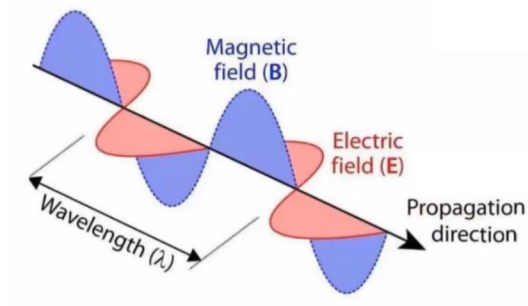
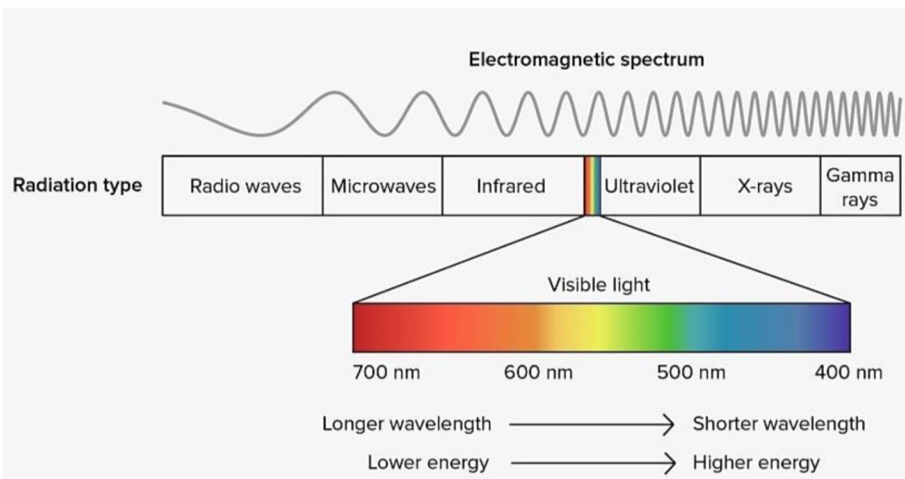
Light in medicine

The light is a particular form of the electromagnetic radiation (EMR). Electromagnetic radiation consists of an electrical field (E) which varies in magnitude in a direction perpendicular to the direction in which the radiation is traveling, and a magnetic field (B) oriented at right angles to the electrical field. Both these fields travel at the speed of light (c).



Electromagnetic radiation as a wave travels through space at the speed of light C which is $3*10^8$ m/s. Figure below gives an overview over the whole spectrum of electromagnetic waves.



Ultraviolet light has wavelengths from about 100 to 400 nm
Visible light extends from about 400 to 700 nm
IR light extents from about 700 to over 10^4nm.

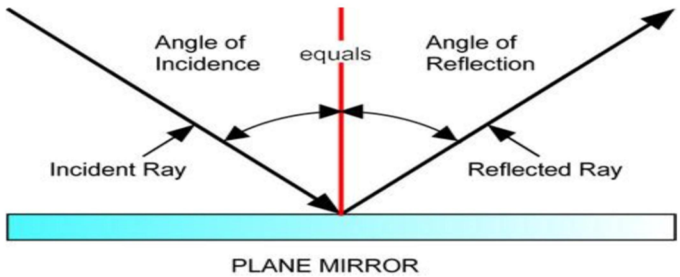
Properties of light:

1. The speed of light changes when it goes from material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the index of refraction. If a light beam meets a new material at an angle other than perpendicular, it bends, or is refracted.

2. Light behaves both as a wave and as a particle. **As a wave** it produces interference and diffraction.

3. As **a particle** it can be absorbed by a single molecule this can lead to one of the followings:
a. It can cause a chemical change in the molecule that in turn can cause an electrical change such as in the retina (the light-sensitive part of the eye).
b. The absorbed energy may produce heat in the tissue as in the application of IR and LASER in medicine.

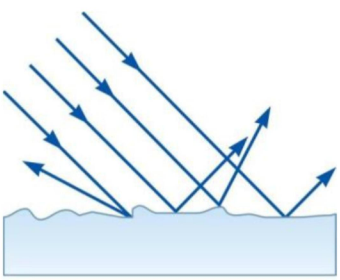
4. Light is reflected to some extent from all surfaces.

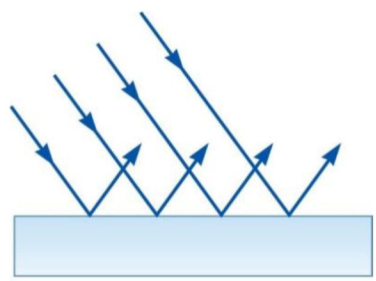


There are two types of reflection:

1- Diffuse reflection occurs when rough surfaces scatter the light in many directions.

2- Specular reflection is more useful type of reflection; it is obtained from very smooth shiny surfaces such as mirrors where the light is reflected at an angle that is equal to the angle at which it strikes the surface.





Measurement of light and its units
Wavelengths of light used to be measured in microns ($1\mu=10^{-6}m$) or in angstroms ($1Å=10^{-10}m$), but at present the recommended unit is the nanometer ($1nm=10^{-9}m$).

Uses of visible Light in medicine:
We will discuss the uses three general categories of light UV, visible, and IR in addition to LASER.

1-Curved surfaces

When we wish to look into a body opening, we have to get light into the opening without obstructing the view. The curved surface focuses the light at the region of interest. More sophisticated instruments, such as the ophthalmoscope for looking into the eyes and the otoscope for looking into the ears, use basically the same principle.

1- Endoscopy

Endoscopes are used for viewing internal body cavities. Special purpose endoscopes are often given names indicating their purpose. For example, **cystoscopes** are used to examine the bladder, **proctoscopes** are used for examining the rectum, **enteroscopy** are used to examine small intestine, **colonoscopy** used to examine large intestine colon, **hysteroscopy** used to examine the uterus and **bronchoscopes** are used for examining the air passages into the lungs. Some endoscopes are rigid tubes with a light source to illuminate the area of interest.

Flexible endoscopes that are made of fiber optics can be used to obtain information from regions of the body that cannot be examined with rigid endoscopes, such as the small intestine and much of the large intestine. Flexible endoscopes usually have an opening or channel that permits the physician to take samples of the tissues (biopsies) for later microscopic examination.

2- Transillumination

Transillumination is the transmission of light through the tissues of the body.

1- the detection of hydrocephalus

Since the skull of young infants is not fully calcified, light is able to penetrate to the inside of the skull; if there is an excess of relatively clear cerebrospinal fluid (CSF) in the skull, light is scattered to different parts of the skull producing patterns characteristic of hydrocephalus (water-head).

The infant is taken into a dark room for the study. The physician then point the barrel at the part of the head to be studied with an intense white light used for the study. Infrared absorbing glass in the beam removes almost all of the IR radiation so that the light striking the infant is primarily visible light.

2-Detection of pneumothorax

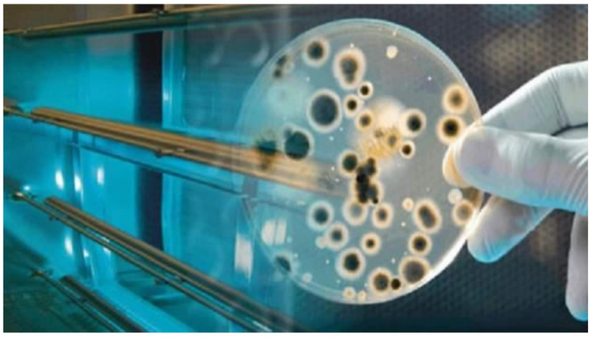
The bright light penetrates the thin front chest wall of an infant and reflects off the back chest wall to indicate the degree of pneumothorax (collapsed lung). The physician can then insert a needle attached to a syringe into the area of collapse to remove the air between the lung and chest wall, causing the lung to reinflate.

2- Recovering from jaundice

Many premature infants have jaundice, a condition in which an excess of bilirubin is excreted by the liver into the blood. Most premature infants recover from jaundice if their bodies are exposed to visible light (phototherapy).

Applications of ultraviolet light in medicine

-Ultraviolet photons have energies greater than visible photons, while IR photons have lower energies. Ultraviolet light with wavelengths below about 290nm is germicidal-that is, it can kill germs- and it is used to sterilize medical instruments.



Certain materials fluoresce in the presence of UV light and give off visible light. The amount of fluorescence and the color of the emitted light depend on the wavelength of the UV light and on the chemical composition of the material that is fluorescing. One way fluorescence is used in medicine is in the detection of porphyria, a condition in which the teeth fluoresce red when irradiated with UV light.

-One of the major beneficial effects of UV light from the sun is the conversion of molecular products in the skin into vitamin D.
-Dermatologists have found that UV light improves certain skin conditions.
-Ultraviolet light from the sun affects the melanin in the skin to cause tanning.
-Solar UV light is also the major cause of skin cancer in humans. This can be related to the fact that the UV wavelengths that produce sunburn are also very well absorbed by the DNA in the cells.

Applications of infrared light in medicine

-Heat lamps that produce a large percentage of IR light with wavelengths of 1000 to 2000 nm are often used for physical therapy purposes. Infrared light penetrates further into the tissues than visible light and thus is better able to heat deep tissues.

Two types of IR photography are used in medicine: reflective IR photography and emissive IR photography. The latter, which uses the long IR heat waves emitted by the body that give an indication of the body temperature, is usually called thermography. Reflective IR photography, which uses wavelengths of 700 to 900 nm, shows the patterns of veins just below the skin.

-Since the temperature at the skin depends on the local blood flow, a thermogram with good resolution shows the venous pattern much like a near-IR photograph. Cancer and other diseases can cause changes in the venous pattern, but these changes can be masked by the normal variations.

-Infrared can also be used to photograph the pupil of the eye without stimulating the reflex that changes its size.

LASERs in medicine

A LASER is a unique light source that emits a narrow beam of light of a single wavelength (monochromatic light) in which each wave is in phase with the others near it (coherent light). LASER is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.

Useful Properties of Laser Beams:

1- LASER beams are highly directional and can be well collimated (i.e. made to not diverge very much over long distances). This characteristic allows their energy to be directed and confined to a specific location without a lot of residual light elsewhere.
2- Some applications require a LASER with a continuous beam (“continuous wave” or “CW” LASERs) while others are better served by the application of short pulses of laser light (pulsed LASERs). Multiple laser technologies are available in both modalities.
3- LASERs can have extremely high peak and/or average powers compared to other light sources, with average powers as high as megawatts, and peak powers as high as terawatts in the most extreme cases.
4- Some LASER beams have a long coherence length. This means that there is a well-defined relationship between the locations and timings of the maxima and minima of the laser’s light field.

LASER effects on tissue:

1- **Photothermal Effects**

LASERs can be used to rapidly heat a volume of tissue. Some of the light energy absorbed by molecules in the tissue is converted to heat through molecular vibrations and collisions. Depending on the laser's parameters, the rise in heat can be used to affect tissue in various ways. These include coagulation, vaporization and selective thermolysis (heat-induced chemical/cell decomposition).

2- **Photoablation**

LASERs can directly induce ablation (removal of tissue) through two mechanisms. The first is through molecular dissociation. In this mechanism, high-energy photons (or multiple lower-energy photons) are absorbed by the tissue's molecules. The photons have a sufficiently high energy to break molecular bonds, leading to ablation by the immediate dissociation of the molecules.

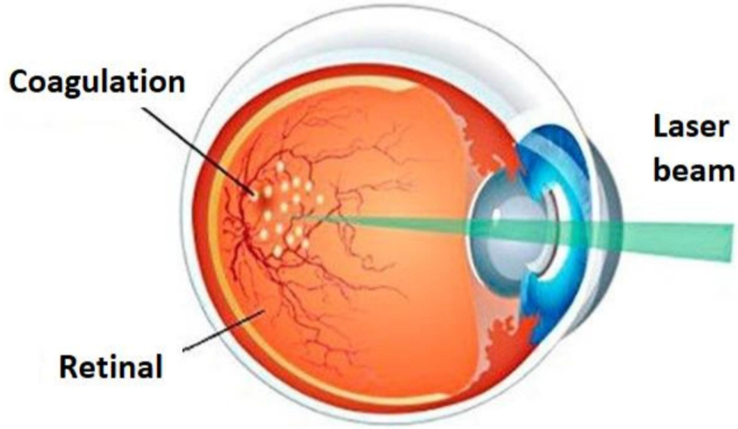
3- **Photochemical Reactions**

Some chemical reactions are induced by the absorption of photons. Such reactions are called photochemical. In medicine, the primary use of photochemistry is in activating administered drugs called "photosensitizers." These drugs lead to cell-death of surrounding tissue when light of a particular wavelength is shone on them, inducing a chemical reaction in the photosensitizer and tissue (photodynamic therapy).

4- **Photomechanical Effects or Photodisruption**

Intense LASERs can induce mechanical effects in tissue. These effects include acoustic shockwaves, bubble formation and cavity formation. While these effects are detrimental in some cases, they have been put to use in breaking up certain tissues, such as kidney or gall stones.

When all of the energy of the laser is concentrated in such a small area, the power density (power per unit area) becomes very large. The total energy of a typical laser pulse used in medicine, which is measured in millijoules (mJ), can be delivered in less than a microsecond, and the resultant instantaneous power may be in megawatts. Most of laser damage is due to heating in addition it can produce noticeable damage due to photochemical effects.



In ophthalmology LASERs are primarily used for photocoagulation of the retina, that is, heating a blood vessel to the point where the blood coagulates and blocks the vessel.

The minimum amount of laser energy that will do observable damage to the retina is called the Minimal Reactive Dose (MRD). For example, the MRD for 50µm spot in the eye is about 2.4mJ delivered in 0.25sec.

Photocoagulation is useful for repairing retinal tears or holes that develop prior to retinal detachment. When the retina is completely detached, the laser is of no help. A complication of diabetes that affects the retina, called diabetic retinopathy, can also be treated with photocoagulation.