E2 Perception of Stimuli

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Diversity of Stimuli

A wide range of stimuli can be detected by diverse receptors in humans. Each receptor is specific to its stimulus and adapted to suit its function.

**Mechanoreceptors**
- changes in pressure
- changes in texture
- changes in vibration
  - e.g. touch, pain and tension receptors in skin
  - e.g. touch receptors in skin
  - e.g. inner ear for hearing and balance

**Chemoreceptors**
- chemical solutes
- chemical vapours
  - e.g. taste in the tongue
  - e.g. CO₂ concentration in the blood
  - e.g. smell in the nose

**Photoreceptors**
- electromagnetic radiation
  - e.g. rod and cone cells in the retina

**Thermoreceptors**
- changes in temperature
  - e.g. thermoreceptive nerve endings in skin
TOK: Perception

Many other species detect stimuli outside the range of our receptors - or even completely different types of stimuli!

Caltha palustris (marsh marigold) shows a different set of markings when lit by UV light (below), compared to visible light (above).

Pollinating insects detect this pattern as a 'target' for landing.

Sharks have **electroreceptors** to detect electric fields:

Read a study on juvenile sharks:

[http://youtube.com/watch?v=MWfbr0thgU](http://youtube.com/watch?v=MWfbr0thgU)
Structures of the Eye

Adapted from:
Structures of the Eye

- **blind spot**: (no receptor cells)
- **optic nerve**: (carries nerve impulses to the occipital lobe)
- **fovea**: (concentrated cone cells)
- **choroid**: (layer of light-absorbing pigment)
- **receptor cells: rod cells**
- **retina**: (layer of light-sensitive cells)
- **sclera**: (tough, protective outer layer)
- **ligament**: (muscular portion of iris)
- **cornea**: (outer layer, some fixed focusing)
- **aqueous humour**: (transparent fluid)
- **pupil**: (hole: entry of light to eye)
- **lens**: (adjustable focus of light)
- **conjunctiva**: (outer layer: protective and mucous secretion)
- **iris**: (pigmented, controls opening and closing of pupil, regulating entry of light)
- **vitreous humour**: (transparent jelly)
- **eyelid**: (protection, opening, cleaning)

Adapted from:
The eye is not 'irreducibly complex'; it is the product of millions of years of natural selection.

The lens is responsible for focusing the image to the retina. The inverted image is reverted later by the visual cortex.

How to Test Shortsightedness
Normal vision people will see Einstein in the picture below.
Short-sighted people will see Marilyn Monroe.
If you see Einstein in the picture walk back a few metres and you'll see it into Marilyn Monroe.

Normal vision occurs when light is focused directly on the retina rather than in front or behind it.

Nearsightedness: visual image is focused in front of the retina.
Farsightedness: visual image is focused behind the retina.

http://www.sumanasinc.com/webcontent/animations/content/visualpathways.html
Close your left eye

Stare at the + and move your head closer to the screen.
Keep staring at the +, but pay attention to the red dot.
What happens at a certain distance?

Can you explain what's happening?
The Blind Spot

The lens focuses light onto the retina - rod and cone cells at the back of the eye which act as photoreceptors.

When you focus on an object, light directly hits the fovea, a region of the retina with densely-packed rods and cones.

All this information is processed by the retina and converted to nerve impulses. These are collected and carried to the brain for processing along the optic nerve.

There are no rod and cone cells where the optic nerve meets the retina, so any light which falls on this 'blind spot' is not perceived.

Your brain fills in the rest!

Demonstration taken from http://serendip.brynmawr.edu/bb/blindspot1.html
The Blind Spot

Move closer and the image of the dot falls on the retina and so is perceived.

Demonstration taken from
http://serendip.brynmawr.edu/bb/blindspot1.html
The Blind Spot

Move closer and the image of the dot falls on the retina and so is perceived.

Move further away and the same happens.

This illusion shows us that the blind spot of the right eye falls within the left part of the retina - which is responsible for collecting stimuli from the right visual field.

Demonstration taken from http://serendip.brynmawr.edu/bb/blindspot1.html
Visual Fields

the range over which an eye can detect visual stimuli.

Light from your left visual field falls onto the right side of the retina and vice versa.
Visual Fields

the range over which an eye can detect visual stimuli.

Light from your left visual field falls onto the right side of the retina and vice versa. Stimuli from both left retinas are processed in the left visual cortex of the occipital lobe. Therefore both sides of the brain process images from both eyes. More on contralateral processing later.
The Retina

Light enters the eye via the lens, and is reflected by the choroid cells. Rod and cone cells (photoreceptors) convert light stimuli into an action potential. Bipolar neurons are specialised sensory neurons. Retinal ganglion cells transmit the impulse to the occipital lobe of the brain. Ganglia have a very long axon and form the optic nerve.

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Images adapted from QuestionBank CD Rom
The Retina: Perception of Light

1. Light reflects off choroid and hits rods and cones.

2. Pigments in rods and cones break down.

3. This stimulates an action potential.

4. Synapses pass impulses from photoreceptors to bipolar neurons and then to the ganglia.

5. Ganglia carry the impulse via the optic nerve to the occipital lobe.

Images adapted from QuestionBank CD Rom
Rod Cells vs. Cone Cells

- dominant in dim light conditions ('bleached' in bright light)
- one type
- throughout retina
- responsive to all visible wavelengths (420-590nm)
- high: many rods connect to one ganglion
- poor

- light brightness diversity
- distribution
- wavelength sensitivity
- receptor: ganglion ratio
- visual acuity
- three types
- concentrated around fovea
  - Short - violets (420-440nm)
  - Medium - greens (534-545nm)
  - Long - reds (560-590nm)
- very low (even 1:1)
- high

SEM of rod and cone cells
http://cas.bellarmine.edu/tietjen/images/Eyes!.htm

http://tinyurl.com/45pzsc
Count the black dots: and explain the illusion!

http://www.123opticalillusions.com/
Receptive Fields and Processing Stimuli
A receptive field is the area of the retina over which a single ganglion collects stimuli.

Many rod cells feed into one ganglion. This gives a large receptive field and low accuracy. Differences in light within the receptive field are not likely to be perceived with clarity.

Cone cells feed into their own ganglion cells. This gives many small receptive fields and high accuracy. Different types of cone cells detect different wavelengths of light and can perceive small details.

Photoreceptors are densely packed in the fovea, with a low ratio of cone : ganglion cells.

This ratio increases, giving larger receptive fields further away from the fovea.

Images adapted from Fuji
http://tinyurl.com/45pzscc
Receptive Fields and Processing Visual Stimuli

There are two types of retinal ganglion.

One type is *stimulated* by light hitting the edge of the receptive field and *inhibited* by light hitting the centre.

One type is *inhibited* by light hitting the edge of the receptive field and *stimulated* by light hitting the centre.

Images adapted from Fuji
http://tinyurl.com/45pzsc
Edge Enhancement

The retina is the first step in visual perception.

The brain receives information about where the biggest areas of contrast are in the receptive fields, and this is processed into an image.

It also allows the brain to fill in gaps in the receptive field, such as in the + and O illusion.

Notice how you perceive areas that seem extra-white and also some blocks of grey? This is an example of edge-enhancement.

When light falls onto a receptor, it is stimulated.
If light also falls onto its neighbouring receptors, they inhibit each other. This is called lateral inhibition. The grey spots on the grid are the result of lateral inhibition in your retina - areas of white next to each other cause inhibition of receptors in between, giving the illusion of being slightly darker.

Images adapted from Fuji
http://tinyurl.com/45pzscc

Hermann Grid:
http://serendip.brynmawr.edu/bb/latinhib.html
Edge Enhancement
Lateral inhibition explains contrast illusions.

Lateral inhibition enhances the contrast between the colours of neighbouring areas. A dark surrounding makes the grey patch look lighter and vice versa.

Each of these bands is uniformly shaded.

appears darker here
(as it contrasts with the lighter band to the left)

appears lighter here
(as it contrasts with the darker band to the right)

http://dragon.uml.edu/psych/mach.html

http://serendip.brynmawr.edu/bb/latinhib_app.html
Try this illusion again and explain why the area around the dot is black when it disappears.
Try it one more time and explain the outcome.
The Visual Cortex Processes Visual Stimuli

Images are focused by the cornea and lens. An inverted image is focused to the retina.

Both eyes send visual information to both sides of the brain. This is achieved through the optic chiasm, where information from the inner halves of the retinas (nasal retinas) are crossed over.

The optic tracts carry the visual nerve impulses to the visual cortex, in the occipital lobe. This is called contralateral processing.

This means that both sides of the brain are responsible for processing information from both eyes.

http://scienceblogs.com/purepedantry/2007/10/ocular_dominance_columns_and_t.php
Processing Visual Stimuli

Both eyes have a right and left visual field. The right side of each retina collects light from the left visual field and vice versa.

Perception of visual stimuli begins in the retina, with edge enhancement. Retinal ganglia carry nerve impulses through the optic nerve to the brain.

The nasal ganglia cross over at the optic chiasm. This means both sides of the brain process images from both eyes and is called contra-lateral processing.

The right side of the visual cortex processes images on both right retinas (therefore both left visual fields).

The visual cortex constructs images in the brain from the stimuli received. Because the two eyes are apart, the images are slightly different. This stereoscopic vision leads to the production of a 3D image - and depth perception.

The inverted image that hits the retina is also corrected.

http://www.nature.com/nrn/journal/v6/n3/fig_tab/nrn1630_F4.html
Explain how visual stimuli are processed in humans.

(8 marks)
Explain how visual stimuli are processed in humans.

(8 marks)

Lens focuses light onto rod and cone cells in the retina; Visual stimuli are processed by the retina and visual cortex in the brain;

Bipolar neurons communicate visual stimuli to ganglion cells; Receptive field is region of retina which communicates with one ganglion; Low ratio of cone:ganglion cells in the fovea gives high acuity (small visual fields);

There are two types of ganglion cells; One type of ganglia are stimulated by light hitting the centre of the receptive field and inhibited by light hitting the edge (and vice-versa); **Edge enhancement** occurs when light/dark edges fall in the receptive field;

Both the left and right visual cortex process images from both eyes; The optic nerve carries impulses from the retina to the visual cortex; Stimulus from the right visual field of both eyes is processed in the right visual cortex (and vice versa); This crossing over of nerves is called **contra-lateral processing** (and is facilitated by the optic chiasm).
Label it and explain how sound is perceived!
(5) (6)
The Ear and Hearing

The ear is a neat example of a mechanoreceptor in action: vibrations in the air are converted into action potentials.

- **Eardrum**: vibrated by air pressure changes due to sound waves.
- **Pinna**: collection of sound waves.
- **Middle ear bones**: stimulated by ear drum, knock against each other and magnify sound (around 20X).
- **Semicircular canals**: balance (not hearing).
- **Oval window**: transmits vibrations from middle ear bones.
- **Cochlea**: tiny hairs respond to individual wavelengths of sound, generating AP.
- **Auditory nerve**: transmit nerve impulse from cochlea to brain.
- **Eustachian tube**: joins throat and sinus - for equalisation of pressure.
- **Round window**: dissipates vibrations (dampens 'used' sound stimulus).

*Image from SMART Gallery*
Explain how sound is perceived by the human ear

(8 marks)
Explain how sound is perceived by the human ear

(8 marks)

Sound waves are collected by the pinna;
Ear drum vibrated by air pressure changes (due to sound waves);
Middle ear bones stimulated by ear drum, enhancing sound by 20x;
Oval window transmits vibrations from middle ear bones to cochlea;
Tiny hairs in cochlea act as receptors for individual wavelengths of sound;
Action potential generated in the cochlea;
Auditory nerve transmits AP to brain;
Round windows of cochlea dissipate sound.

Test your hearing range:

How do cochlear implants and hearing aids work in different ways?

http://kidshealth.org/parent/general/eyes/cochlear.html

http://www.merckmanuals.com/home/sec19/ch218/ch218a.html
"You're lucky. You can eat all you want because stripes make you look thinner."

For more IB Biology resources:
http://sciencevideos.wordpress.com