12

Physiology of color vision

PHYSIOLOGY
CNS BLOCK
TEAM 443

MED 443
King Saud University

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Color Index:

- Main text
- Important
- Girls Slides
- Boys Slides
- Notes
- Extra

Editing File

Objectives

1. Define color version.
2. Identify and describe the mechanism of color vision and the three types of cones, including the range of spectral sensitivity and color blindness.
3. Identify color vision theory.
4. Describe the items needed for any color perception.
5. Compare different types of color blindness.

Photopic vision (cones)

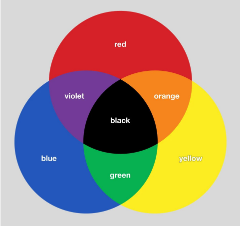
1. The visible spectrum of light spans wavelengths of 390 to 670 nm.
2. Individual rod or cone photoreceptors are sensitive to a broad range of wavelengths (black and white curves) but each is most responsive to light in a particular spectral band.
3. as a result, cone photoreceptors are classified as red, green and blue types.
4. The specific colors perceived, result from the relative activation of the three cone types.

Color Vision

Definition

Is the ability to discriminate (differentiate) between different colors.

- There are **3 primary colors**: Blue, Red & Green sensed by **cones** in fovea & appreciated within photopic vision.



- Sensation of **extraspectral colors** as White, Yellow, Orange, Purple can be produced by **mixing properties** of the blue, red & green in different combinations.

- Colors have three attributes:
    1. Hue (means shadow)(pure form of colours)
    2. intensity
    3. saturation (degree of freedom from dilution with white)

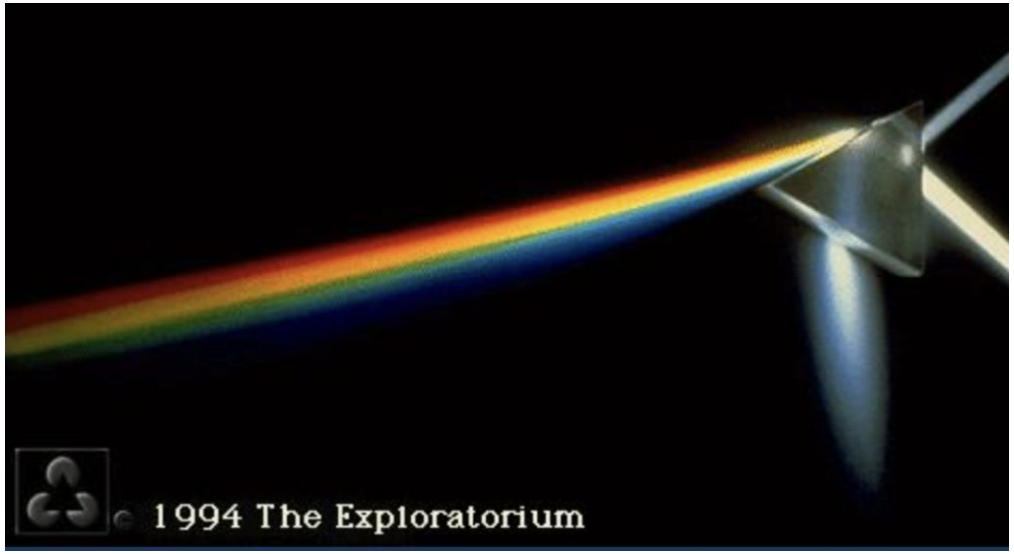
- For any color there is a complementary color that when properly mixed with it, produce a sensation of **white.**

Perception of Blackness

1. Black is the sensation produced by the absence of light, however it is still different from the blind eye.
2. It is probably a positive sensation because the blind eye doesn't "see black" rather it "sees nothing at all".
3. Black means absence of light not darkness, because in the dark we don't see black only.
4. Black has no wavelength.

History of Color Vision

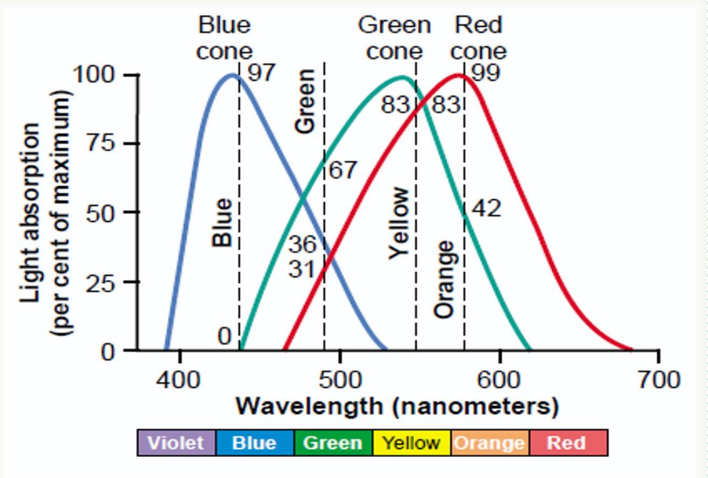
Newton (1704) used a prism to show that sunlight was composed of light with all colors in the rainbow. He defined it as the spectrum.



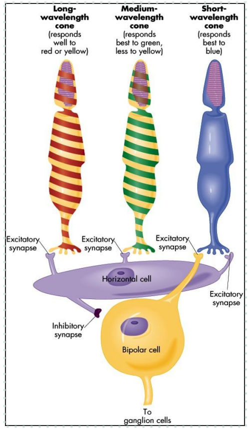
Color Vision Theory (Young-Helmholtz Theory)

1. We have 3 kinds of cones, each has a specific photopigment (rhodopsin/iodopsin) & is sensitive to one of the 3 primary colors.

	Blue cone system	Green cone system	Red cone system
Pigment	**S pigment** Blue sensation pigment	**M pigment** Green sensation	**L pigment** Red sensation pigment
Wavelength (Male dr:know the numbers)	Respond to **SHORT** wavelength (440nm)	Respond to **MIDDLE** wavelength (535 nm)	Respond to **LARGE** wavelength more than (≥535nm) - (565nm)
Color sensation	Sense the Blue color	Sense the Green color & less to yellow & absorb light at the green portion	Sense the Red & Yellow color & absorb light at the red portion



Light absorption by the pigments of three color-receptive cones of human retina.



2. **Sensation of any color determined by:**

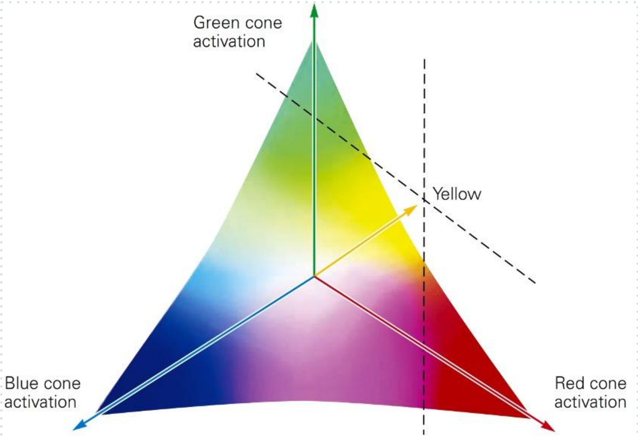
- **Wavelength** of light S , M AND L cones.
- **Amount of light** absorbed by each type of cones other colors
- **Frequency of impulses** from each cone system to ganglion cells which is determined by wavelength of light.

The longer the wavelength, the greater the frequency of the action potential.

Color Vision Theory (Young-Helmholtz Theory)

3. Each cone system respond to its color at a **lower threshold than needed** to sense other colors (red cones respond to red or yellow color at a lower threshold than to green color).

4. Perception of white is due to **equal stimulation** of blue, red & green cones. There is no single wavelength corresponds to white, **white is a combination of all wavelengths.**



As can be seen in this vector diagram white occupies the middle of the vector.
Equal stimulation means equal percentage of all 3 types of cones.

Color Vision is coded by:

- Different responses in ganglion cells that depends upon the **wavelength** of stimulus which determine **frequency of impulses** in ganglion cells.
- The color perception in the brain depends on the **amount of activity in each of the 3 cone** systems as mentioned above.

Interpretation of color in the nervous system

Referring to Figure 50-10, one can see that an orange monochromatic light with a wavelength of 580 nanometers stimulates the red cones to a value of about 99, it stimulates the green cones to a value of about 42, but the blue cones not at all. Thus, the ratios of stimulation of the three types of cones in this instance are 99:42:0. The nervous system interprets this set of ratios as the sensation of orange.

Color	Cone stimulation percentage imp	ratio
orange	99% of red cones 42% of green cones 0% of blue cones	(99:42:0)
yellow	50% of red cones 50% of green cones 0% of blue cones	(50:50:0)* (83:83:0)*
Blue	0% of red cones 0% of green cones 97% of blue cones	(0:0:97)

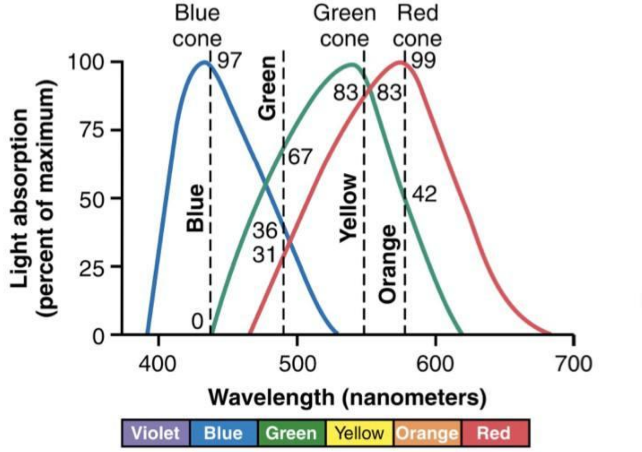
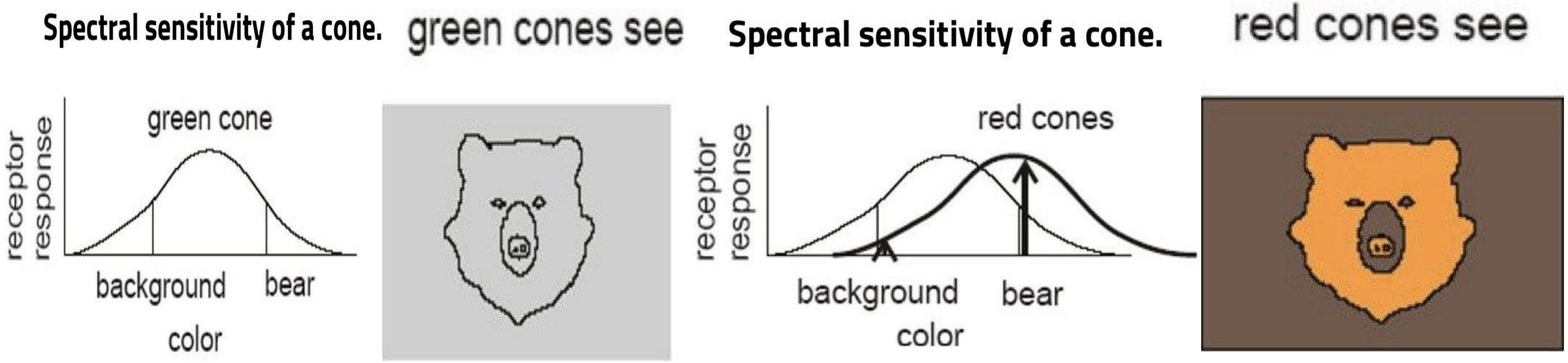


Figure 50-10 Demonstration of the degree of stimulation of the different color-sensitive cones by monochromatic lights of four colors: blue, green, yellow, and orange.

(31:67:36) = green
(99:42:0) = orange
(50:50:0) = yellow
(0:0:97) = blue

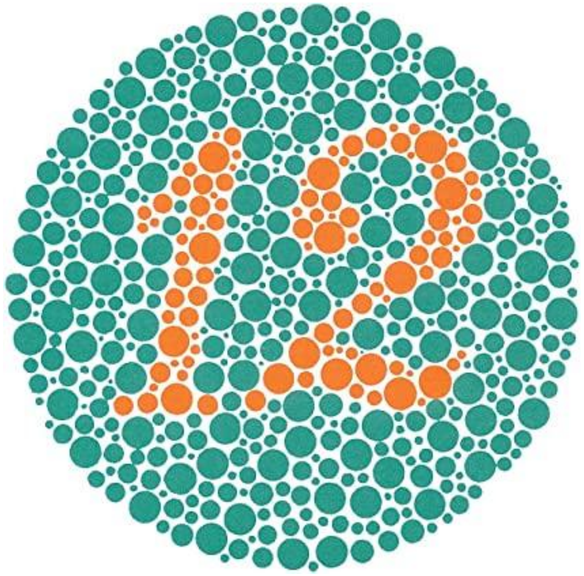
what is the advantage of color vision?

-Color is important for distinguishing an object from its background



The ishihara charts

Ishihara charts, is **a test for color blindness** which are plates containing figures made of colored spots on a background of similarly shaped colored spots.*
The figures are intentionally made up of colors that are liable to look the same as the background to an individual who is color blind.*
Some color blind individuals are unable to distinguish certain colors, whereas others have only a color weakness.*



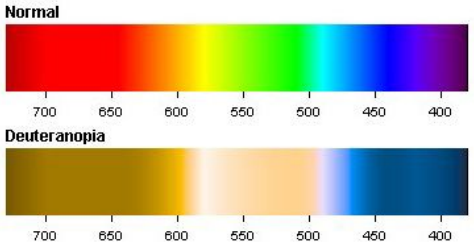
Genes of cone pigments

❖ When a single group of color receptive cones is absent **(due to absence of there gene)** the person can not see or distinguish some colors from others.

Gene for	The chromosome
rhodopsin (**red**)	Chromosome (3)
S pigment (**blue**)	Chromosome (7)
Red & **green** sensitive pigments (L&M)	Chromosome (x)

Red-Green Blindness

- **Green** & **Red** cones see color between the wavelengths of **525-675 nm** & distinguish them.
- If either of these cones are absent, the person can not distinguish 4 colors **(Red-Green -Yellow-Orange).** and he can not distinguish red from green (primary colors) so called (**Red-Green blindness**).
- It's **X-Linked (recessive disease*)** disease that is transmitted from females to their male sons, never occurs in females as they have 2X Chromosomes.
- 8% of female are carrier*.



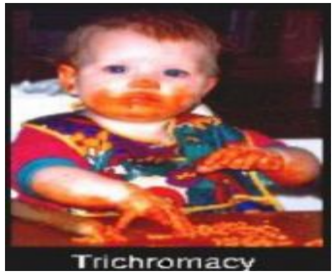
Have or carry the disease

- Female
  - Female show the disease only if **both of their X chromosomes lack the gene.**
  - Female from color-blind fathers are only **carriers and transmit the disease to half (1/2) of their children.**
- Male
  - Males have one x & one y chromosome so **If this one x chromosome miss the gene for color vision , he will get red-green color blindness**(their gene is on x chromosome).

Types of color Blindness

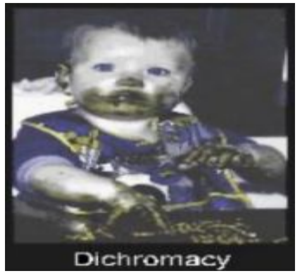
1 **Trichromats**

have 3 cone pigments normal or have slight weakness in detecting red or green or blue color.
See the 3 primary colors.



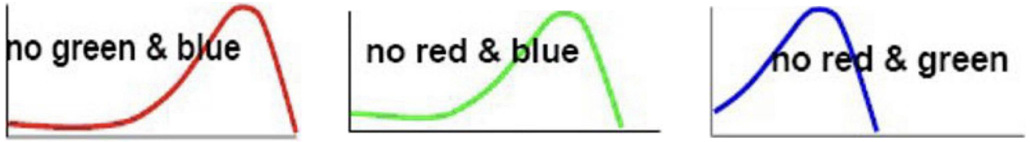
2 **Dichromats**

have only 2 cone pigments systems only so he is completely blind to red or green or blue, (so they may have protanopia, deuteranopia, or tritanopia) they get color by mixing only 2 of the primary colors.
Blind to one primary color.



3 **Monochromats**

have only one cone system or loss of all so see only black or grey or have no color perception. Have only one color pigment.



Types of color Blindness

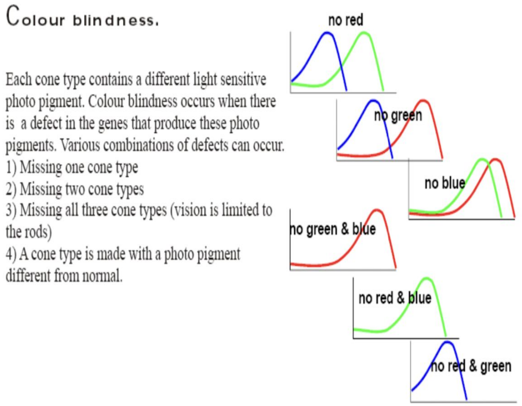
Anopia = blindness/total loss   Anomaly =weakness

Anomaly (Trichromats)

- **Protanomaly** — If only weakness in **red** color vision
- **Deuteranomaly** — If only weakness in **green** color vision
- **Tritanomaly** — If only weakness in **blue** color vision

Anopia (Dichromats)

- **Protanopia (red-blindness)** — no red cones system so person has **shortened** spectrum wavelength*
- **Deuteranopia (green-blindness)** — no green cones system so person see only **long & short** wavelength
- **Tritanopia (blue-blindness)** — no blue cones system



TEST YOURSELF !

1- what is the best photoreceptor that respond to short wavelength light?

A) blue
B) red
C) green
D) yellow

2- mohammad was diagnosed with protanopia which of the following cones affected?

A) blue
B) red
C) green
D) yellow

3- how can we increase the sensation of the color?

A) by increasing the frequency of impulses
B) by dilation of pupils
C) by accommodation
D) by constricting of pupils

4- what is the sensation that produced by the absence of light?

A) blue
B) red
C) black
D) white

1-A 2-B 3-A 4-C

SAQ

1) Enumerate the types of cones and their pigments for each of them ?

1- **Blue cone** ——--> has short (s) pigment. for short wave length.
2- **Green cone** ——--> has medium (M) pigment for middle wave length.
3- **Red cone** ——-> has Large (L) pigment. for large wave length.

2) Sensation of any color is determined by ?

1- **Wavelength** of light
2- **Amount of light** absorbed by each type of cones
3- **Frequency of impulses** from each cone system to ganglion cells which is determined by wavelength of light

3) What's the difference between anomaly and Nopia , and give the meaning for each term : Prot , Deuter and Trit ?

Anomaly=weakness, Nopia=complete loss, prot=red , deuter=green, trit=blue.

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