answers

- 1 A False
B True
C False
D True
E True

The visual system needs a changing pattern of stimulation to function irrespective of the light conditions. Some ganglion cells can transmit either rod or cone signals. In scotopic conditions only the slower rods are able to signal, as the light level increases to mesopic conditions both rods and cones signal until, once photopic levels are reached, the faster cone signals reach the ganglion cells first, leaving them refractive to the rod signals.

- 2 A False
B True
C True
D False
E True

The smallest W ganglion cells are the majority, making up some 50% of neurons. They are the smallest and slowest with the largest field size, projecting complex information to the parvocellular layers of the LGN.

3 Y ganglion cells

- A Have a wider distribution than X ganglion cells
- B Are more frequent than X
- C Have a phasic response to standing contrast
- D Are twice as fast as X
- E Project only to the LGN

4 X ganglion cells

- A Have poor spatial resolution
- B Have a short latency
- C Have predominantly bipolar input
- D Are less focus dependent than Y
- E Optimally require a large target

5 Which of the following statements are true

- A The separation of phasic and tonic information is maintained from the LGN to the cortex
- B Area 17 has input from X, Y and W ganglion cells
- C Area 18 has no X input
- D The superior colliculus has input from both the retina and cortex
- E The LGN may function as a 'foveation center'

Time-dependent functions of vision: Answers

- 3** A True
B False
C True
D True
E False

Y ganglion cells are less frequent than X, but with a wider distribution. They are larger, twice as fast, phasic, orientated to detect movement, and some project to the superior colliculus as well as the LGN.

- 4** A False
B True
C True
D False
E False

X ganglion cells are intermediate in size and speed. They are orientated to form with predominantly bipolar input, poor temporal resolution, short latency, and maximal response to a small target in perfect focus.

- 5** A True
B True
C True
D True
E False

The temporal separation of phasic and tonic information is maintained through to the cortex, such that while area 17 has input from X, Y and W ganglion cells, area 18 is biased for movement detection with no X input. The superior colliculus can function as a comparator with input from both the retina and the cortex, and as such may act as a foveation centre, comparing desired with actual foveation.

6 Temporal summation

- A Has photochemical and neural components
- B Is independent of luminance
- C Has a critical limit imposed by photochemical changes
- D The visual capacity for temporal summation is constant
- E The visual capacity for temporal summation depends on the level of adaptation

7 Regarding saccades

- A Optokinetic nystagmus can be used to measure scotopic thresholds
- B Objects moving toward the fovea attract fixation more strongly than those moving away
- C The tracking velocity of central vision is faster
- D Vision is suppressed during saccades
- E Phasic cells in the LGN may inhibit tonic cells during saccades

8 True or false

- A Microsaccades are essential to sustained fixation
- B Microsaccades are due to antagonistic extraocular muscles
- C A long flash is seen as brighter than a short one
- D The optimal duration for flash brightness is >200 ms
- E The pupil response to light is unaffected during saccades

Time-dependent functions of vision: Answers

- 6 A True
B False
C False
D False
E True

Temporal summation has both photochemical and neural components. It affects how long a light has to shine to be seen, and depends on the luminance, with the critical limit imposed by neural summation. The visual capacity for temporal summation is not constant, depending on the state of adaptation, the background luminance, and spatial summation.

- 7 A True
B True
C False
D True
E True

Optokinetic nystagmus is an involuntary reflex and can therefore be used to measure visual thresholds. Objects moving towards the fovea attract fixation more strongly than those moving away, with the tracking velocity of peripheral vision faster than that of central vision. Vision is suppressed during saccades, possibly by phasic cells inhibiting tonic.

- 8 A True
B True
C False
D False
E False

During sustained fixation the image would be lost by adaptation if it were not kept moving over several receptors by microsaccades produced by the antagonistic extraocular muscles. Both vision and pupil response are suppressed during saccades. A brief flash is seen as brighter than a longer one, with an optimum of 50–100 ms duration, after which the intensity is reduced by adaptation.

9 Regarding critical flicker frequency

- A Flicker changes to fusion suddenly and at specific frequency
- B Is a measure of the temporal resolving power of the visual system
- C Is increased by decreased luminance
- D Is lower for rods than cones
- E Is increased with an increase in the stimulus area

10 Visual masking

- A Takes place wholly at the level of the LGN
- B Involves interactions of stimuli to alter their detectability
- C Includes the masking of light by light
- D Includes the masking of a pattern by a pattern
- E Includes the masking of a pattern by light

Time-dependent functions of vision: Answers

- 9** A False
B True
C False
D True
E True

Critical flicker frequency is the gradual range of frequencies at which there is a change from flicker to fusion. It is a measure of the temporal resolving power of the visual system. The range is increased by increased luminance and stimulus area, and is lower for rods than cones.

- 10** A False
B True
C True
D True
E True

Visual masking involves the interactions of stimuli that alter their visibility, detectability, or threshold. It takes place throughout the neural network from receptor to cortex. The four significant categories include the masking of light by light, pattern by structurally related pattern, pattern by structurally unrelated pattern, and pattern by light.