UNIT-2 PHYSICAL & GEOMETRIC OPTICS AND COLOR THEORY

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LEARNING OUTCOME

2a. List out properties of light and laser.

2b. State the Laws of Refraction.

2c. What happened when light waves interact with an object?

2d. Explain color theory.

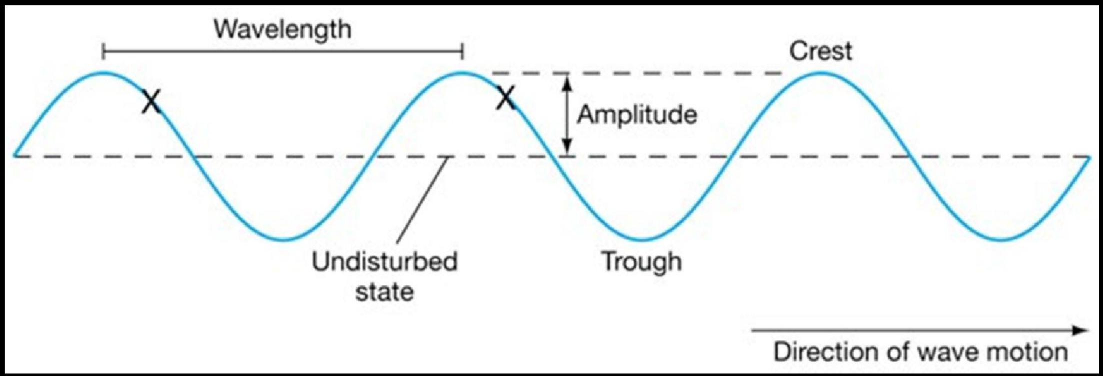
2e. Classify color blindness and explain test for detection of color blindness.

LIGHT

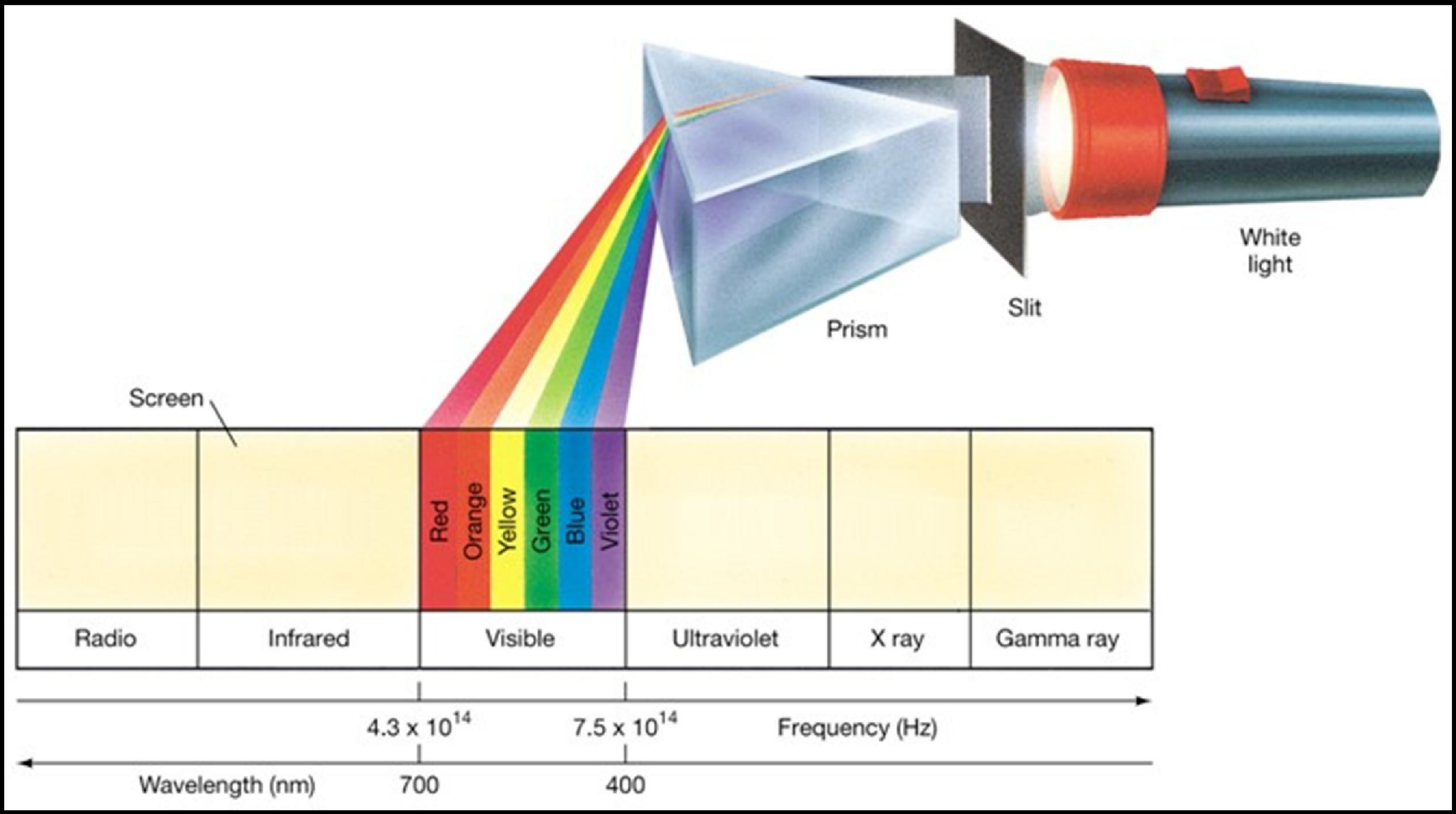
LIGHT AS A WAVE

Light is a form of energy that causes the sensation of vision. **Light (or electromagnetic radiation), can be thought of as either a particle or a wave.** Light is a form of electromagnetic radiation that behaves both as a particle and a wave. **As a wave, light has a**

- **wavelength, (distance between waves)**
- **a frequency, (number of waves passing you each second)**
- **a speed, c (this is always the same: 300,000 km/s)**
- **an energy, E (where h is just a constant)**



EM SPECTRUM



White light
Slit
Prism
Screen
Red
Orange
Yellow
Green
Blue
Violet
Radio
Infrared
Visible
Ultraviolet
X ray
Gamma ray
4.3 x 10^14
7.5 x 10^14
Frequency (Hz)
Wavelength (nm)
700
400

PROPERTIES OF LIGHT

Following are the important properties of light –

- Light travels in a straight line.
- The speed of light is faster than sound. Light travels at a speed of 3×10^8 m/s.
- Reflection of light

Wavelength:

Wavelength is the distance between successive peaks or troughs of a wave. Different colors of light are associated with different wavelengths.

Frequency:

Frequency is the number of oscillations or cycles of a wave per unit of time. The relationship between wavelength (λ) and frequency (ν) is given by the equation $c = \lambda\nu$, where c is the speed of light.

Energy:

The energy of a photon (a particle of light) is directly proportional to its frequency. The higher the frequency, the higher the energy. This relationship is described by Planck's equation: $E = h\nu$, where E is energy, h is Planck's constant, and ν is the frequency.

PROPERTIES OF LIGHT

Reflection:

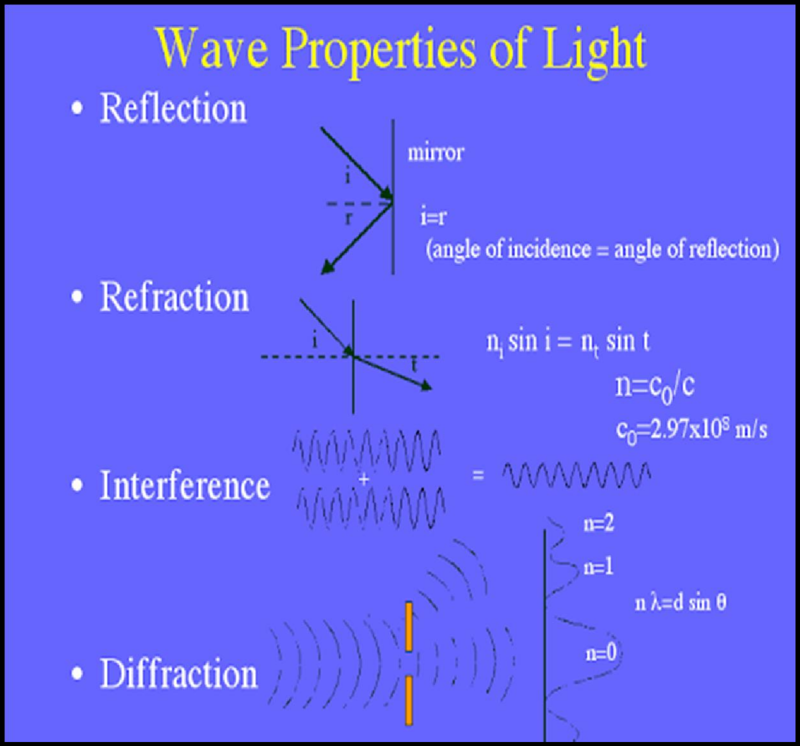
Light can bounce off surfaces when it encounters them, a phenomenon known as reflection. The angle of incidence is equal to the angle of reflection.

Refraction:

Refraction occurs when light passes from one medium to another, causing a change in its speed and direction. This is responsible for phenomena like the bending of light in a prism.

Interference:

Interference occurs when two or more light waves overlap. Depending on whether the waves reinforce or cancel each other out, interference can result in patterns of bright and dark areas.



PROPERTIES OF LIGHT

Diffraction:

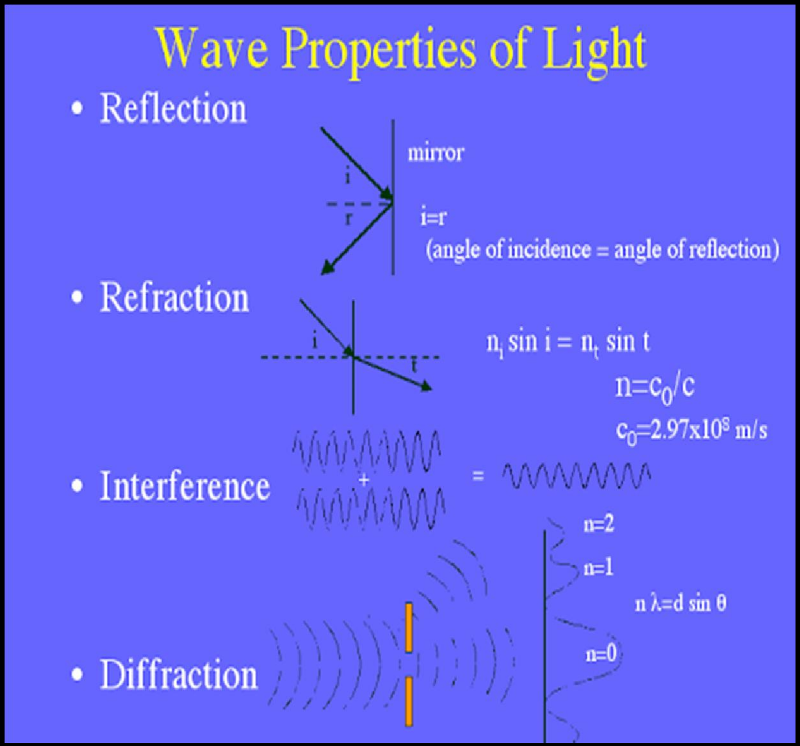
Diffraction is the bending of light waves around obstacles and the spreading of light as it passes through small openings. This phenomenon is more pronounced when the wavelength is comparable to the size of the obstacle or opening.

Polarization:

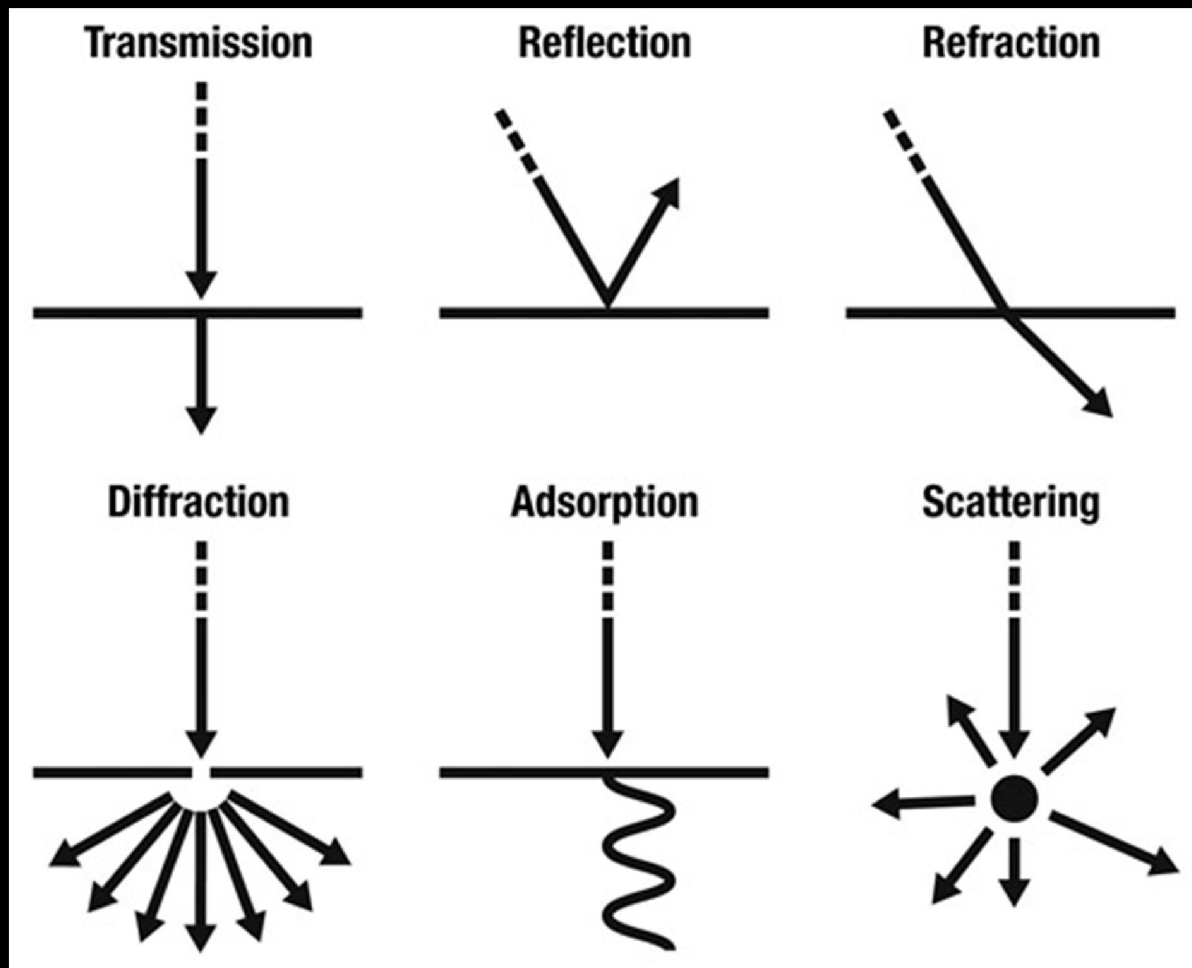
Light waves can be polarized, meaning that their oscillations are restricted to a specific plane. Polaroid sunglasses, for example, use this property to reduce glare.

Dispersion:

Dispersion is the separation of light into its component colors based on their different wavelengths. This is commonly observed when white light passes through a prism.



LIGHT WAVES INTERACTION WITH AN OBJECT



LIGHT WAVES INTERACTION WITH AN OBJECT

The simplest interaction with light is **transmission**, which occurs when light passes through the object without interacting. Light coming through window is a simple example of **transmission**.

Reflection occurs when the incoming light hits a very smooth surface like a mirror and bounces off, like a mirror.

Refraction occurs when the incoming light travels through another medium, from air to glass for example. When this happens the light slows down and changes direction. This change in direction is dependent on the light's wavelength so its spectrum of wavelengths are separated and spread out into a rainbow.

LIGHT WAVES INTERACTION WITH AN OBJECT

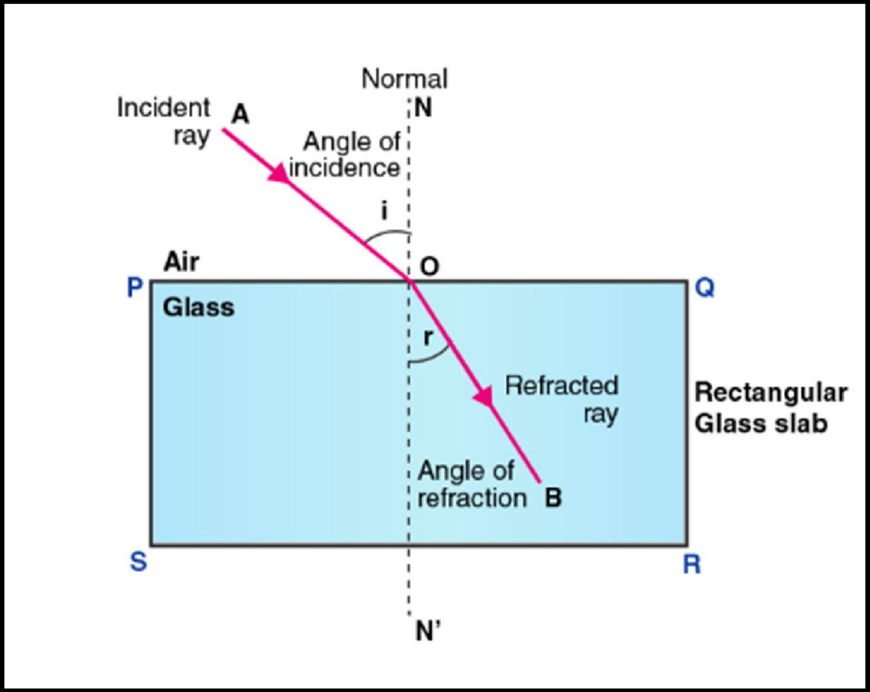
Diffraction occurs when light hits an object that is similar in size to its wavelength. When light passes through a sufficiently-thin slit it will diffract and spread. If it's visible light, this will also create a rainbow.

Absorption occurs when the incoming light hits an object and causes its atoms to vibrate, converting the energy into heat which is radiated. Anyone with a dark-colored car on a hot day will experience the effects of adsorption.

Scattering occurs when the incoming light bounces off an object in many different directions. A good example of this is known as Rayleigh scattering, where sunlight is scattered by the gasses in our atmosphere. This is what gives the sky its blue color.

LAWS OF REFRACTION OF LIGHT

The laws of refraction, also known as Snell's laws, describe how light waves change direction when they pass from one medium to another with a different refractive index. The refractive index is a measure of how much the speed of light changes when it passes through a medium.



LAWS OF REFRACTION OF LIGHT

First Law (Snell's Law):

The incident ray, the refracted ray, and the normal (a line perpendicular to the surface at the point of incidence) all lie in the same plane.

Mathematically, Snell's Law is expressed as:

$n1 \cdot \sin(\theta 1) = n2 \cdot \sin(\theta 2)$where:

n1 and n2 are the refractive indices of the first and second media, respectively.

$\theta 1$ is the angle of incidence.

$\theta 2$ is the angle of refraction.

LAWS OF REFRACTION OF LIGHT

Second Law (Snell's Law Continued):

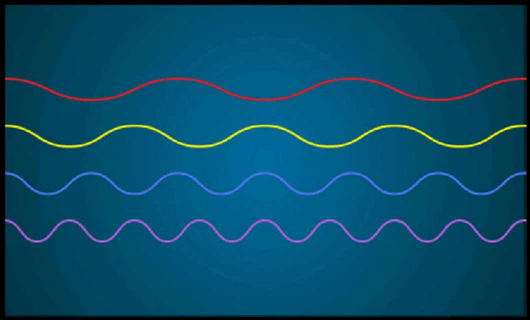
The ratio of the sine of the angle of incidence to the sine of the angle of refraction is a constant for a given pair of media. This constant is equal to the ratio of the refractive indices of the two media.

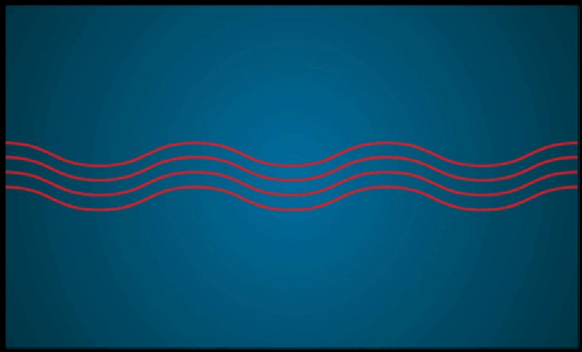
Mathematically, this can be expressed as:

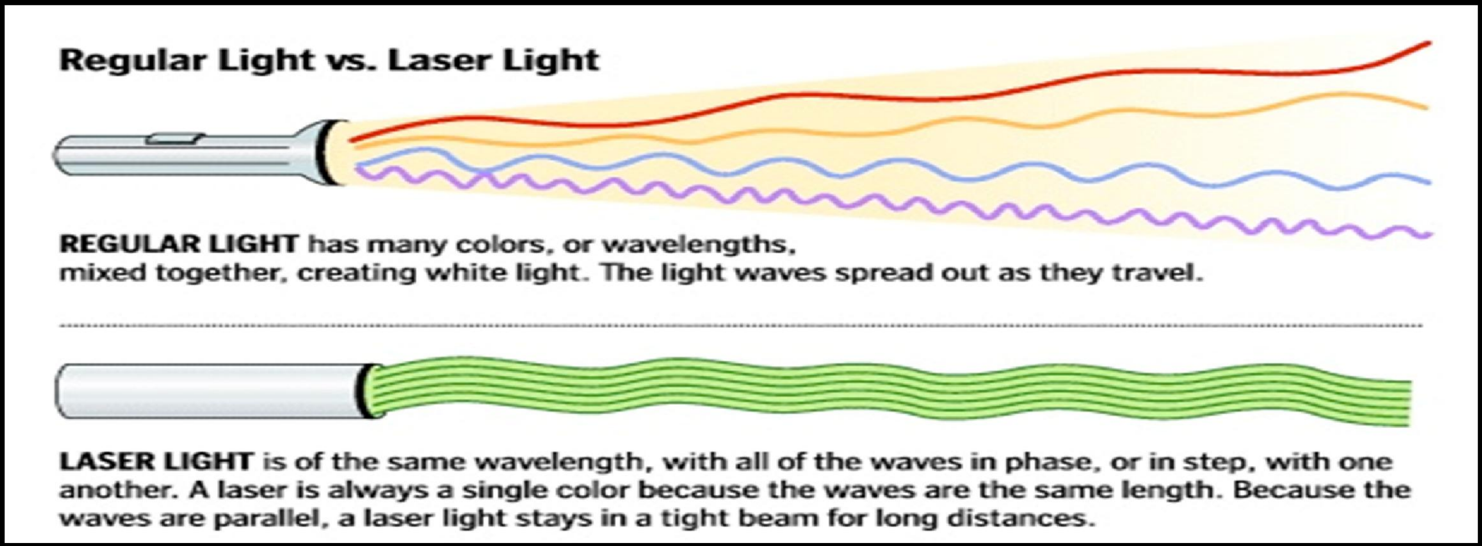
$\sin(\theta 1)/\sin(\theta 2)=n2/n1$

These laws explain how light bends as it passes from one medium to another, and they are fundamental in understanding phenomena such as the bending of light through lenses, the formation of rainbows, and the behaviour of light in various optical devices.

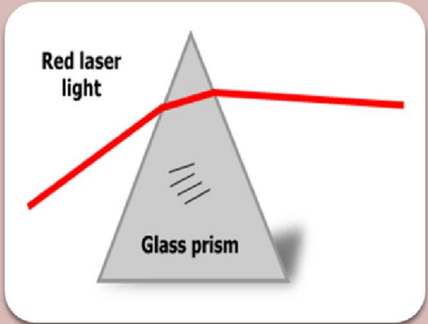
LASER : (LIGHT AMPLIFICATION BY STIMULATED EMISSION OF RADIATION)

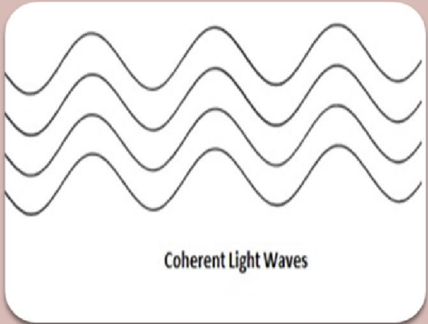


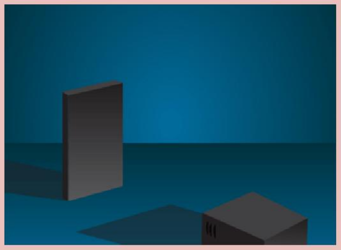




PROPERTIES OF LASER







Monochromatic :

Concentrate in a narrow range of wavelengths (one specific color)

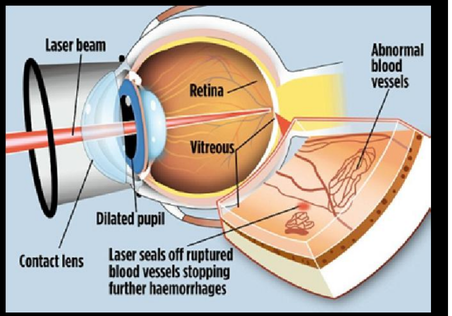
Coherent :

All the emitted photons bear a constant phase relationship with each other in both time and phase

Directional :

A very tight beam which is very strong and concentrated

LASERS IN OPHTHALMOLOGY



Here are some common applications of lasers in ophthalmology:

Photocoagulation:

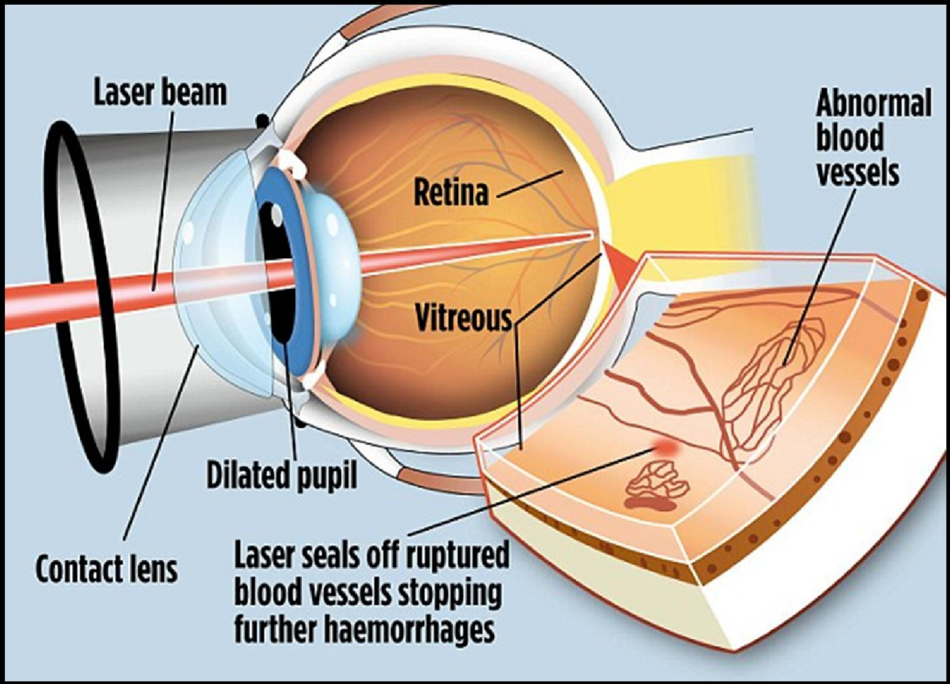
Diabetic Retinopathy: Laser photocoagulation is used to treat diabetic retinopathy by sealing leaking blood vessels or destroying abnormal blood vessels that can develop in the retina.

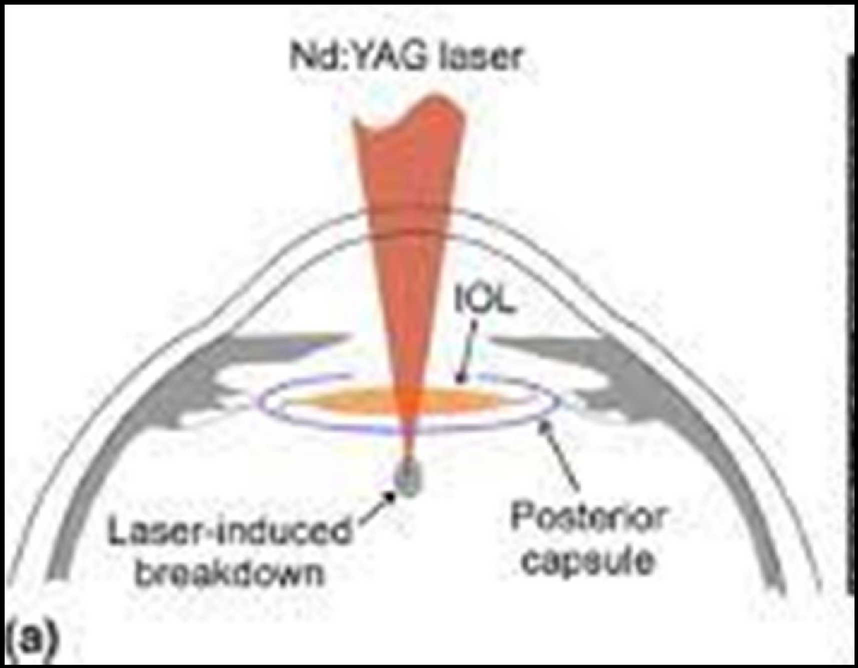
Retinal Tears and Detachments: Laser therapy is employed to create small burns or scars that seal retinal tears or reattach the retina.

Photodisruption:

Posterior Capsulotomy: After cataract surgery, a cloudy membrane (posterior capsule opacification) can develop behind the intraocular lens. YAG laser capsulotomy is a non-invasive procedure that uses a laser to create an opening in this membrane, restoring clear vision.

LASERS IN OPHTHALMOLOGY





LASERS IN OPHTHALMOLOGY

Laser Refractive Surgery:

LASIK (Laser-Assisted In Situ Keratomileusis): LASIK is a popular laser refractive surgery used to correct refractive errors like nearsightedness (myopia), farsightedness (hyperopia), and astigmatism. The laser reshapes the cornea to improve the focusing of light on the retina.

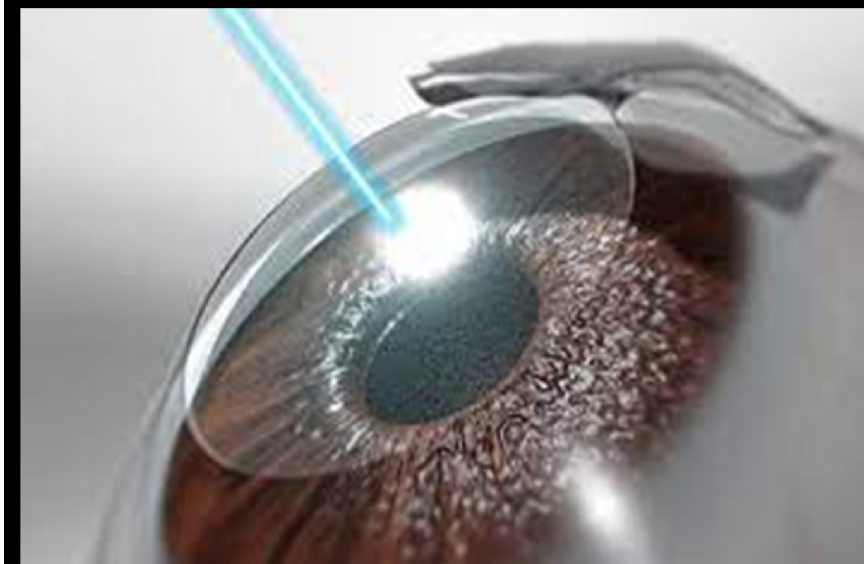
Laser Trabeculoplasty:

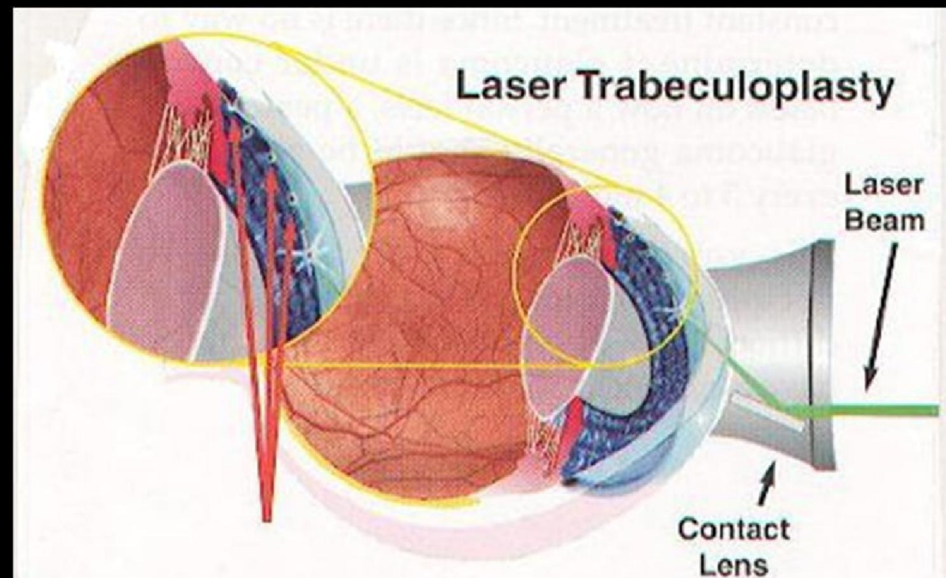
Glaucoma Treatment: Laser trabeculoplasty is used to treat certain types of glaucoma by improving the drainage of aqueous humor from the eye. This helps to lower intraocular pressure and reduce the risk of optic nerve damage.

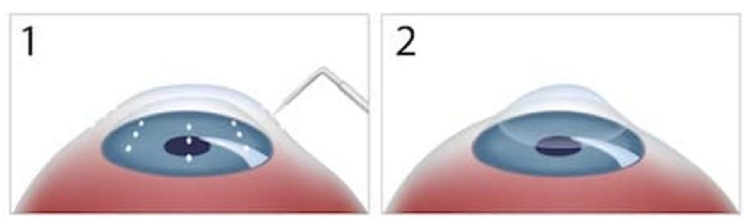
Laser Keratoplasty:

Corneal Surgery: Laser keratoplasty is used for corneal reshaping in conditions like keratoconus or irregular astigmatism. Excimer lasers are often used for their precision in tissue removal.

LASERS IN OPHTHALMOLOGY



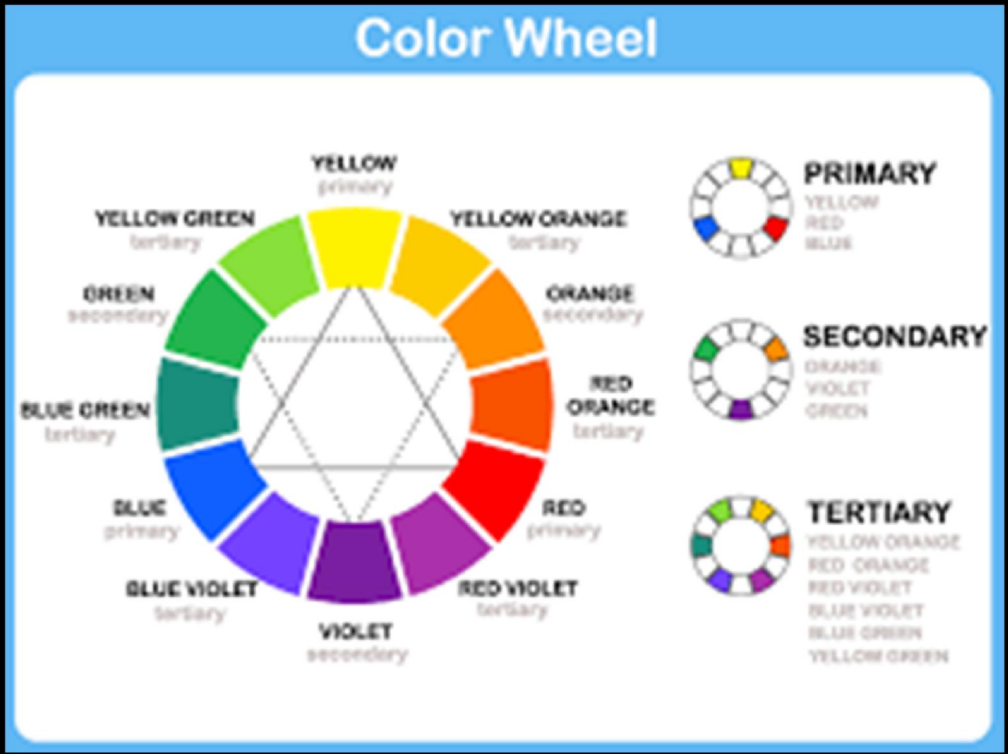




Conductive Keratoplasty
(NearVision CK)

COLOR THEORY

Color theory is a conceptual framework that provides guidance on how colors interact, combine, and evoke certain emotions. It plays a crucial role in art, design, and various other creative fields. Here are some fundamental concepts in color theory:



COLOR THEORY

Primary Colors:

In traditional color theory, primary colors are the foundation of all other colors and cannot be created by mixing other colors. The classic primary colors are red, blue, and yellow.

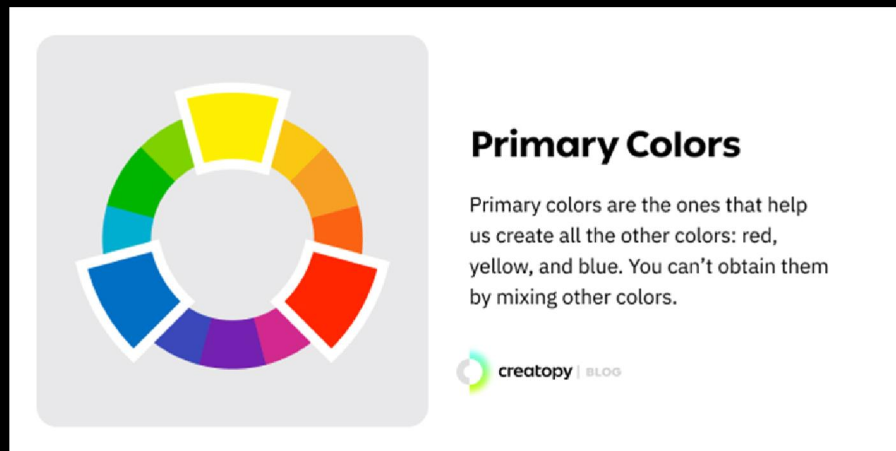
Secondary Colors:

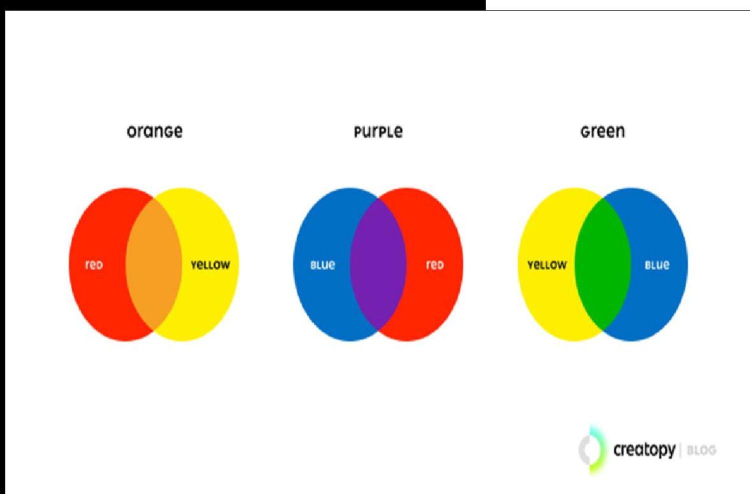
Secondary colors result from the mixing of two primary colors. The secondary colors are green (from blue and yellow), orange (from red and yellow), and purple (from red and blue).

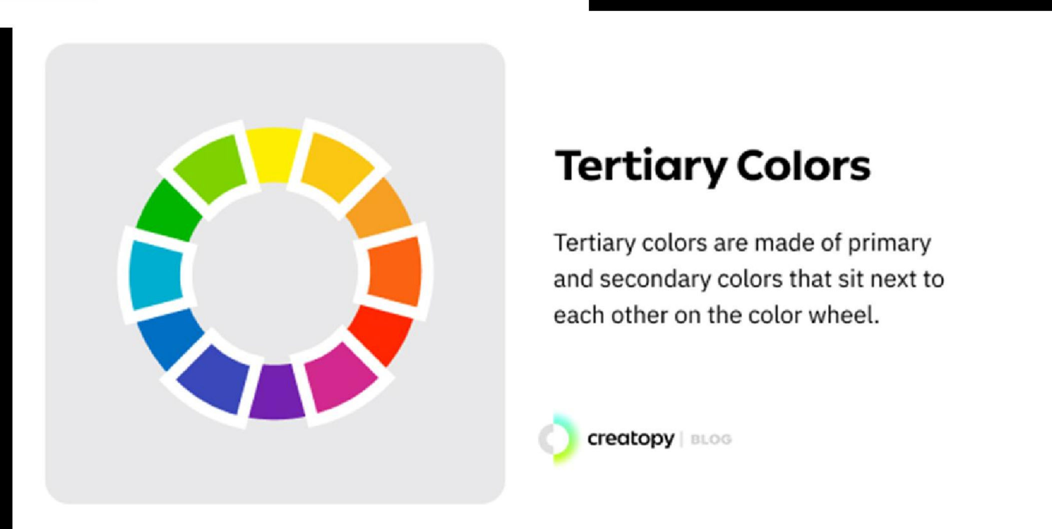
Tertiary Colors:

Tertiary colors are created by mixing a primary color with a neighboring secondary color. Examples include red-orange, yellow-green, and blue-violet.

COLOR THEORY







COLOR THEORY

Complementary Colors:

Complementary colors are opposite each other on the color wheel. When placed together, they create strong contrast and reinforce each other. Examples include red and green, blue and orange, and yellow and purple.

Analogous Colors:

Analogous colors are adjacent to each other on the color wheel. They usually match well and create serene and comfortable designs. An example is blue, blue-green, and green.

Triadic Colors:

Triadic color schemes involve three colors that are evenly spaced around the color wheel. This creates high contrast while retaining color richness. An example is the primary colors red, blue, and yellow.

COLOR THEORY

Split-Complementary Colors:

This scheme is a variation of the complementary color scheme. It uses a base color and the two colors adjacent to its complementary color. This provides high contrast without the strong tension of complementary colors.

Tetradic (Double-Complementary) Colors:

Tetradic color schemes involve two sets of complementary colors. This creates rich color palettes but can be challenging to balance.

Monochromatic Colors:

Monochromatic color schemes involve using variations in lightness and saturation of a single color. This creates a harmonious and unified look.

COLOR THEORY

Warm and Cool Colors:

Warm colors (reds, oranges, yellows) evoke warmth, energy, and excitement. Cool colors (blues, greens, purples) suggest calmness, serenity, and coolness.

Color Harmony:

Achieving color harmony involves creating a pleasing visual experience. This can be achieved through various color combinations, considering factors like contrast, balance, and unity.

Color Psychology:

Colors can evoke emotional and psychological responses. For example, red may symbolize passion or danger, while blue is often associated with calm and trust.

THE TRICHROMATIC THEORY

Any color can be matched by varying the intensities of the three primary lights because every color we see is the result of a ratio of activity among three receptors, each maximally responsive to those three lights

Thus, we sense color through the relative rates of response by three primary of cones

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

THE TRICHROMATIC THEORY

Trichromats-have all 3 cone systems

- Normal color vision
- Protanomaly R cone weak
- Deuteranomaly G cone weak

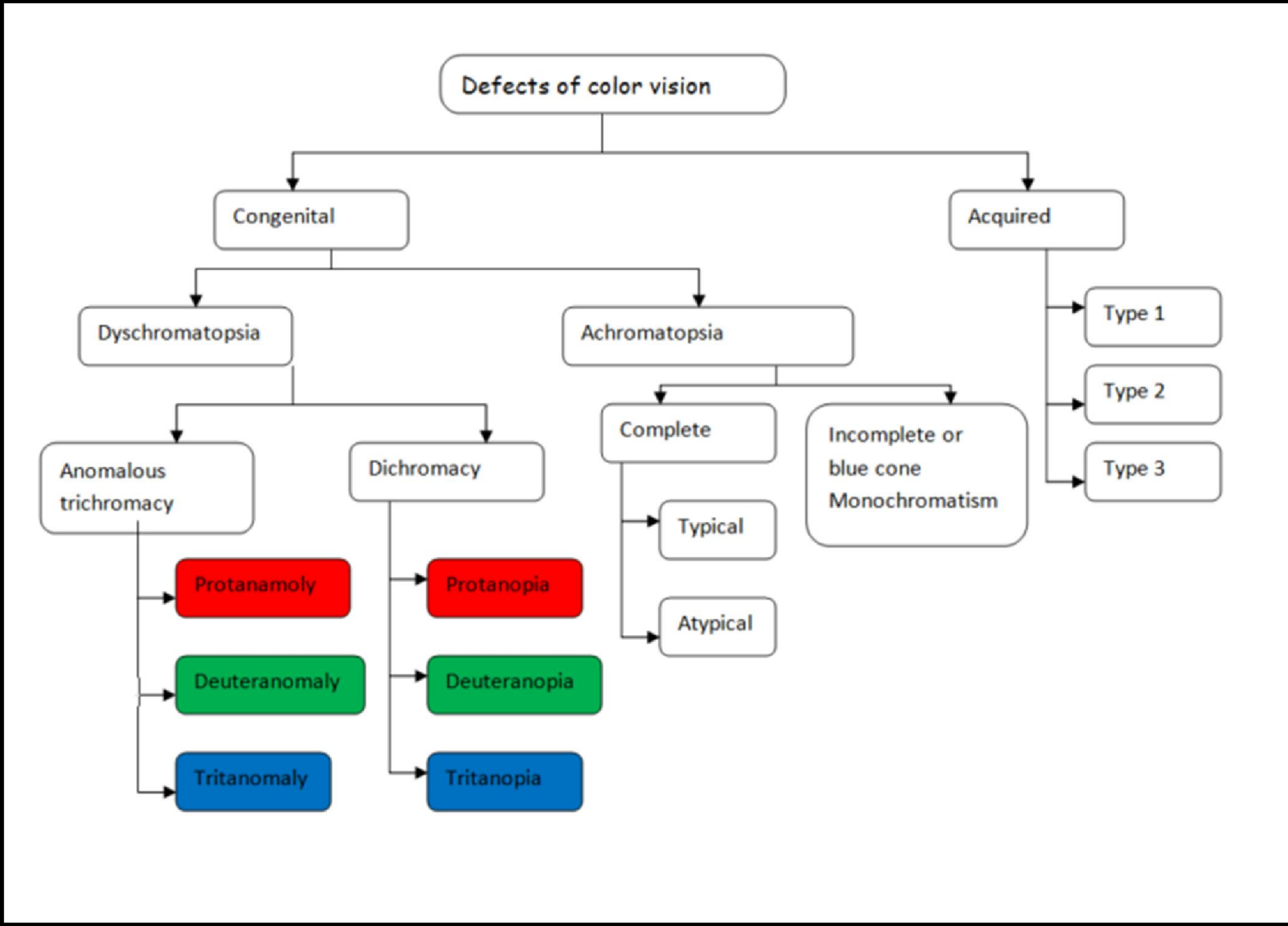
Dichromats - with only 2 cone systems

- Protanopia R cone absent
- Deuteranopia G cone absent
- Tritanopia B cone absent

Monochromats - have only one cone system

COLOR BLINDNESS

Color blindness, also known as color vision deficiency, is a visual impairment that affects a person's ability to perceive certain colors accurately



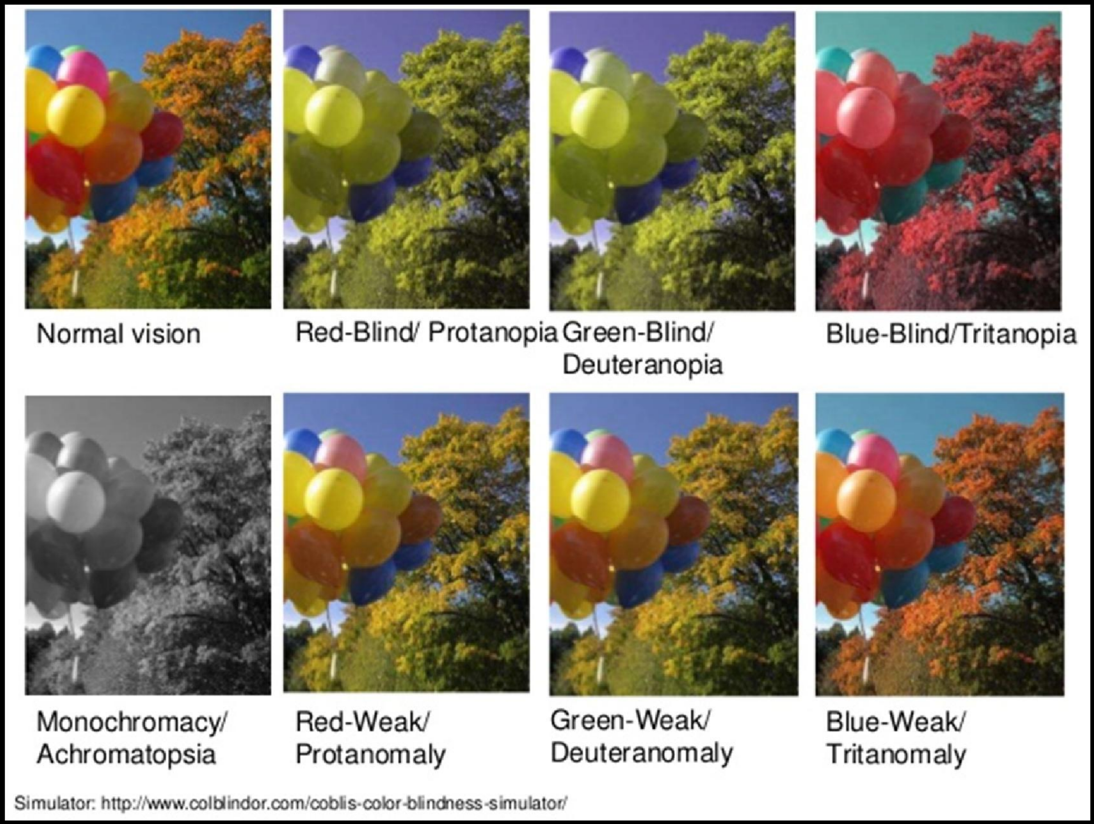
CONGENITAL COLOR VISION DEFECT

1. Congenital Color Vision defect

Inherited genetically, without associated abnormalities, non-pathological and incurable

1.1 Dyschromatopsia:

Either one type of the cones is altered in spectral sensitivity or it is absent or non-functional.

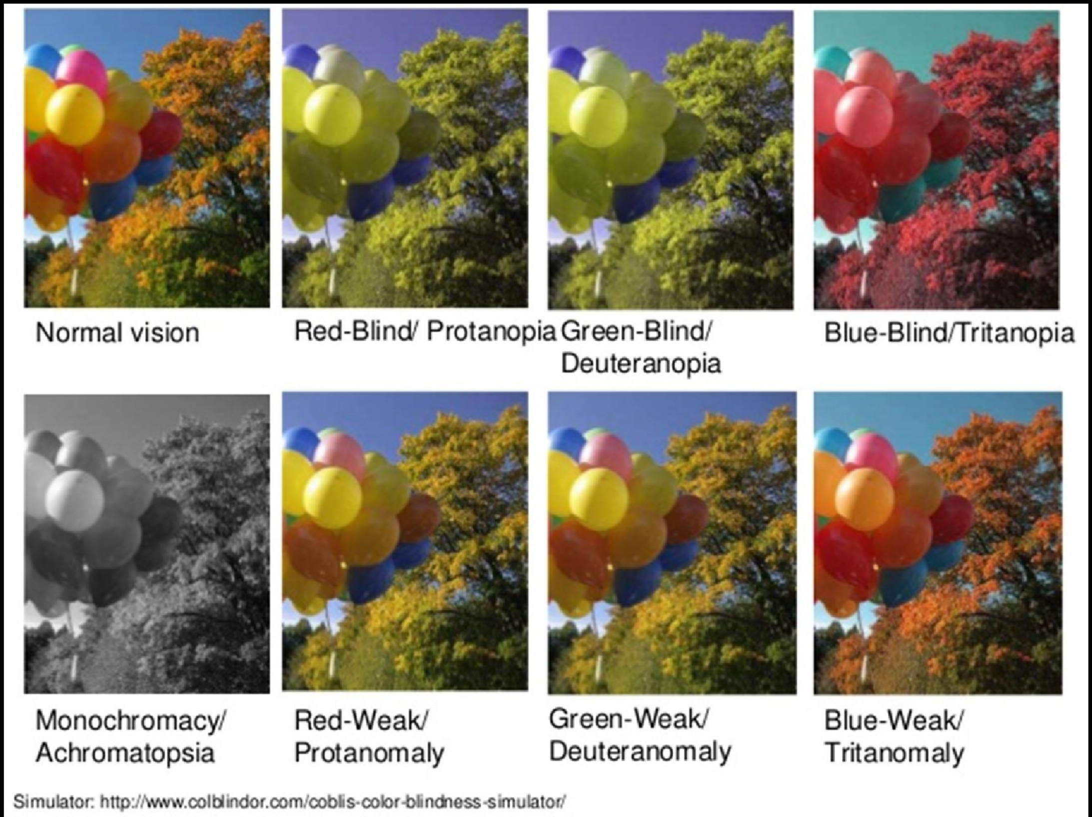


CONGENITAL COLOR VISION DEFECT

Anomalous trichromacy:

One of the cone pigments is altered in spectral sensitivity.

- **Protanomaly:**
- Photopic vision for red wavelength is low.
- **Deuteranomoly:**
- Photopic vision for green wavelength is low.
- **Tritanomaly:**
- Photopic vision for blue wavelength is low.



CONGENITAL COLOR VISION DEFECT

Dichromacy:

One of the cone pigments is absent or non-functioning.

- **Protanopia:**
- Complete absence or non-functioning of red retinal photoreceptors
- **Deuteranopia:**
- Complete absence or non-functioning of green retinal photoreceptors.
- **Tritanopia:**
- Complete absence or non-functioning of blue retinal photoreceptors.

CONGENITAL COLOR VISION DEFECT

1.2 Achromatopsia or monochromacy or Total colour blindness:Two or three cone pigments are missing.

1.2.1Complete Achromatopsia:

Absence of more than one cone or all cones

- Typical Achromatopsia or Rod Monochromacy:
- The total absence of cones in the eye.
- Atypical Achromatopsia or Cone Monochromacy:
- Lack or damage of more than one cone
- People with both Protanopia and Tritanopia(only green cones are present)

1.2.2 Incomplete Achromatopsia or Blue cone Monochromatism:

Only blue cones and rods are functioning.

ACQUIRED COLOR DEFECTS

Type 1 red green-Similar to protan deficiency – displaced relative luminous efficiency to short wavelengths, associated with Progressive cone dystrophies, Retinal pigment epithelium dystrophies

Type 2 red green-Similar to deutan deficiency but with a greater reduction in short-wavelength sensitivity, associated with optic neuritis

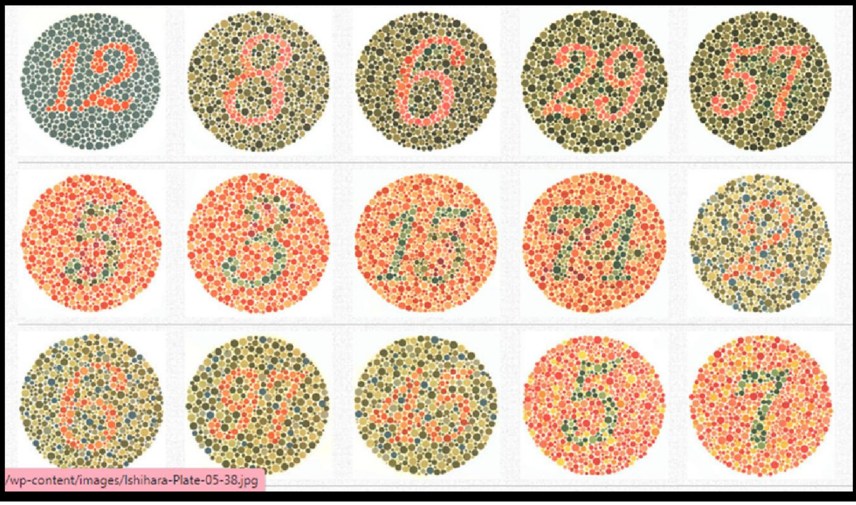
Type 3 -Similar to Tritan deficiency but with displaced relative luminous efficiency to short wavelengths, associated with central serous chorioretinopathy, Age-related macular degeneration, Rod and rod-cone dystrophies, Retinal vascular disorders, Peripheral retinal lesions, Glaucoma and Autosomal dominant optic atrophy

ISHIHARA TEST

The Ishihara test for color blindness is a widely employed diagnostic tool designed to assess an individual's ability to perceive colors accurately, particularly red-green color deficiencies.

Developed by Dr. Shinobu Ishihara in 1917, the test consists of a series of plates, each displaying circles composed of colored dots.

Within these circles, numbers or shapes are embedded, discernible to individuals with normal color vision but challenging for those with color blindness.



ISHIHARA TEST

The test consists of a number of **Ishihara plates**, which are a type of pseudoisochromatic plate.

Each plate depicts a solid circle of colored dots appearing randomized in color and size.

Within the pattern are dots which form a number or shape clearly visible to those with normal color vision, and invisible, or difficult to see, to those with a red-green color vision defect.

Other plates are intentionally designed to reveal numbers only to those with a red-green color vision deficiency, and be invisible to those with normal red-green color vision.

The full test consists of 38 plates, but the existence of a severe deficiency is usually apparent after only a few plates. There are also Ishihara tests consisting of 10, 14 or 24 test plates, and plates in some versions ask the viewer to trace a line rather than read a number.

ISHIHARA TEST

The plates make up several different test designs:[5]

Demonstration plates: (plate number one, typically the numeral "12"); designed to be visible by all persons, whether normal or color vision deficient. For demonstration purposes only, and usually not considered in making a score for screening purposes.

Transformation plates: individuals with color vision defect should see a different figure from individuals with normal color vision.

Vanishing plates: only individuals with normal color vision could recognize the figure.

Hidden digit plates: only individuals with color vision defect could recognize the figure.

Diagnostic plates: intended to determine the type of color vision defect (protanopia or deuteranopia) and the severity of it.

Tracing plates: instead of reading a number, subjects are asked to trace a visible line across the plate.[4]

HOLMGREN COLORED WOOL

Holmgren's wool test also known as **Holmgren's colored wool test** is a color vision test used to detect color vision deficiency.

Swedish physiologist Frithiof Holmgren introduced the test in 1874. It was the first successful attempt to standardize the detection of color blindness.

William Thomson simplified the original Holmgren test, and later named as **Holmgren-Thomson test**.

HOLMGREN COLORED WOOL

Unlike modern color vision tests that use plates or charts, the Holmgren test involves sorting skeins of colored wool.

During the test, an individual is asked to match or sort various shades of colored wool into groups based on their perceived similarities in color. The test includes colors that are challenging for individuals with red-green color deficiencies to differentiate. Those with normal color vision can more accurately group the colors according to their subtle differences.

LANTERN TEST

The **Farnsworth Lantern Test**, or **FALANT**, is a color vision test originally developed specifically to screen sailors for tasks requiring color vision, such as identifying signal lights at night.

It screens for red-green deficiencies, but not the much rarer blue color deficiency.

LANTERN TEST

The test consists of showing a pair of vertically oriented lights consisting of combinations of either red, green or yellow-white.

The test subject is asked to identify the two colors (some of which are identical). Nine color pairs are administered during the test, beginning with a red/green combination, to allow the patient to see these two colors prior to seeing a white light, which decreases testing errors.

The examinee is shown the target for only two seconds, as color-deficient patients can sometimes correctly identify the colors with prolonged exposure.

The yellow-white light, or one of the identical paired lights, employs a 50% neutral gray filter to reduce luminance cues to the color-deficient patient. Random presentation reduces memorization of the test sequence by motivated persons

- https://slideplayer.com/slide/7347434/
- https://weeklysciencequiz.blogspot.com/2011/09/when-light-meets-matter.html
- https://www.toppr.com/ask/question/a-state-and-explain-the-laws-of-refraction-of-light-with-the-help-of-a/
- https://www.creatopy.com/blog/color-theory/#f
- https://optometryzone.com/2017/10/10/color-vision-deficiency/
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