RECEPTOR CELLS

- **Some receptor cells detect stimuli and connect to the nervous system.**
- **Receptor cells are specific** – there are many different types which respond to different stimuli such as light, temperature and pressure.
- **Receptor cells convert the energy of the stimulus into electrical energy** which is used by neurons to create a nerve impulse.

How Receptors Work

- The sensory nerve endings which connect to receptors have two types of sodium channels: non-voltage gated (which open in response to a stimulus) and voltage-gated (which open in response to changes in charge across a membrane).
- Sensory nerve endings in receptors have a **resting potential** (about-70mV): the inside of their membranes is more negative than the outside.
- A stimulus (e.g. pressure) causes sensory nerve endings to **become more permeable to sodium ions**. (This happens because the stimulus causes non-voltage gated sodium channels to open). The inside of the sensory nerve ending becomes less negative. This change in potential is called a **generator potential**.
- If the stimulus is strong enough, enough non-voltage gated sodium channels open to reach the **threshold level** (around -50mV).
- Once the threshold potential is reached, all the voltage-gated channels in the sensory nerve ending open, causing an influx of sodium ions, triggering an **action potential** (about +40mV).
- The action potential sets up a **nerve impulse** in a sensory neuron attached to the receptor – this is how all nerve impulse start.
- Note that this is an **all-or-nothing response**: the stimulus either sets off an action potential or it doesn't. Once an action potential is started, it is transmitted along neurons with the same value (+40mV).

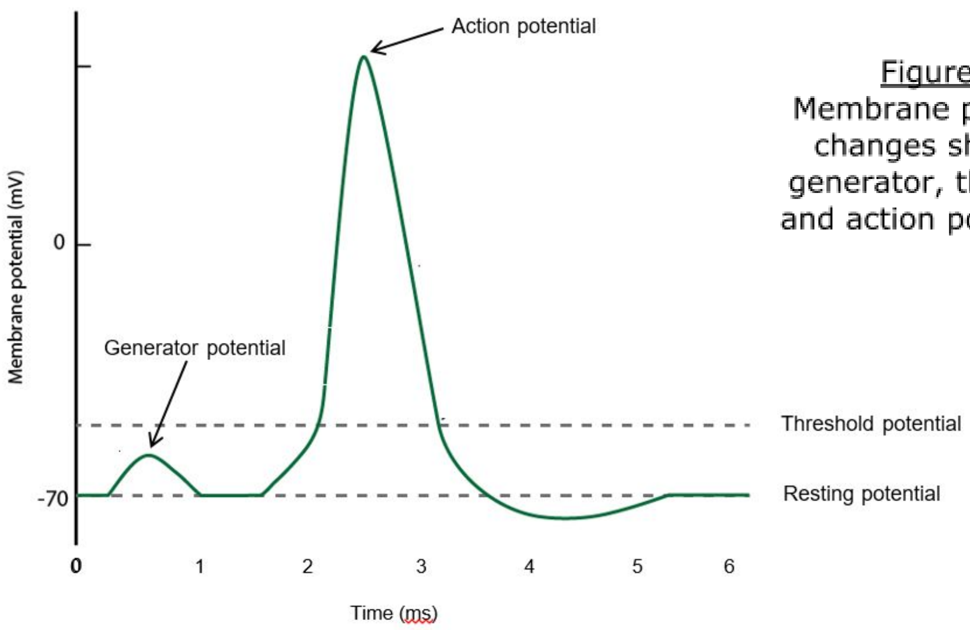
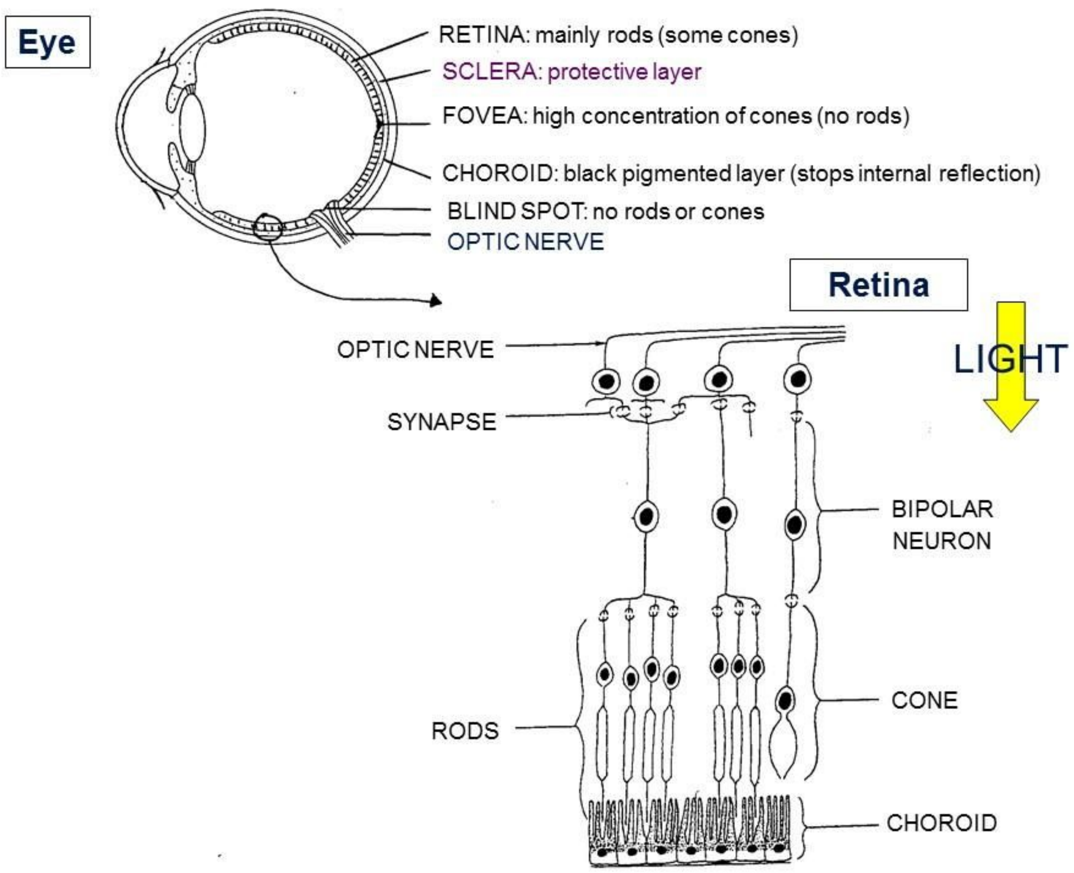


Figure 1
Membrane potential changes showing generator, threshold and action potentials.

RODS & CONES

- The **retina** at the back of the eye contains two types of **photoreceptor cells** (called **rods** and **cones**) which detect light.
- Rods and cones contain different **light-sensitive pigments** which absorb light and undergo a chemical change ("bleaching") which releases energy. This results in **increased permeability of photoreceptor membranes to sodium ions**.
- Sodium ions diffuse into the photoreceptors, creating a **generator potential**. If a **threshold level** is reached, an **action potential** is created in a nearby bipolar neuron. This connects to neurons in the **optic nerve** which carry impulses to the brain.

Figure 2
Location and structure of the retina in the human eye

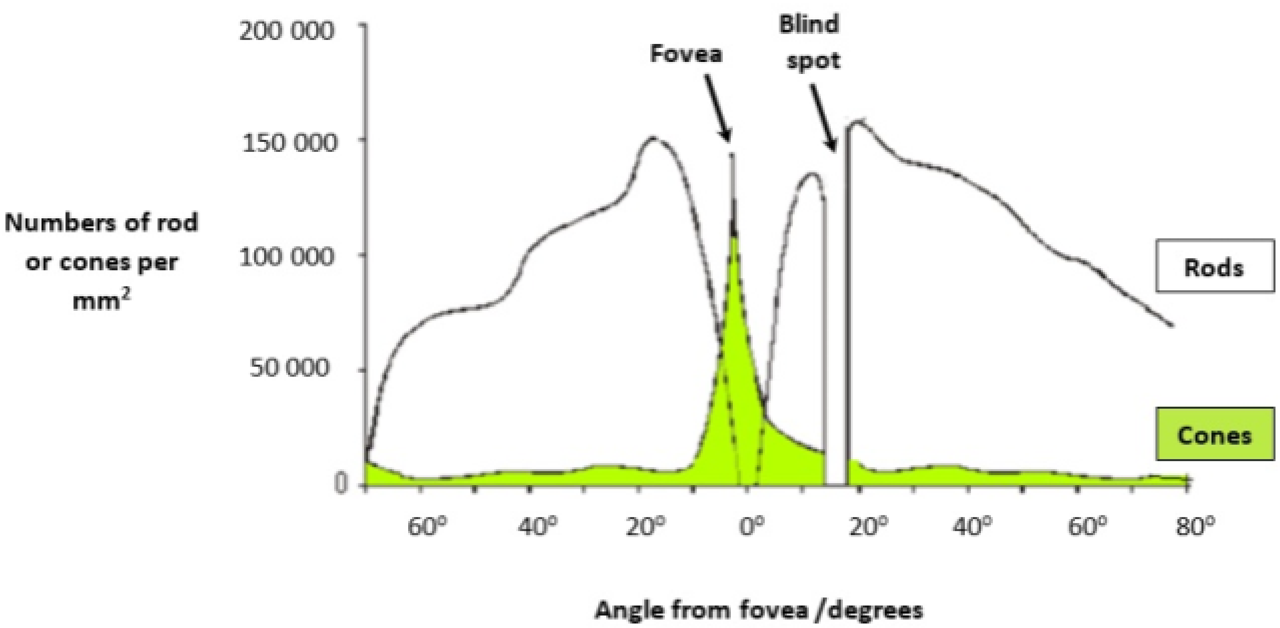


Note that several rods synapse with one bipolar neuron, whereas one cone synapses with one bipolar neuron.

RODS & CONES

- **Rods** are located in the **peripheral parts** of the retina and detect light, but not the colour of light.
- **Many rods join one bipolar neuron** so that:
    - Rods are **sensitive to dim light** (because many weak generator potentials combine to reach the threshold level to trigger an action potential to send nerve impulses to the brain). The photosensitive pigment in rods (rhodopsin) bleaches at low light intensity.
    - Rods give **low visual acuity** (the ability to tell part points that are close together) because the brain cannot tell where exactly the light fell on a group of rods.
- **Cones** are found closely packed in the **fovea.** They contain the photosensitive pigment iodopsin and there are three types which are sensitive to red, green and blue lights. Hence they are used for **colour vision**.
- **One cone joins one bipolar neuron** so that:
    - Cones are **not sensitive to dim light.** *Compared to rods, are less sensitive at low light intensity,* because a generator potential must reach the threshold level on its own to trigger an action potential to send nerve impulses to the brain). That's why you can't see colours in the dark!
    - Cones give **high visual acuity** (the ability to tell apart points that are close together) because the brain can tell exactly which cone the light fell upon.

Figure 3
Distribution of rods and cones in the retina of the human eye



RODS & CONES: SUMMARY

Rods	Cones
Mainly located in the peripheral parts of the retina	Mainly located in the fovea of the retina
Do not give information in colour	Give information in colour
Many rods join to one bipolar neuron	Single cones join to one bipolar neuron
High light sensitivity	Low light sensitivity
Low visual acuity	High visual acuity
High light sensitivity Several rods connect to one bipolar neuron so many **weak generator potentials combine to reach threshold** level to trigger action potential to send nerve impulses to the brain **Low visual acuity** Several rods connect to one bipolar neuron so brain cannot tell exactly which rod light fell upon, giving an indistinct image.	**Low light sensitivity** One cone connects to one bipolar neuron so **a generator potential must reach threshold level on its own** to trigger action potential to send nerve impulses to the brain **High visual acuity** One cone connects to one bipolar neuron so brain can tell exactly which cone light fell upon, giving a distinct image.

COLOUR PERCEPTION

The Visible Spectrum

White light is made up of all the colours of the rainbow (and everything in between). In a rainbow, colours merge smoothly and continuously from one colour to another. We call this the visible spectrum, as colours represent a narrow range of the wavelengths in the wider electromagnetic spectrum which are visible to the human eye.

But light waves are colourless. Colour doesn't actually exist!

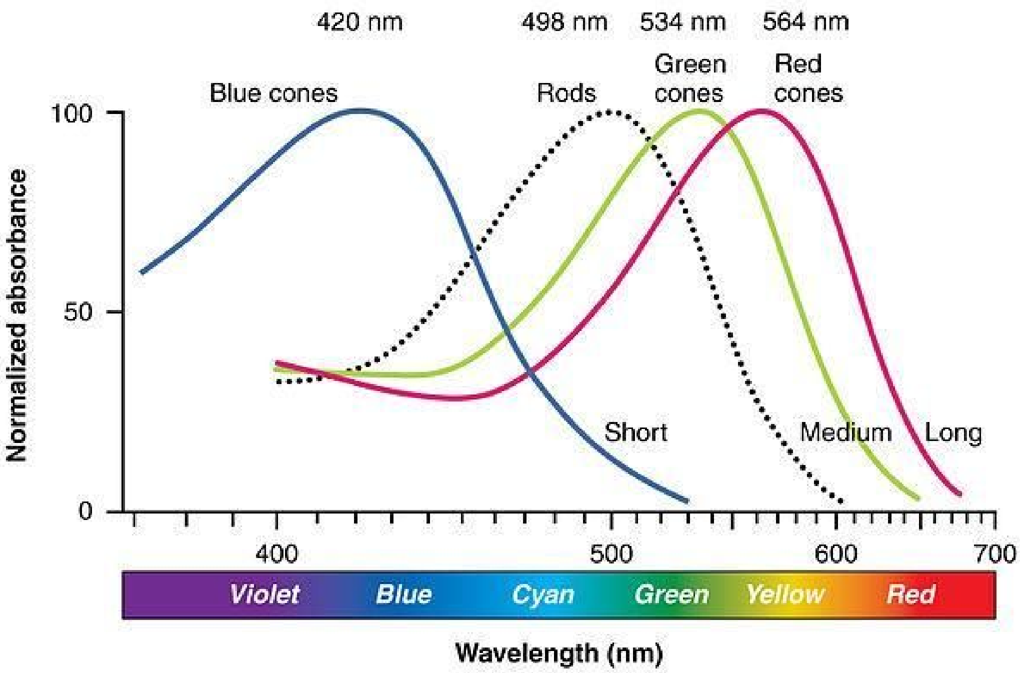
How do you see colour?

Colour is a perception – it is a construct of your brain.

Your eye contains two photoreceptor cells called rods and cones. Rods contain a photosensitive pigment (rhodopsin) which shows maximum absorbance for light of 498 nm, although it absorbs a wider range of wavelengths either side of this (see figure 4).

According to the trichromatic theory, there are three types of cone which contain different forms of a different photosensitive pigment (iodopsin), each showing maximum absorption of blue, green or red light.

Figure 4
Absorption spectra of rods and three different types of cone

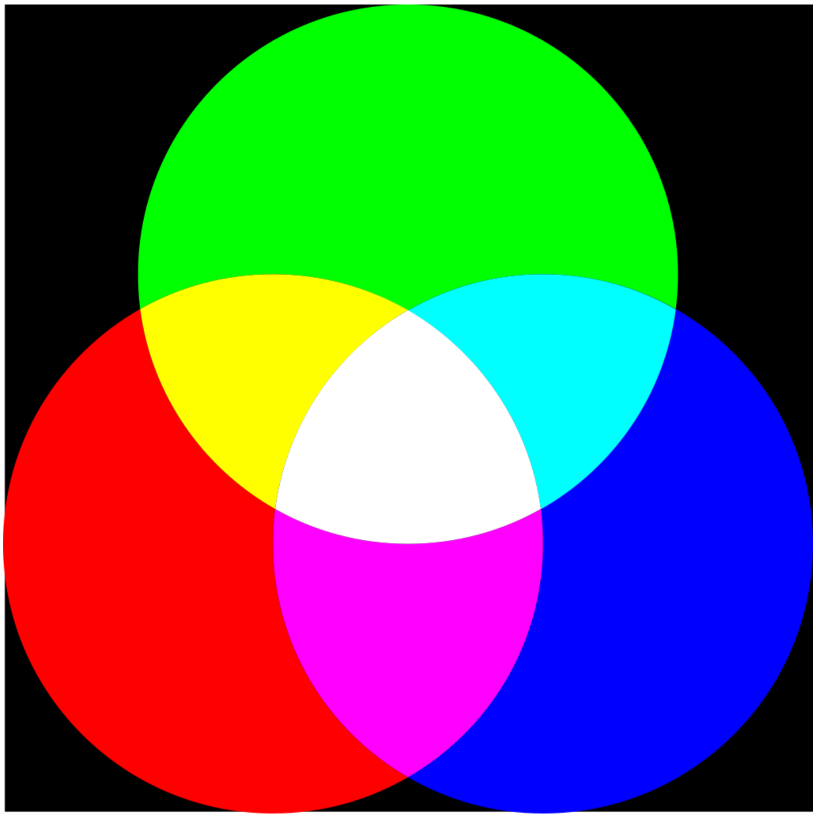


When your rods and cones are stimulated by light, nerve impulses are sent from your eyes to your brain via the optic nerve. Nerve impulses do not have colour either. If the impulses come from rods, the brain interprets them as being caused by light. If the nerve impulse come from cones, your brain makes up what colour the light was by taking into account the relative numbers of blue, green or red cones that were stimulated.

By processing a massive range of permutations of cone combinations, you brain is able to detect 10 million different colours.

Figure 5
How different combinations of stimulation of blue, red and green cones are perceived by the brain

Green + red = yellow
Green + blue = cyan
Red + blue = magenta
Red + blue + green = white



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