1. The diagram below shows a nerve pathway in an animal.

(a) The nerve pathway shown in the diagram may be regarded as a simple reflex arc. Use the diagram to explain why.

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___________________________________________________________________

___________________________________________________________________

(b) Suggest two advantages of simple reflexes.

1. _________________________________________________________________

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2. _________________________________________________________________

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___________________________________________________________________
In the nerve pathway in the diagram, synapses ensure that nerve impulses only travel towards the muscle fibre.

Explain how.

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(2)

Axon P was found to conduct impulses much faster than other axons in the nerve pathway shown in the diagram.

Describe and explain one feature of axon P that might cause this difference.

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(2)
(Total 7 marks)
When a person looks directly at an object, its image is focused on the fovea.

(a) When the image is focused on the fovea, the person sees the object in colour. Explain why.

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(Extra space)

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(b) Vision using the fovea has high visual acuity but low sensitivity to light compared with vision using other parts of the retina.

(i) Explain why vision using the fovea has high visual acuity.

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(Extra space)

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(ii) Explain why vision using other parts of the retina has high sensitivity to light.

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(Extra space)

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(Total 7 marks)
A biologist investigated the stimulation of a Pacinian corpuscle in the skin of a fingertip. She used microelectrodes to measure the maximum membrane potential of a Pacinian corpuscle and its sensory neurone when different pressures were applied to the fingertip.

The figure below shows the Pacinian corpuscle, its sensory neurone and the position of the microelectrodes.

The table below shows some of the biologist’s results.

<table>
<thead>
<tr>
<th>Pressure applied to the fingertip</th>
<th>Membrane potential at P / millivolts</th>
<th>Membrane potential at Q / millivolts</th>
</tr>
</thead>
<tbody>
<tr>
<td>None</td>
<td>–70</td>
<td>–70</td>
</tr>
<tr>
<td>Light</td>
<td>–50</td>
<td>–70</td>
</tr>
<tr>
<td>Medium</td>
<td>+30</td>
<td>+40</td>
</tr>
<tr>
<td>Heavy</td>
<td>+40</td>
<td>+40</td>
</tr>
</tbody>
</table>

(a) Explain how the resting potential of –70 mV is maintained in the sensory neurone when no pressure is applied.

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(2)
(b) Explain how applying pressure to the Pacinian corpuscle produces the changes in membrane potential recorded by microelectrode P.

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(3)

(c) The membrane potential at Q was the same whether medium or heavy pressure was applied to the finger tip. Explain why.

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(2)

(d) Multiple sclerosis is a disease in which parts of the myelin sheaths surrounding neurones are destroyed. Explain how this results in slower responses to stimuli.

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(2)

(Total 9 marks)
Read the following passage.

Complete achromatopsia is a form of complete colour blindness. It is caused by having only rods and no functional cone cells. People with complete achromatopsia have difficulty in seeing detail. Complete achromatopsia is caused by an autosomal recessive allele and is usually very rare in populations with only one in 40 000 being affected. However on the Pacific island of Pingelap ten percent of the population are affected.

One form of red-green colour blindness is caused by a sex-linked recessive allele which affects more men than women. People with this red-green colour blindness are unable to distinguish between red and green, and also between other colours. They have green-sensitive cones but the photoreceptive pigment they contain does not function.

Scientists investigated the use of gene therapy to correct red-green colour blindness in monkeys. They injected viruses containing the gene for the green-sensitive pigment directly into the eyes of the monkeys. Although the monkeys maintained two years of colour vision, there is debate on whether this form of gene therapy is worthwhile. No clinical trials of this procedure have been carried out on humans. Current research into the treatment of red-green colour blindness involves the use of induced pluripotent stem cells (iPS cells). The use of iPS cells could have advantages over the use of gene therapy.

Use the information in the passage and your own knowledge to answer the following questions.

(a) People with complete achromatopsia have difficulty in seeing detail (lines 2–3).

Explain why.

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(b) Ten percent of the population on the Pacific island of Pingelap are affected by complete achromatopsia (lines 3–6).

Use the Hardy-Weinberg equation to calculate the percentage of this population who are heterozygous for this disorder. Show your working.

Answer = ____________________ %

(2)

(c) Red-green colour blindness affects more men than women (lines 7–8).

Explain why.

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(2)

(d) People with red-green colour blindness are unable to distinguish between red and green, and also between other colours (lines 8–10).

Explain why.

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(3)
Current research into the treatment of red-green colour blindness involves the use of induced pluripotent stem cells (iPS cells) (lines 17–19).

Suggest how iPS cells could correct red-green colour blindness.

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The use of iPS cells could have advantages over the use of gene therapy to correct red-green colour blindness (lines 19–20).

Using the information from the passage, suggest and explain reasons why.

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The human retina contains three types of cone cells:

- cone cells sensitive to red light
- cone cells sensitive to green light
- cone cells sensitive to blue light.

Staring at a white card causes all three types of cone cells to be stimulated.

A student investigated the duration of afterimages using red squares and purple squares. His results are shown in the table.

<table>
<thead>
<tr>
<th>Colour of square</th>
<th>Cone cell(s) stimulated</th>
<th>Colour of afterimage</th>
<th>Mean duration of afterimage / seconds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Red</td>
<td>Red</td>
<td>Blue-green</td>
<td>15</td>
</tr>
<tr>
<td>Purple</td>
<td>Red and blue</td>
<td>Green</td>
<td>12</td>
</tr>
</tbody>
</table>

(a) Suggest a null hypothesis for this investigation.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(b) Suggest a statistical test that would be appropriate for this investigation. Give a reason for your answer.

Statistical test ________________________________________________

Reason for choice ________________________________________________

___________________________________________________________________
After the student had stared at a purple square, he saw a green afterimage. Suggest why.

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(3)

Use the results in the table to calculate the percentage increase in the mean duration of the afterimage after staring at the red square compared with the purple square.

Answer = ____________________________ %

(2)
(Total 7 marks)
The retinas in the eyes of humans and birds have cone cells that absorb light of different wavelengths.

A scientist recorded the absorption of light of different wavelengths by different types of human cone cells. Her results are shown in Figure 1. Each curve shows the absorption of light by one type of cone cell.

She also recorded the absorption of light of different wavelengths by different types of bird cone cells. These results are shown in Figure 2. Each curve shows the absorption of light by one type of cone cell.
Human colour vision has been explained by the trichromatic theory, meaning that it is based on three colours.

(a) Explain how the evidence from Figure 1 supports this theory.
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(2)

(b) Humans see more than three colours. Use evidence from Figure 1 to suggest how.
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(1)

(c) Compare and contrast the wavelengths of maximum absorption by the cone cells in bird retinas and human retinas.
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(3)
(d) Cone cells give higher visual acuity than rod cells. Explain how.

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(e) The cone density is highest on the fovea in the centre of the retina. In a human fovea there are 150 000 cones per mm\(^2\). The diameter of a human fovea is 1.4 mm. Calculate the number of cones on the human fovea. The formula for calculating the area of a circle is \(\pi r^2\).

Answer = _______________________________

(Total 10 marks)

(a) Describe how a Pacinian corpuscle produces a generator potential when stimulated.

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7. Doctors investigated the relationship between heart rate and arterial blood pressure. They recruited healthy volunteers. For each volunteer, they recorded their normal arterial blood pressure at rest. With each volunteer, they then carried out the following experiments.

<table>
<thead>
<tr>
<th>Experiment</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>They recorded heart rate at different blood pressures.</td>
</tr>
<tr>
<td>2</td>
<td>They repeated experiment 1 after injecting a drug that inhibited the parasympathetic nervous system.</td>
</tr>
<tr>
<td>3</td>
<td>They repeated experiment 1 after injecting a drug that inhibited the sympathetic nervous system.</td>
</tr>
</tbody>
</table>
The graph shows the results for one volunteer.

(b) Calculate the ratio of heart rate in experiment 2 to heart rate in experiment 3 at an arterial blood pressure of 10 kPa. Show your working.

Answer = ____________________

(2)
(c) What do these data suggest about the control of heart rate by the parasympathetic and sympathetic nervous systems in response to changes in arterial blood pressure?

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(Total 8 marks)

The graph shows the distribution of rod cells and cone cells across the retina of a human eye.

Use the diagram to explain why

(i) no image is perceived when light is focused on the retina at \( Y \);

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________

(1)
The diagram shows part of the retina in a human eye.

(a) Explain each of the following observations.

(i) When light falls on cells 1 and 2, only one spot of light is seen. But, when light falls on cells 2 and 3, two spots of light are seen.

(ii) An image formed at X is perceived in more detail than an image formed at Z.
(ii) When one unit of light energy falls on cell 3, no light is seen. But, when one unit of light energy falls on cell 3, one unit falls on cell 4 and one unit falls on cell 5, light is seen.

(b) Cells of the same type as cells 6 and 7 are found in large numbers at the fovea. This results in colour vision with high visual acuity.

Explain what causes vision using the fovea.

(i) to be in colour;

(ii) to have high visual acuity.

(Total 6 marks)
The diagram shows the distribution of cone cells across the retina of a human eye.

(a) On the diagram draw a line to show the distribution of rod cells across the retina.

(b) Nocturnal mammals are active at night. Describe how the number and distribution of rods and cones across the retina would differ in a nocturnal mammal from the number and distribution in a human. Explain your answer.

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(Total 5 marks)
After moving from bright light into darkness, it takes several minutes for the rod cells to recover their sensitivity. Researchers measured the ability of the rod cells to detect small spots of light of different colours and intensity after a person moved into darkness. The results are shown in Figure 1.

Figure 2 shows the amount of light of different wavelengths that rhodopsin absorbs.

(i) Explain why it takes time for the rod cells to recover their sensitivity to light after moving into darkness.

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(ii) Use information in Figures 1 and 2 to explain the differences in sensitivity of rod cells to red and green light.

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___________________________________________________________________
___________________________________________________________________
(iii) Suggest an explanation for the difference in sensitivity of rod cells to the white and green spots after 30 minutes.

___________________________________________________________________

___________________________________________________________________

(Total 5 marks)

(a) The blink reflex is caused by stimulation of receptors in the eye or eyelid. Suggest two types of stimuli to which these receptors might respond.

1. _________________________________________________________________

2. _________________________________________________________________

(1)

(b) In humans, resting blink rate varies widely from 8 to 24 blinks per minute. This variation could result in the investigations into effect of stimulation on blink rate producing means that are not significantly different. Explain why.

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(2)

(c) Some diseases cause changes in blink rate. Doctors do not often use blink rate to diagnose these diseases. Suggest two reasons why.

1. _________________________________________________________________

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(2)
A student completed an investigation to determine if the length of time eyes are closed before opening them affected blinking rate. His results are shown below.

The student did **not** draw a line of best fit.
Suggest **two** reasons why.

1. ________________________________________________
   ________________________________________________

2. ________________________________________________
   ________________________________________________

The student did **not** carry out repeats. He was still able to carry out a statistical test. Explain why.

___________________________________________________________________
___________________________________________________________________
___________________________________________________________________
(f) The blink reflex can be stopped by drugs which prevent the opening of sodium ion channel proteins in the axons of motor neurones. Suggest how these drugs affect the passage of nerve impulses along the axons. 
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(2)

(g) The blink reflex involves synapses. Channel proteins on presynaptic neurones are involved in reflex responses. Explain how. 
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(3)
A student wanted to investigate the resting blink rate in people 60 years of age and people 15 years of age. Describe how the student could find out whether there was a significant difference in blink rates between the two age groups.

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(3)
(Total 16 marks)

Answers should be written in continuous prose, where appropriate. Quality of Written Communication will be assessed in these answers.

The kidney plays an important part in the regulation of blood water potential. This involves control of the amount of water reabsorbed from the filtrate produced in the kidney tubules. The amount of water reabsorbed affects the volume of urine produced, the rate at which the bladder fills and how often it has to be emptied.

(a) Explain how the loop of Henle maintains the gradient of ions which allows water to be reabsorbed from filtrate in the collecting duct.

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(5)
(b) Explain how ADH is involved in the control of the volume of urine produced.

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(c) The diagram shows the systems involved in controlling the emptying of the bladder. In babies, emptying of the bladder is controlled by an autonomic reflex involving the internal sphincter muscle. Conscious control is learnt between the ages of two and three and involves the external sphincter as well.

Using information in the diagram, explain how the autonomic reflex arc is different from a simple reflex arc involving voluntary muscle;

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___________________________________________________________________

(Total 11 marks)
Mark schemes

1. (a) Only 3 neurones / nerve cells (in reflex arc)

(b) 1. Rapid;
2. Protect against damage to body tissues;
3. Do not have to be learnt;
4. Help escape from predators;
5. Enable homeostatic control.

2 max

(c) 1. Neurotransmitter only made in / stored in / released from pre-synaptic neurone;
2. (Neuro)receptors only on the post-synaptic membrane;

(d) 1. Axon \( P \) is myelinated;
2. So shows saltatory conduction / impulses jump between nodes of Ranvier

OR

3. Axon \( P \) has a larger diameter;
4. So less resistance to flow of ions.

Mark as 1 & 2 OR 3 & 4

2

2.

(a) Colour detected by \textit{cone} cells;
Fovea contains (only / mainly) cone cells;
\textbf{Three types of cone / cells described} / each sensitive to different wavelength / to red or green or blue;

\textit{Max 2 if 'rods' and 'cones' confused consistently}

(b) (i) Each receptor (in fovea)/each cone connected to separate neurone / rods/cells in other parts share a neurone;
Accept nerve cell / nerve fibre

1
(ii) Many rods in other parts of retina; Rhodopsin / pigment in receptors / rod cells very sensitive to light/ works in low light; Receptors / rods connected in groups to ganglion cell / neurone; Summation; Description of summation, eg if enough light above threshold hits any cells in the group, then get nerve impulses to brain/along optic nerve;

3 max

(a) 1. Membrane more permeable to potassium ions and less permeable to sodium ions;
2. Sodium ions actively transported / pumped out and potassium ions in.

(b) 1. (Pressure causes) membrane / lamellae to become deformed / stretched;
2. Sodium ion channels in membrane open and sodium ions move in;
3. Greater pressure more channels open / sodium ions enter.

(c) 1. Threshold has been reached;
2. (Threshold or above) causes maximal response / all or nothing principle.

(d) 1. Less / no saltatory conduction / action potential / impulse unable to ‘jump’ from node to node;
2. More depolarisation over length / area of membranes.

4.

(a) 1. No (functional) cones
OR
Only rods;
2. Cones are connected to a single neurone
OR
Several rods connected to a single neurone;
   Accept correct reference to retinal convergence
   Accept ‘bipolar/nerve cell’ for neurone
   Accept ‘many’ 2 or more for ‘several’

3. (Cones) Separate (sets of) impulses to brain
OR
(Rods) Single (set of) impulse/s to brain;
   Accept ‘optic nerve’ for brain
   Reject ‘signals’, ‘messages’ for ‘impulses’
   Accept ‘action potential’
(b) 1. Correct answer in range 42 – 44% = 2 marks;;
2. Incorrect answer but shows that understanding that $2pq = \text{heterozygous/carriers} = 1$ mark;

$$1 - (p^2 + q^2)$$

Accept understanding of $2pq$ by using calculation involving $2 \times$ two different numbers

(c) 1. (Gene/allele) is on the X chromosome;
2. Females require two alleles/females can be heterozygous/carriers and males require one allele;

Reference to allele is essential but only required once
Reference to females and males required
Reject dominant allele

(d) 1. Green sensitive pigment/cones non-functional
   OR
   Cones that detect green light non-functional;
2. Three different types of pigment/cone;
3. Other/different colours (‘seen’) due to stimulation of more than one cone/pigment;
   1, 2 and 3. Reject reference to ‘green cones’/‘blue cones’/‘red cones’ but once only
   1, 2 and 3. Reject reference to ‘green pigment’/‘blue pigment’/‘red pigment but once only and only if ‘green cones’ etc, (see above) has not been rejected.

(e) 1. (iPS cells) divide;
2. (iPS cells) develop/differentiate into (green sensitive) cones;
   Accept ‘produce’/‘specialise’/‘turn in to’/‘genes switched on’/‘turned on’ for ‘develop’ but ignore ‘grow’
   Reject develop into ‘green cones’/‘blue cones’/‘red cones’
   Ignore develop/differentiate into (blue/red sensitive) cones;
   Reject reference to develop in to ‘green pigment’/‘blue pigment’/‘red pigment
(f) 1. (Use of iPS cells) long-term;
   Accept ‘gene therapy short-term’ or ‘only two years’
   Accept ‘permanent’

2. (Use of iPS cells) less chance of rejection/immune response;

3. (Use of iPS cells) single treatment;
   Accept ‘gene therapy ‘regular/frequent treatment”

4. Harm/side effects from using viruses (in gene therapy);
   3 max

5. (a) The colour of the square has no effect on the duration of the afterimage / there is no difference in the duration of the afterimage with squares of different colours;

   Accept other ways of expressing the null hypothesis but reference must be made to colour of square and the duration of the afterimage

   Reject ‘there is no difference in the duration of the afterimage and the colour of the square’

(b) Standard error (with 95% confidence limits)/t test because looking for differences between means / measurements (from different samples);

   Test and reason required for the marking point

(c) 1. (When staring at purple) red (sensitive) and blue (sensitive) cones are stimulated / green (sensitive) cones are not stimulated;

2. Red and blue cone cells become exhausted / stop working;

3. (Afterimage due to) green (sensitive) cone cells working;

   Allow 1 extra mark up to the maximum of 3 for additional detail to marking point 2 e.g. exhaustion of pigment, exhaustion of neurotransmitter, exhaustion of ATP

(d) 25% = 2 marks;

   15-12/12 × 100 = 1 mark;
6.

(a) 1. Three peaks / three maximum values / three maxima;

2. At different wavelengths / different colours / blue, green and red;
   
   "Accept 'at 430nm, 515nm, 585nm' (±5nm for all)"

(b) Overlap between different types of cone cells / some wavelengths /
    colours are detected by more than one type of cone cell;

(c) 1. Birds have four peaks, humans have three peaks;

2. Birds and humans have types (that peak) at 515 nm/green and 585 nm/red;

3. (Similar type) but (peak) at 430 nm in humans and 450 nm in birds;

4. Birds have a peak / can see at 370 nm / shorter wavelength / UV range;
   
   "1. Birds have four different types of cone, humans have three
      Accept all numbers read from the graph within ±5 nm.
      3. Do not accept 'both humans and birds absorb blue'"

(d) 1. (Each cone cell has) separate neurone to brain / separate bipolar neurone / separate ganglion cell;

2. (So) no retinal convergence / impulses from each cone kept separate / no summation of impulses;
   
   "Allow converse for rod cells"

   "2. Accept idea that each cone only represents a small area of the retina"

(e) Between 230 790 to 231 000 = 2 marks;

   Area of fovea = 1.54 mm$^2$ = 1 mark;
   
   "Using π as 3.14 or 22/7 or π on the calculator"

   "No credit can be awarded if the area has been incorrectly calculated"

---

7.

(a) 1. (Increased pressure) deforms / changes stretch-mediated sodium (ion) channel;

2. (Sodium channels open and) sodium ions flow in;

   "Accept Na$^+$"

3. Depolarisation (leading to generator potential).
   
   "Accept correct description of depolarisation"
(b) Value between 2.17:1 and 2.29:1;
    Accept rounding up to 2.2 or 2.3
    Accept: number without : 1
    Correct working showing answer but incorrect rounding in answer line = 1

Values between 117 to 119 and between 52 to 54 found but ratio wrong way round = 1 mark.

Wrong way round gives answer between 0.35:1 and 0.46:1

(c) 1. Parasympathetic greater effect than sympathetic;
    Ignore: descriptions of graph

2. Parasympathetic keeps heart rate down / lower / decreases heart rate (as blood pressure increases);

3. Sympathetic keeps heart rate up / higher / increases heart rate (as blood pressure increases);
   2. and 3. Accept converse for blood pressure decreases

4. Parasympathetic greatest / greater effect at high blood pressure / sympathetic greatest effect at low blood pressure.

8. (i) no (photo)receptor cells at Y / no rods and cones;

(ii) X has many / only cones / more cones than Z;
    which each synapse to a single neurone / bipolar cell / no retinal convergence;
    OR
    Z has mainly rods / more rods than cones;
    which share / converge on neurones / bipolar cells;

9. (a) (i) 1 and 2 share neurone but 2 and 3 have separate neurones (to brain);
        Ignore wrong names of neurones

(ii) 1 unit is sub-threshold / 3 units are above threshold / give sufficient depolarisation;
    (1 unit) No impulses / no action potential / in (sensory) neurone / does not stimulate (sensory) neurone / 3 units → impulses;
    (Spatial) summation / sufficient neurotransmitter released / from 3 receptors / insufficient N-T from one;
    Reject ‘temporal’
(b) (i) (Three) different types of (cone) cells / types 6 and 7 sensitive to different wavelengths / different frequencies / different colours;

(ii) Impulses along separate neurone from each receptor cell / each receptor cell connects to separate neurone;

(a) no rods at blind spot or fovea; greater distribution of rods at edge;

(b) more rods and no / fewer cones present; rods at the fovea / rods not mainly at periphery;

rhodopsin ‘bleached’ at low light intensities / iodopsin ‘bleached’; at high light intensities;

10. (i) rhodopsin bleached / broken down by light; time for resynthesis;

(ii) rhodopsin / pigment absorbs green light more readily than red / is more sensitive to green light; (after resynthesis) less (intense) green light needed to break down rhodopsin (than red);

(iii) white has (high proportion of) wavelengths to which rhodopsin not sensitive;
(a) Any two from:

- light
- pressure
- touch
- temperature
- chemicals
- (loud) noise
- smell;

Two required for 1 mark
Do not accept unqualified reference to dust / particles / objects
Accept (rapid) movement (of particles / air) towards the eye
Accept humidity / moisture / tears

(b) 1. Standard deviations / standard errors;
    2. (So) likely to overlap;

(c) 1. Would not know the patient’s / human’s normal blink rate so unable to make a comparison;
    2. Blink rate could be affected by stress of seeing a doctor;
    3. Many factors could affect blink rate so it would be difficult to tell if blink rate was due to illness

2 max

(d) 1. Not possible to predict intermediate values;
    2. Only one result for each time period / not mean values;

2

(e) Collected paired data;

1

(f) 1. No / low influx of sodium ions;
    2. So no depolarisation / action potential;
    2. ‘so no impulses’ insufficient

2

(g) 1. Allows calcium ions in;
    2. At end of presynaptic neurone;
    3. Causing release of neurotransmitter;

1. Accept Ca$^{2+}/Ca$ ions but not Ca/Ca+$

2. The idea of the end of the presynaptic neurone must be given
e.g. presynaptic knob

(h) 1. Reference to large group size;
2. Reference to matching a specific, named variable;
3. Applying a statistical test to the data;
   1. Accept ‘≥ 20 / many / lots’ but not ‘several / less than 20’
   2. Accept any named variable other than age.
   3. Accept ‘use SE / 95% confidence limits’

13. (a) Epithelial cell) of tubule cells carry out active transport;
   transport chloride / sodium ions out (of filtrate);
   against concentration gradient;
   into surrounding tissue / tissue fluid;
   creates / maintains water potential gradient for water reabsorption;
   countercurrent multiplier;

(b) if water potential of blood falls, detected by receptors in hypothalamus;
   leads to ADH released from pituitary gland;
   ADH makes cells of collecting duct / distal convoluted tubule permeable to water;
   (accept DCT)
   water leaves filtrate by osmosis;
   smaller volume of urine produced;
   (accept converse if water potential of blood rises)

(c) (autonomic reflex),
   autonomic ganglion involved;
   extra synapse outside the spinal cord;
   inhibitory rather than excitatory neurone;
   more neurones involved;