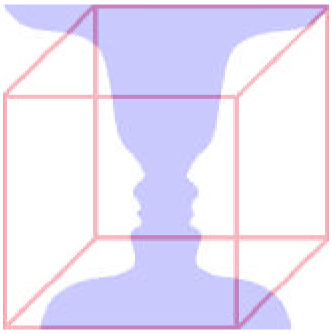
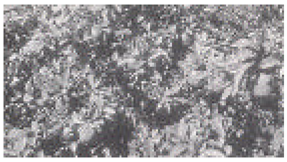
Lecture 4
Colour Perception



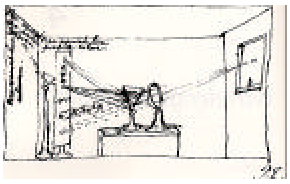
What does color do for us?

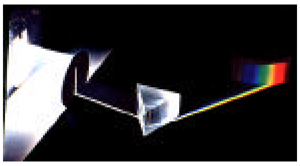
- The world of color is a world of yellow daffodils, painted window shutters, orange-red sunsets. We pick favourite colours and react emotionally to color (purple with rage, green with envy).
- Few mammals except primates have colour vision, so other than creating aesthetic appearance and mood what does it do for us?
- The images on the right suggest that evolution of color vision was probably related to the advantages it provides in finding food.



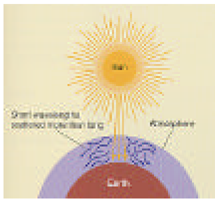
What is colour?

- In his room at Cambridge University, Isaac Newton placed a prism so that sunlight shining through a hole in the shutter of his window entered the prism.
- He discovered that the prism split the sunlight into a spectrum of colours.
- The visible spectrum ranges from 400 nm (violet) to 700 nm (red).





Why does the sky look blue?

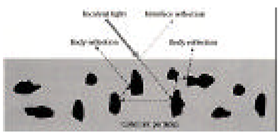


- One way to interpret Newton's result is that the perception of color occurs when some wavelengths are subtracted from white light.
- This occurs naturally when light from the sun is scattered by particles of air in the atmosphereto create the perception of blue sky and yellow sun.

- Short wavelenght light (blue) is scattered more than long wavelength light (red). This effect becomes most pronounced when the light has to travel further (sunset)

Why are objects the color they are?

- The colour of an object depends on wavelengths contained in the incident light and which of these wavelengths it reflects.
- The red apple contains colourant particles (pigments) that absorb green and blue light and allow red to be reflected, whereas the yellow banana contains colourant particles that absorb blue light reflecting red and green.

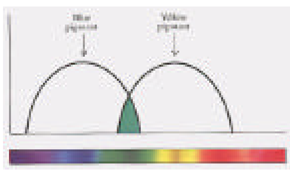


- Light that is reflected at the interface of a surface has the same color as the incident light.

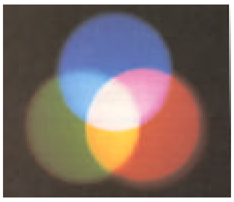
Mixing paint versus mixing colour

- The artist can never perfectly duplicate the effects of light because pigments and light do not combine in the same way.

- When painters mix blue and yellow to produce green, they are subtracting blue and yellow from the total spectrum of light.
- In contrast, when different coloured lights combine, the effect is additive making more of the spectrum visible.

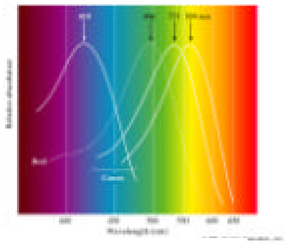


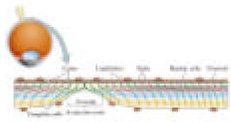
The trichromacy theory of colour vision



- Young and Helmholtz realised that the brain could not have a receptor for every colour.
- Consequently, he proposed that our perception of colour was based on the relative activation of three receptors (red, green and blue).
- Support for this theory comes color matching experiments in which any colour can be produced by a combination of the three primary colours.

Physiology of trichromatic theory

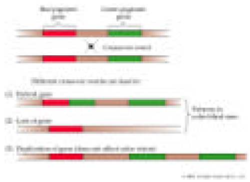


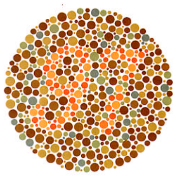


- Support for the trichromacy theory was established when it was discovered that there were three types of cone in the human retina that respond to different wavelengths of light.
  - red (long wavelength)
  - green (middle wavelength)
  - blue (short wavelength)

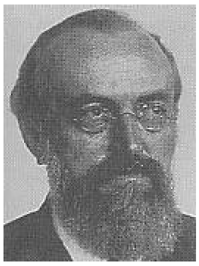
Colour blindness

- Acquired or congenital colour blindness can result from failure to make one of the cone pigments.
- People with normal vision are known as trichromats
- People with only two cones are known as dichromats.
  - protanopia (long wavelength)
  - deuteranopia (middle wavelength)
  - tritanopia (short wavelength)





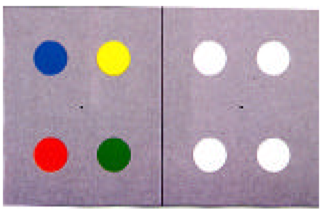
Opponent-process theory of color vision

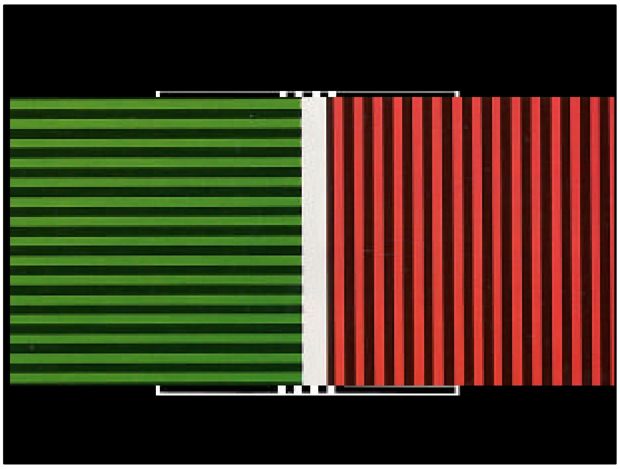


- Although trichromatic theory explains a number of color vision phenomena, there are some perceptions that it cannot explain.
- These color perceptions were demonstrated by Hering and were invorporated into the opponent-process theory of color vision.
- He proposed that are perception of color was based on the relative amount of colour in the scene
  - red *versus* green
  - blue *versus* yellow
  - dark versus light

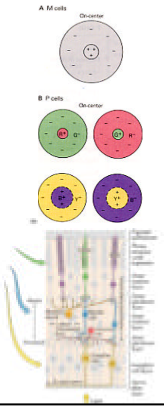
Afterimages

- Afterimages support the idea of opponent processes.
  - Prolonged viewing of red gives an after-effect of green and vice versa.
  - In contrast, prolonged viewing of blue gives rise to an after-effect of yellow and vice versa.





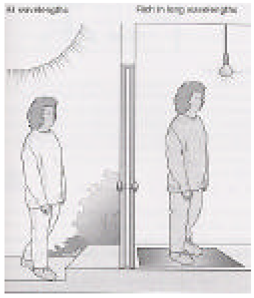
The physiology of opponent-process theory



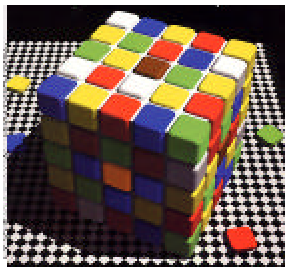
- Evidence for the opponent-process theory of color vision came from the discovery of opponent neurons in the retina and lateral geniculate nucleus.
- Signals from cones are transformed early in the visual pathway.
  - M retinal ganglion cells are achromatic
    - dark - light
  - However, P retinal ganglion cells have an opponent organisation in which the centre and surround of the receptive field are sensitive to different wavelengths of light
    - red - green
    - blue - yellow

Colour constancy

- When looking at the color of an object one is usually confident that the color is: grass is green, London buses are red etc.
- However, the colour reflected by an object depends on the illumination.
  - A white shirt in room illumination reflects more long wavelength light compared to outside. However, in both circumstances we perceive the shirt to be white.
- This phenomenon known as color constancy and is determined by comparing the wavelength of light reflected from a single object to the wavelengths of light in the surround.

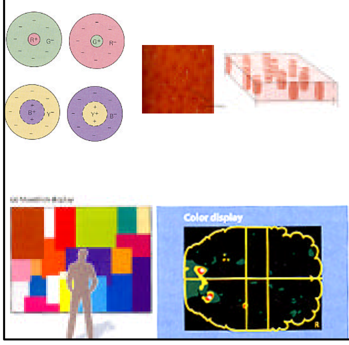


The importance of context in colour perception



- The importance of context in color perception is shown in this example where the tiles in the centre of both patches are identical in terms of color and brightness
- However, the perceptual system assumes that they must be different color because one of the tiles is in shade.

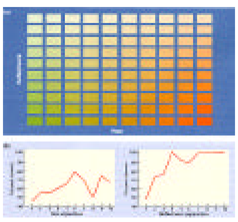
Is there a color area in the brain?



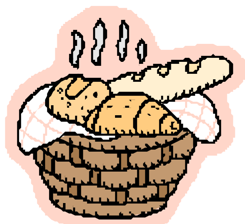
- V1
  - Blobs in primary visual cortex are selective for the wavelength of light. However, the wavelength of light often bears little relationship to the perceived colour.
- V4
  - However in area V4 neurons behave as if they are responding to colours as seen by human observers

Achromatopsia

- Lesions to areas such as V4 result in a condition known as achromatopsia.
- People with achromatopsia are unable to distinguish between different colours (hues).
- They often report that colours become bland reflecting dirty shades of grey.



How color affects taste



- The appearance of food influences its desirability and research also indicates that peoples ability to identify tastes and smells depends to some degree on color.
- For example, when asked to distinguish tastes of beer, subjects identified only 70% when the beer was colourless and accuracy dropped to 25% when the beer was coloured red!