Light in Medicine

18/May/2021

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2002

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جامعة ذي قار
Thi- Qar University
2002

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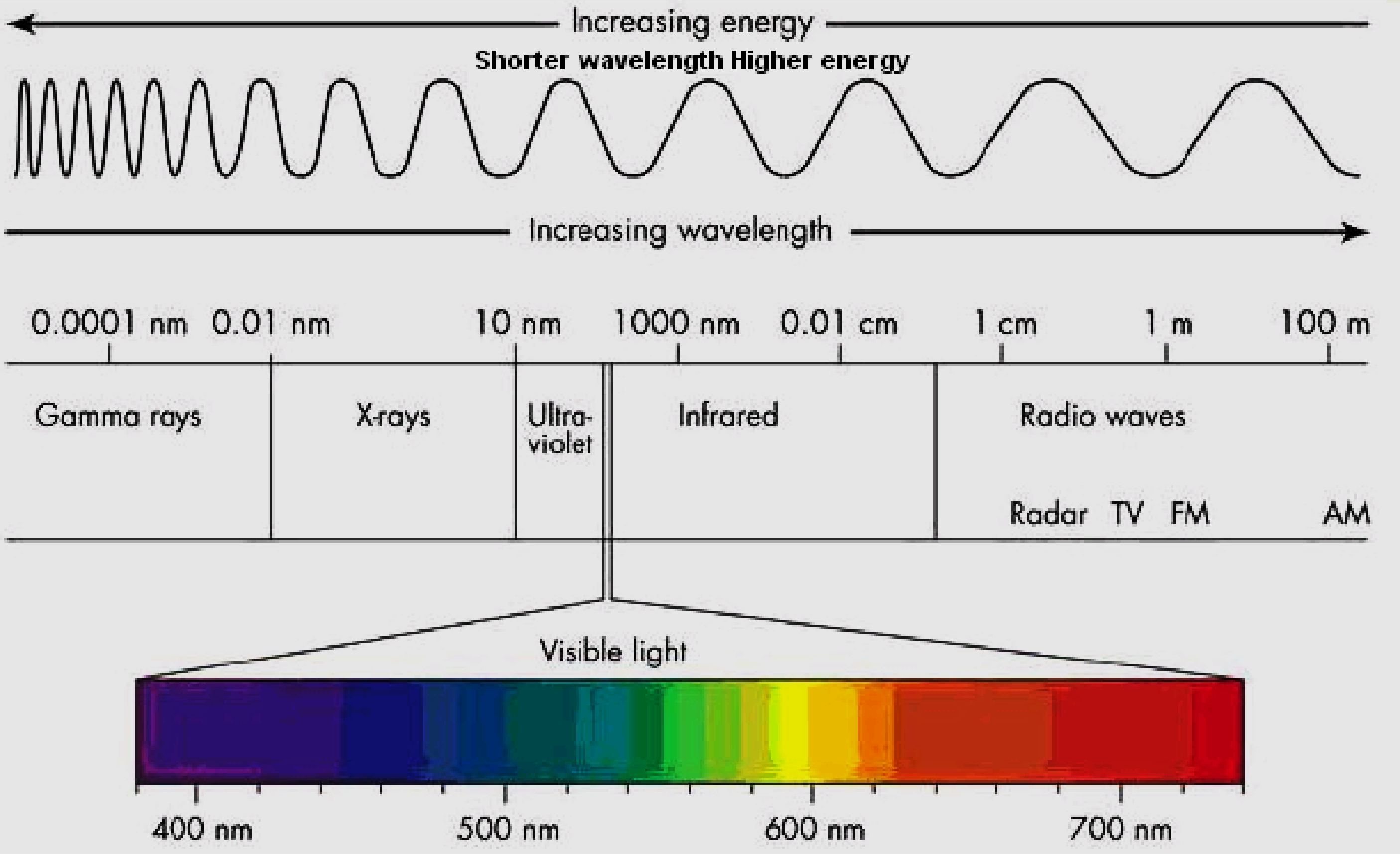
1. Introduction

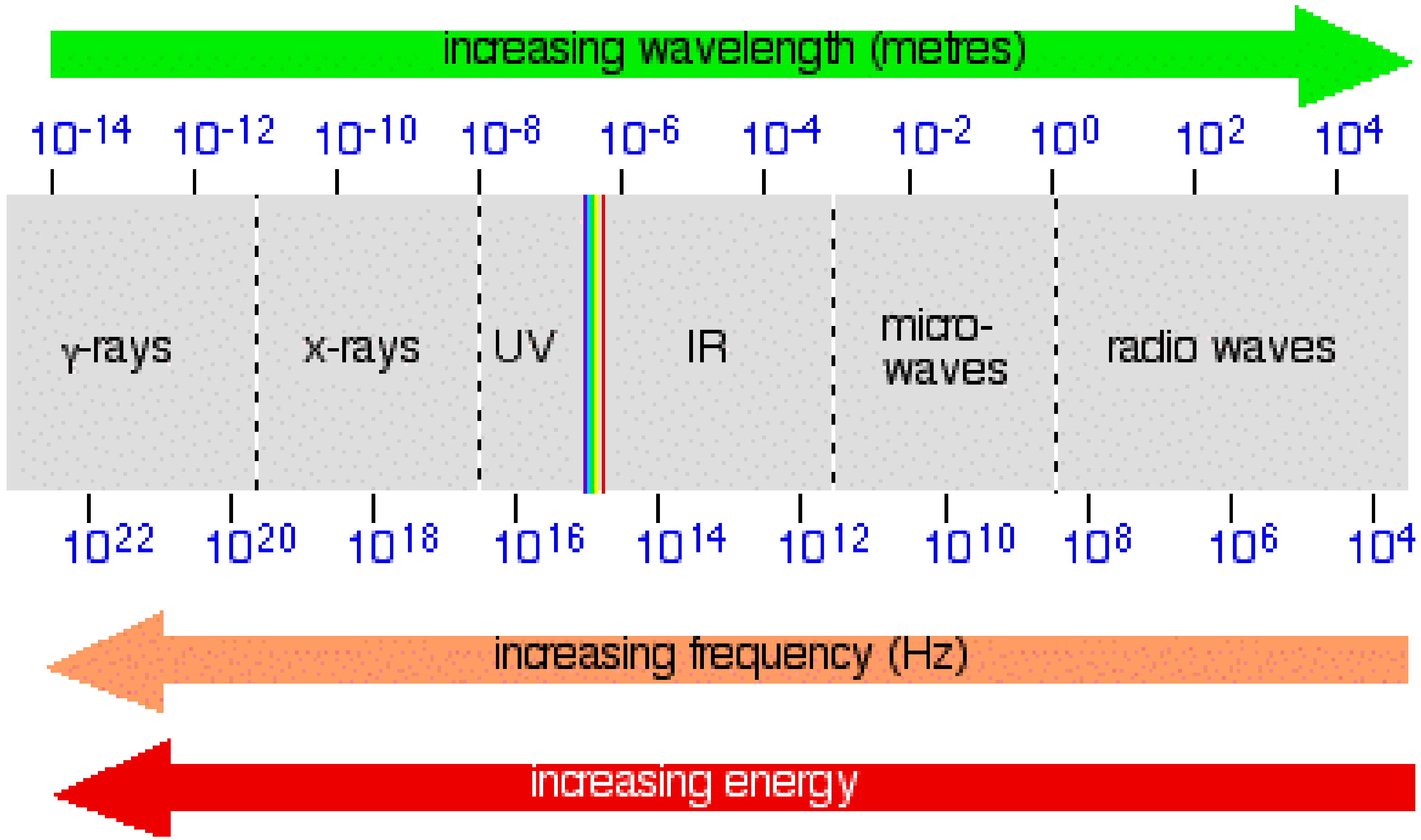
In this chapter we discuss the medical applications of light in **diagnosis** and **therapy** and also **hazards** of light.

Definition:
Light or visible light is **electromagnetic radiation** within the portion of the electromagnetic spectrum.

1. Travel at the speed of light
2. Have no electric charge

We will study light in three categories (visible & ultraviolet & infrared)




increasing wavelength (metres)
10^{-14} 10^{-12} 10^{-10} 10^{-8} 10^{-6} 10^{-4} 10^{-2} 10^{0} 10^{2} 10^{4}
γ-rays
x-rays
UV
IR
micro-waves
radio waves
10^{22} 10^{20} 10^{18} 10^{16} 10^{14} 10^{12} 10^{10} 10^{8} 10^{6} 10^{4}
increasing frequency (Hz)
increasing energy

2. Light properties

Light has some interesting properties, many of which are used in medicine:

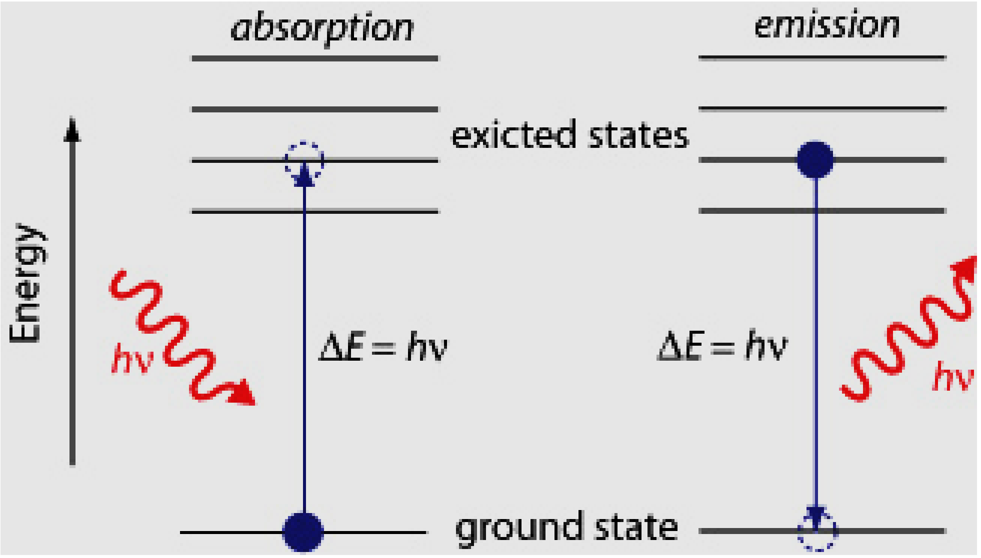
1. The speed of light changes when it goes from material into another. The ratio of the speed of light in a vacuum to its speed in a given material is called the **index of refraction**. If a light beam meets a new material at an angle other than perpendicular, it bends, or is refracted.

2. Light behaves both as a **wave** and as a **particle**. As a wave it produces **interference** and **diffraction**. As a particle it can be **absorbed** by a single molecule.

When a light photon is absorbed its energy is used in various ways. It can cause a **chemical change** in the molecule that in turn can cause an electrical change.

Photons are the particle form of **light.**

This is basically what happens when a light photon is absorbed in one of the sensitive cells of the **retina**. The chemical change in a particular point of the retina triggers an electrical signal to the brain to inform it that a light photon has been absorbed at that point.



3. When light is **absorbed**, its energy generally appears as heat. This property is the basic for the use in medicine of lR light to heat tissues. Also, the heat produced by laser beams is used to "**weld**" a detached retina to the back of the eyeball and to coagulate small blood vessels in the retina.

4. Sometimes when photon is absorbed, a lower energy light photon is emitted. This property is known as **fluorescence**, it is the basis of the fluorescent lightbulb. Certain materials fluoresce in the presence of UV light, sometimes called "**black light**," and give off visible light.

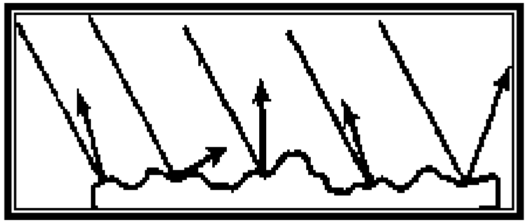
The amount of fluorescence and the color of the emitted light **depend** on the wavelength of the UV light and on the chemical composition of the material that is fluorescing.

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. Another important application is in fluorescent microscopes.

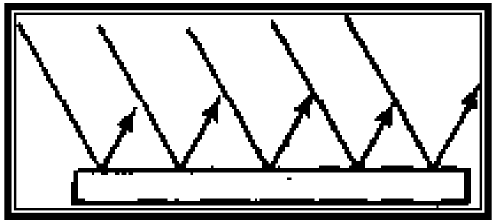
A skin rash in a person with porphyria

5. Light is **reflected** to some extent from all surfaces. There are **two** types of reflection. **Diffuse reflection** occurs when rough surfaces scatter the light in many directions.

Specular reflection is more useful types 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. Mirrors are used in many medical instruments.



Diffuse reflection



Specular reflection

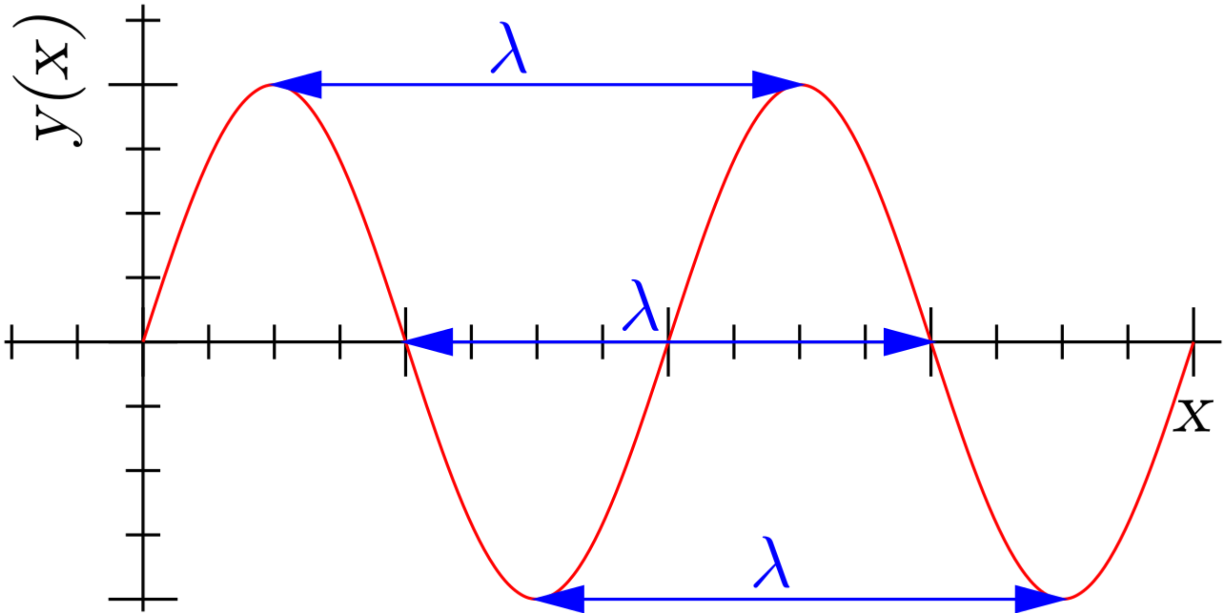
3. Measurement of light and its units

The **three** general categories of **light-UV**, **visible**, and **IR** are defined in term of their wavelengths.

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

Ultraviolet light has wavelengths from about 100 to 400 nm; **visible light** extends from about **400 to 700 nm**; and **IR** light extents from about 700 to over 10^4 nm.

The wavelength λ represents the distance between two points with the same phase, such as between crests (on top), or troughs (on bottom).



Sine wave

Prefix/Symbol	Meaning	Multiplier	
giga (G)	One billion	10^9	1,000,000,000
mega (M)	One million	10^6	1,000,000
kilo (k)	One thousand	10^3	1,000
hector (h)	One hundred	10^2	100
deca (da)	Ten	10	10^1
deci (d)	One-tenth	10^{-1}	0.1
centi (c)	One-hundredth	10^{-2}	0.01
milli (m)	One-thousandth	10^{-3}	0.001
micro (μ)	One-millionth	10^{-6}	0.000001
nano (n)	One-billionth	10^{-9}	0.000000001

4. Applications of visible light in medicine

a) Curved Surfaces

Curved lenses (concave, convex & cylindrical) lenses
Curved mirrors which are used in:

a. ophthalmoscope for locking into the eye.
b. otoscope for locking into the ear.

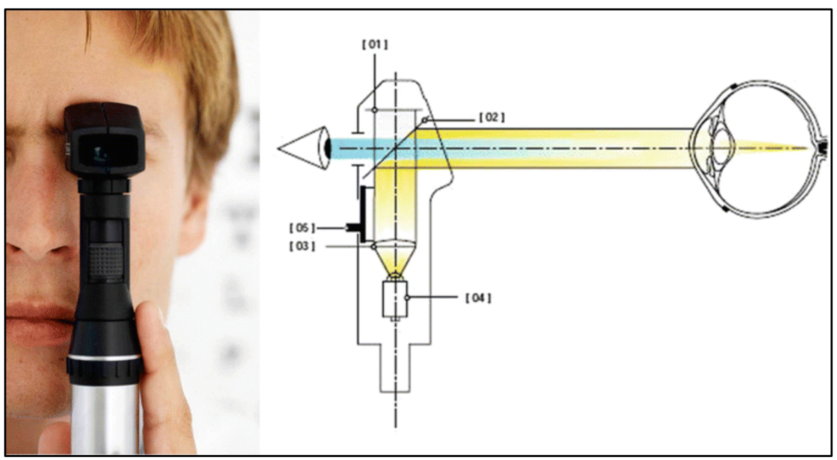
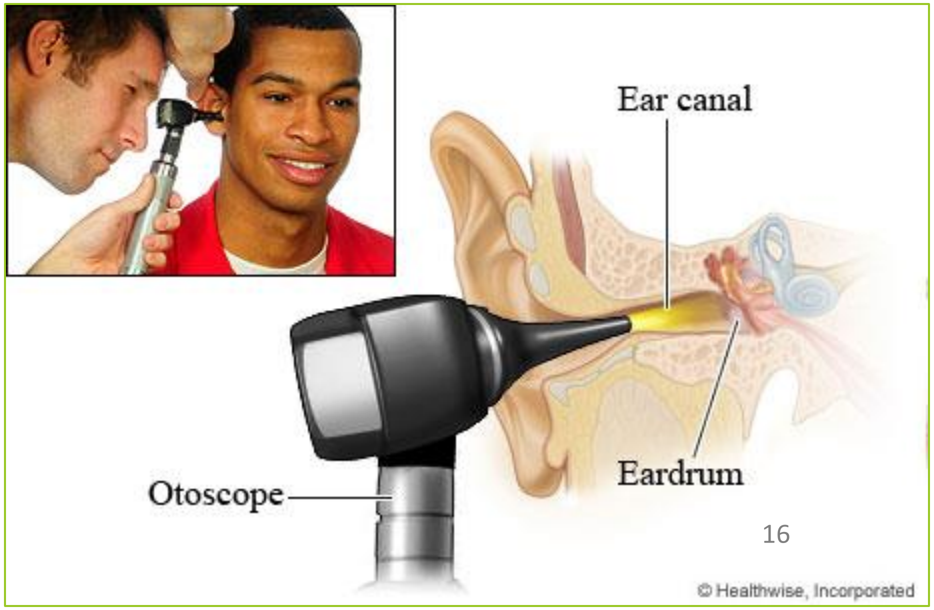


Figure shows retinoscope. An integrated lamp or LED light source (4) shines light through a collimating lens (3) onto a partially reflective mirror (2), which directs the light to the eye.

Ophthalmoscope

Otoscope



b) Endoscopes

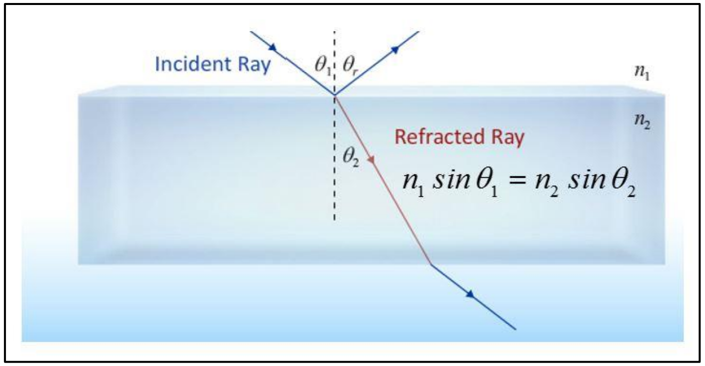
are used for viewing internal body cavities as:

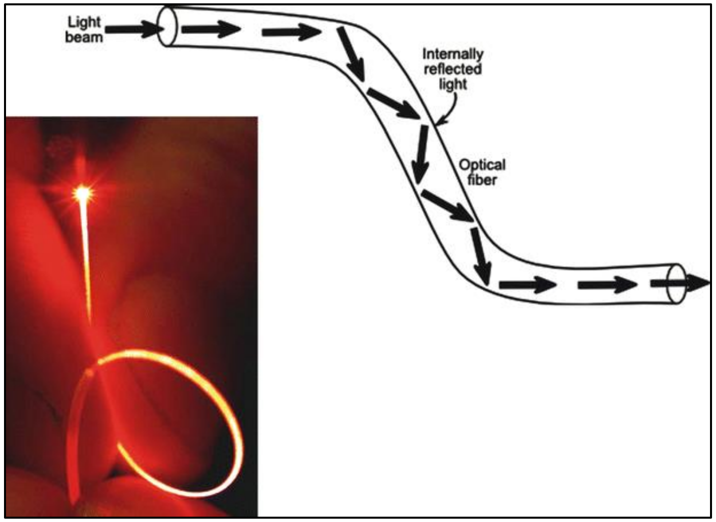
a. cyctoscope for examination of bladder.

b. proctoscope for examination of rectum.

c. bronchoscope for examination of air passages into the lung.

Optical Principles of the Endoscope





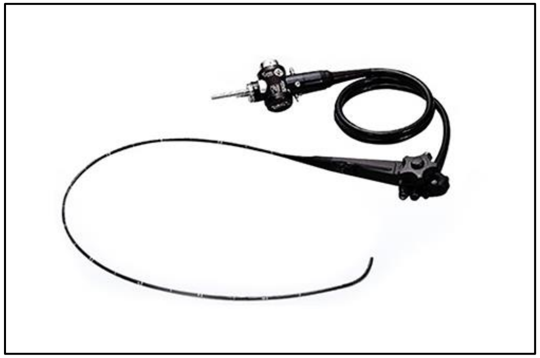
The mathematical expression that describes the refraction phenomena is known as **Snell's law**,

$$n_1 \sin\theta_1 = n_2 \sin\theta_2$$

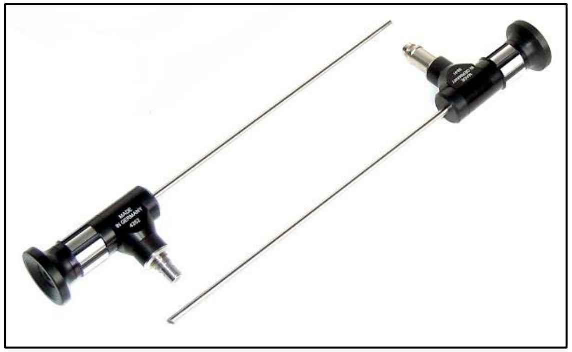
Refractive index of some materials:

Indices of refraction	
medium	index of refraction n
vacuum	1.00 exactly
air	1.0003
water	1.33
oil	1.46
glass	1.50
diamond	2.41

The development of **fiberoptic** techniques permitted the construction of flexible endoscopes. **Flexible** endoscopes 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
To treat a variety of gastrointestinal problems



Rigid endoscopes
To visualize the surface of organs, their vessels, or pathological changes

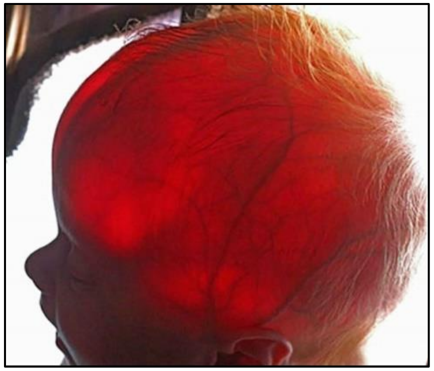
Some flexible endoscopes are over a meter in length.

The image obtained with a flexible endoscope is not as good as that obtained with a rigid endoscope, but often the only alternative to a flexible endoscopic examination is exploratory surgery.

c) Transillumination

It is the transmission of light through the tissue of the body.

It used clinically in the detection of:



a. hydrocephalus (water head) in infant.
b. pneumothorax (collapsed lungs) in infant.
c. the sinuses
d. the gums
e. the breast
f. the testes.

d) Phototherapy

Premature infant recover from jaundice when they exposed to visible light.

A premature infant is a baby born before 37 completed weeks of gestation.

5. Applications of ultraviolet and infrared light in medicine

The wavelengths adjacent to the visible spectrum also have important uses in medicine. Ultraviolet photons have energies greater than visible photons, while IR photons have lower energies, because of their higher energies, UV photons are more useful than IR photons.

Ultraviolet light with wavelengths below about 290 nm is **germicidal**-that is, it can kill germs and it is sometimes used to sterilize medical instruments

Ultraviolet light also produces more reactions in the skin than visible light. Some of these reactions are beneficial, and some are harmful. One of the major beneficial effects of UV light from the sun is the conversion of molecular products in the skin into vitamin D

A **blacklight** (or often black light), also referred to as a UV-A light, Wood's lamp, or ultraviolet light, is a lamp that emits long-wave (UV-A) ultraviolet light and very little visible light.

Robert Williams Wood in 1903 using "Wood's glass", it was in 1925

A **Wood's lamp** is a diagnostic tool used in dermatology by which ultraviolet light is shone (at a wavelength of approximately 365 nanometers)

Wood's glass is an optical filter glass invented in 1903 by American physicist **Wood** (1868–1955), which allows ultraviolet and infrared light to pass through, while blocking most visible light

Wood's lamp

Wood lamp Ultraviolet light lamp for skin diagnose and analysis

Wood's lamp

SKIN CONDITION DISPLAYED COLOR:

- Thick epidermis White fluorescence
- Necrosis cells White spot
- Healthy skin Blue and white
- Water deficiency (thin skin) Purple
- Water deficiency Light purple
- Water abundance Bright fluorescence
- Dark fleck Brown
- Oiled part and pimple Yellow or pink

6. Hazards

Ultraviolet light from the sun affects the melanin in the skin to cause **tanning**. However, UV can produce sunburn as well as tan the skin. The wavelengths that produce sunburn are around 300 nm.

Solar UV light is also the major cause of **skin cancer** in humans. The high incidence of skin cancer among people, who have been exposed to the sun a great deal, such as fishermen and agricultural workers, may be related to the fact that the UV wavelengths that produce sunburn are also very well absorbed by the DNA in the cells.

IR light

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 **thermograph.**

Reflective IR photography, which uses wavelengths of 700 to 900 nm to show the patterns of veins just below the skin.

Some of these veins are visible to the eye, but many more can be seen on a near-IR photograph of the skin.

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

7. Laser 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.

While the basic theory for lasers was proposed by **Albert Einstein** in 1917, the first successful laser was not made until 1960, when **T. H. Maiman** produced a laser beam from a ruby crystal. Since 1960 scientists have made many types of lasers using gases and liquids as well as solids as the laser materials.

In a laser, energy that has been stored in the laser material (**e.g., ruby**) is released as a narrow beam of light-either as a steady beam **continuous wave** (**CW**) or an **intense pulse**. The beam remains narrow over long distances and can be thought of as an ideal "**spot**" light. A laser beam can be focused to be a spot only a few microns in diameter. When all of the energy of the laser is concentrated in such a small area, the power density 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

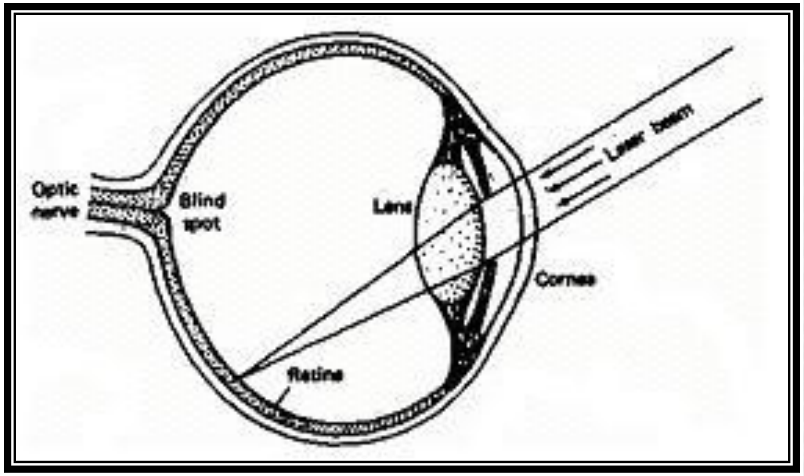
Two types for laser pumping is

1. CW
2. PW

Useful

1. Since in medicine lasers are used primarily to deliver energy to tissue, the laser wavelength used should be strongly absorbed by tissue.
2. The curve varies for different individuals, but the short wavelengths (400 to 600 nm) are always absorbed better than the long wavelengths (~700 nm).
3. The laser is routinely used in clinical medicine only in ophthalmology.
4. Its effectiveness in treating certain types of cancer and its usefulness as a "**bloodless knife**" for surgery are under active investigation.
5. Lasers are also being used in medical research for special three-dimensional imaging called **holography**.

6. 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 **amount** of laser energy needed for photocoagulation **depends** on the **spot size** used. In general, the proper dose is determined visually by the ophthalmologist at the time of the treatment.

The minimum amount of laser energy that will do observable damage to the retina is called the **minimal reactive dose** (**MRD**).

8. Applications of microscopes in medicine

There have been few breakthroughs in science that have had as great an impact as the invention of the **microscope** by **Leeuwenhoek** (1670). The use of the microscope in the pathology laboratory is as common as the use of the thermometer in the clinic.

The standard light microscope usually can be set at any of several magnifications by changing the power of the eyepiece or of the objective lens. The highest magnification that can be obtained is limited by the wavelength of visible light. Since the wavelength of visible light range from 400 to 700 nm, the smallest object that can be resolved is about 1 μm in diameter. Since most cells are 5 to 50 μm in diameter, this type of microscope is adequate for resolving all but subcellular objects.

1. If you put a thin slice of tissue under a microscope you will not see much because most cells are transparent to all wavelengths of **visible light**-red blood cells are an exception.
2. In order to distinguish different cells it is usually necessary to stain them with a chemical that strongly absorbs certain visible wavelengths.
3. It is sometimes advantageous to use **UV light** or **x-rays** in microscopy. Since our eyes cannot see wavelength shorter than those of visible light, it is necessary to convert the image produced by UV light or x-ray beams into images that use visible light.

Thank you

Questions