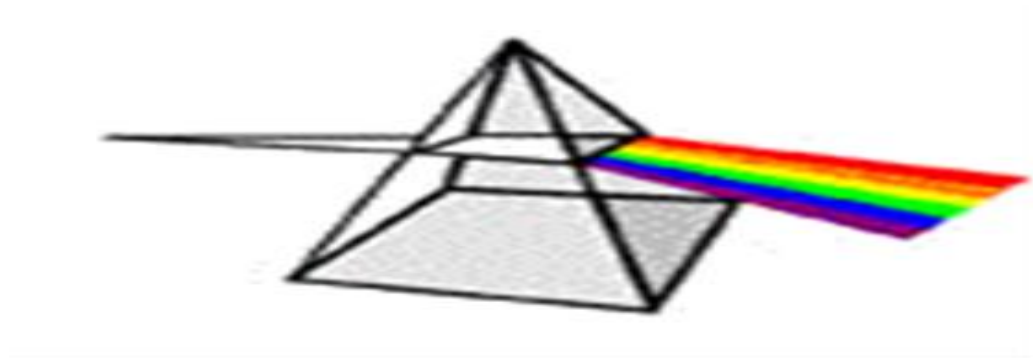


Light in medicine

2019-2020



Dr. Enas S. Al-Mizban

LIGHT IN MEDICINE

The Visible Light Spectrum



Introduction:

In this chapter we discuss the medical application of light in diagnosis and therapy and also the hazards of light. we consider visible light, infra red (IR) light, and ultraviolet (UV) light.

Even though man now is very efficient at making artificial light, the sun is still the major source of the light in the world. the sun is both beneficial and hazards to our health.

PROPERTIES OF LIGHT

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

1- The speed of light changes when it goes from one material into another. the ratio of the speed of light in vacuum to its speed in a given material is called the index of refraction ($n = c/v$).

if a light beam meets a new material at an angle other than perpendicular, it bends, or it is reflected.

2- Light behaves both as a wave or as a particle. as a wave it produces interference and diffraction, which are of less importance in medicine. 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 chemical changes in the molecule that in turn can cause electrical changes. this is basically what happens when a light photon is absorbed in one of the sensitive cells of the retina (the light-sensitive part of the eye).

The chemical changes in particular point of the retina trigger an electrical signal to the brain to inform it that a light photon has been absorbed at that point.

PROPERTIES OF LIGHT

3- When light is absorbed its energy generally appears as **heat**. This property is the basis for the use in medicine of IR light to heat tissues (**diathermy**).

Also, the heat produced by laser beams is used to weld a detached retina to the back of the eyeball and coagulate small blood vessels in the retina (**Photo coagulation**).

PROPERTIES OF LIGHT

4- Sometimes when light photon is absorbed, a lower energy light photon is emitted. This property is known as **fluorescence**, it is the basis of the fluorescent light bulb. 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.

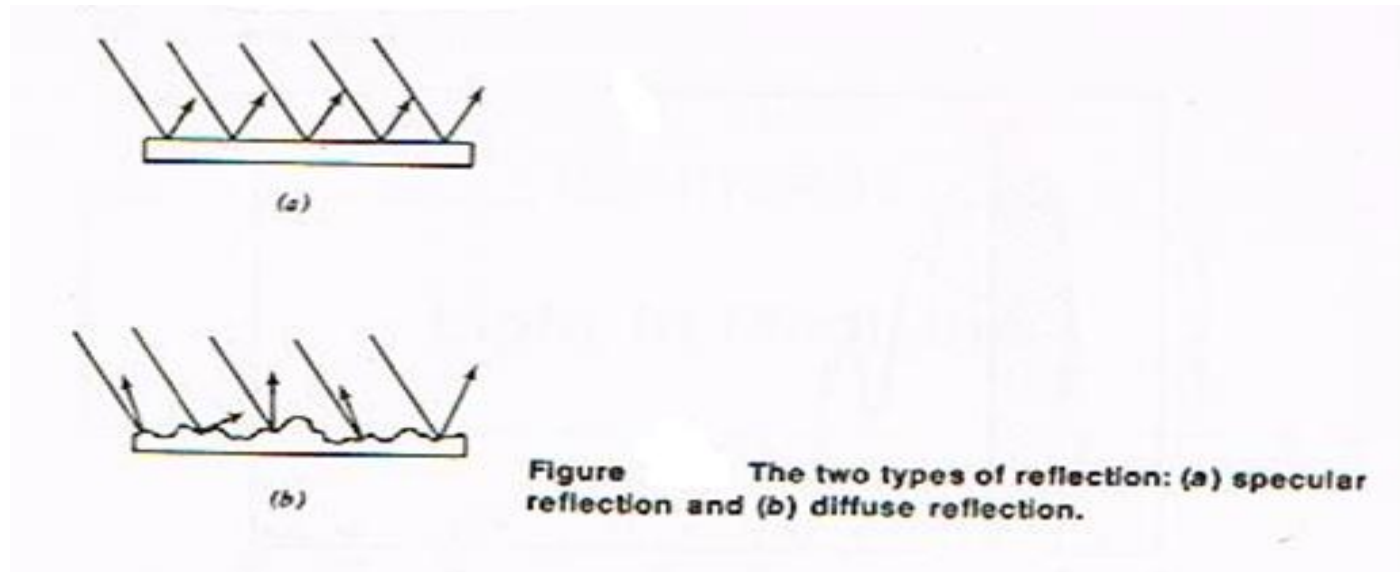
One way fluorescence is used in medicine is in the detection of **porphyries**, a condition in which the **teeth fluoresce** red when irradiated with UV light.

Another important application is in **fluorescent microscopes**

PROPERTIES OF LIGHT

5- Light is reflected to some extent from all surface. There are two types of reflection (see Fig. above). **Diffused reflection** occurs when rough surfaces scatter the light in many directions.

Specular reflection is a 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. Mirrors are used in many medical instruments. One simple instrument is a mirror that is held at the back of a patient's throat to look at his vocal folds.



MEASUREMENT OF LIGHT AND ITS UNITS

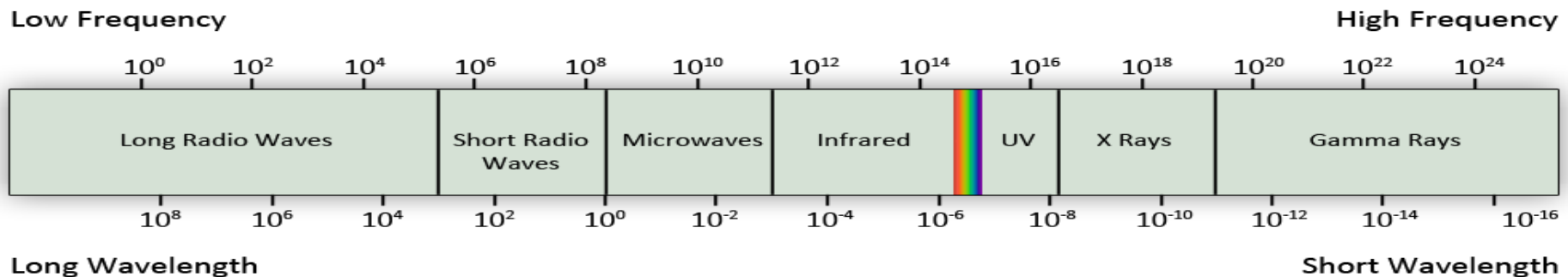
- The three general categories of light- UV, visible, and IR are defined in terms of their wave lengths.
- Wavelengths of light used to be measured in **microns** ($1\mu=10^{-6}\text{m}$) or in **angstroms** ($1\text{\AA}=10^{-10}\text{m}$). but at present the recommended unit is the **nanometer** ($1\text{nm}=10^{-9}\text{m}$).
- **UV**(**Ultraviolet**) light has wavelengths from about **100 to 400nm**,
- **visible** light extends from about **400 to 700nm**,
- and **IR** (**infrared**) light extends from about **700 to over 10^4nm** .

MEASUREMENT OF LIGHT AND ITS UNITS

- Each of these categories is further subdivided according to wavelength (λ) .
- For example, **UV-C:100~290nm**,
UV-B:290~320nm, **UV-A:320~ 400nm**.
- **A photometer** is a device used to measure the luminous intensity of a source.
- **Luminous intensity** (or illuminating power) is the amount of light energy given out per sec. It is measured by the light energy falling for second on a circuit area of the surface placed normally to the rays at unit distance.

ELECTROMAGNETIC SPECTRUM

- Figure below Shows where the wavelengths of light fit into the whole spectrum of electromagnetic radiation. Note that light has wavelengths much shorter than TV and radio waves but much longer than x-rays and gamma rays.
- Since light is a form of energy, it is sometimes useful to talk about the energy of individual light photons. Figure below gives the energies as well as the wavelengths of the different part of the electromagnetic spectrum.
- Visible light has energies ranging from about **2 electron volts (eV)** up to about **4 eV**. For comparison, the kinetic energy of a molecule in air at room temperature is about 0.25 eV and the energy of a typical x-ray photon used in medicine is about **50,000 eV ,or 50 keV**



APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- An obvious use of visible light in medicine is to permit the physician to obtain **visual information** about the patient regarding, for example, the color of his skin and the presence of abnormal structures in or on his body, this can be done by using simple instruments like **curved mirror** or more sophisticated instruments, such as the **ophthalmoscope** for looking into the **eyes** and the **otoscope** for looking into the **ears**.



otoscope

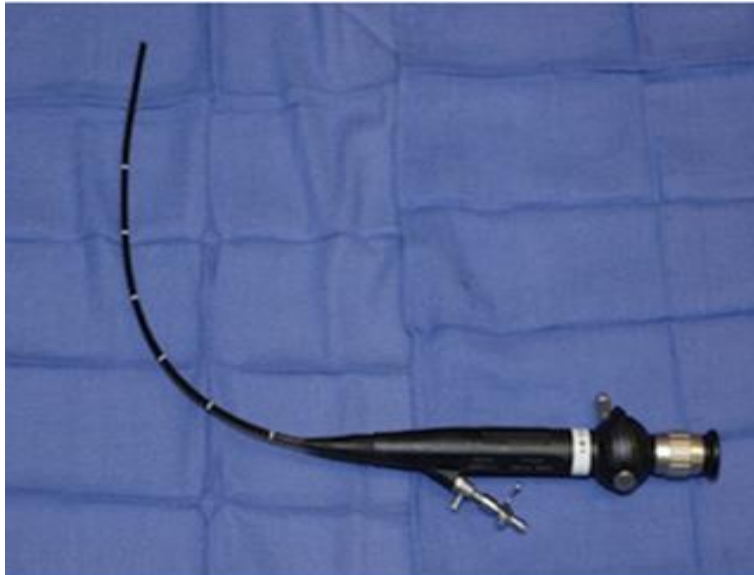
APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- A number of instruments, called **endoscopes**, are used for **viewing internal body cavities**.
- Special purpose endoscopes are often given names indicating their purpose.
- For example, **cystoscope** are used to examine the bladder, **proctoscope** are used for examining the rectum, and **bronchoscope** are used for examining the air passages into the lungs.
- Some endoscopes are rigid tubes with source to illuminate the area of interest. Many of them are equipped with optical attachments to magnify the tissues being studied.
- The development of fiberoptic technique 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.

APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- 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**.
- Flexible endoscopes usually have an opening or channel that permits the physician to take samples of the tissues (biopsies) for later microscopic examination

Flexible Cystoscopy



Rigid Cystoscope



APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- Since light contains energy that largely appears as heat when it is absorbed, there is a limit on the amount of light that can be used in endoscopy.
- The heating can be reduced by reducing the IR light from the source with special **IR absorbing glass filters**.
- In this **cold- light** endoscopy the light source contains very little IR radiation and the heating of tissues is minimized.

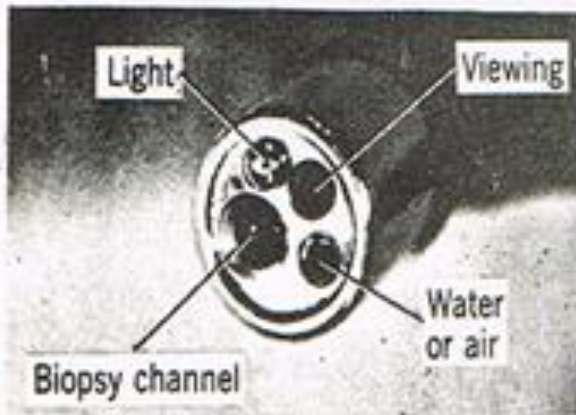


Figure The tip of a colonoscope shows the fiberoptic light channel and viewing channel, the water or air channel, and a biopsy channel that permits passage of a device to take tissue samples.

APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- **Transillumination** : It is the transmission of light through the tissues of the body. Most of us have seen a flashlight through our fingers to see the red glow that is produced.
- The glow is primarily red because most of the other color in the beam are absorbed by the red blood cells, the red light is the only important component that is transmitted.
- Transillumination is used clinically in the detection of **hydrocephalus** (water- head) in infants. 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



APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- Transillumination is also used to detect **pneumothorax** (collapsed lung) in infants (see next Fig.). The bright light penetrates the thin front chest wall and reflects off the back chest wall to indicate the degree of pneumothorax.
- 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 re inflate.



APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- Transillumination is used to study **sinuses** (see Fig. bellow), **gums**, **breasts**, and **testes**



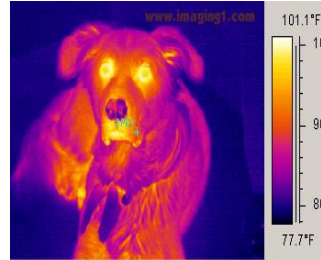
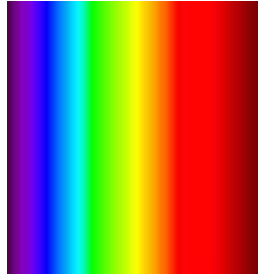
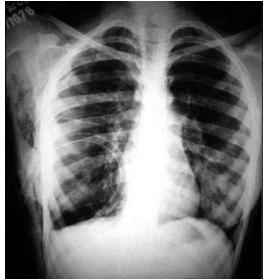
APPLICATIONS OF VISIBLE LIGHT IN MEDICINE

- Visible light has an important **therapeutic use**, Since light is form of energy and is selectively absorbed in certain molecules, it should not be surprising that it can cause important physiological effects. Many premature infants have **jaundice**, a condition in which an excess of bilirubin is excreted by liver into the blood.
- It was discovered that most premature infants recover from jaundice if their bodies are exposed to visible light (**phototherapy**), the blue light (**~450 nm**) appears to be the most important component



Theoretical Background

Electromagnetic Spectrum



X-RAY
0,2 nm

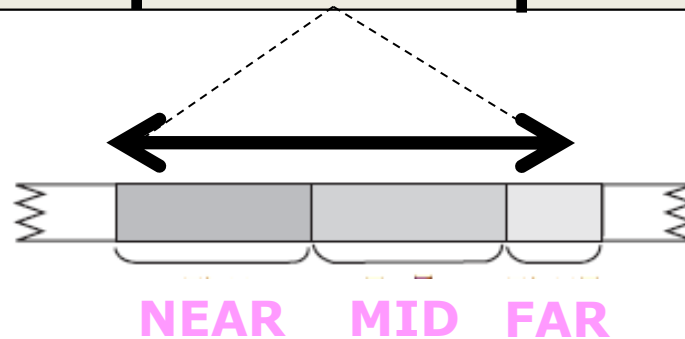
ULTRA-VIOLET
100-400 nm

VISIBLE
400-700 nm

IR 700 -10000 nm

MICROWAVE
3 mm-20 cm

RADIO
10 m-30 Km



Applications of Ultraviolet and Infrared light 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 photon.**

❖ UV light :

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

UV light

- ❖ **Ultraviolet light also produces more reaction in the skin than visible light. Some of these reaction 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).**
- ❖ **Dermatologist have also found that UV light improves certain skin conditions.**
- ❖ **● Ultraviolet light from the sun affect the melanin in the skin to cause tanning. However, UV light can produce sunburn as well as tan the skin. The wavelength that produce sunburn are around 300nm.**

Ordinary window glass permits some near UV to be transmitted but absorb the sunburn component.

UV light

- ❖ **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 fisherman and agriculture workers, may be related to the fact that the UV wavelength that produce sunburn are also very well absorbed by the DNA in the cells. Skin cancer usually appears on those portions of the nose, tops of the ears, and the back of the neck**



UV light

- ❖ UV light cannot be seen by the eye because it is absorbed before it reaches the retina. Fig. below shows the percentage of UV light of different wavelength absorbed by the different structure of the eye

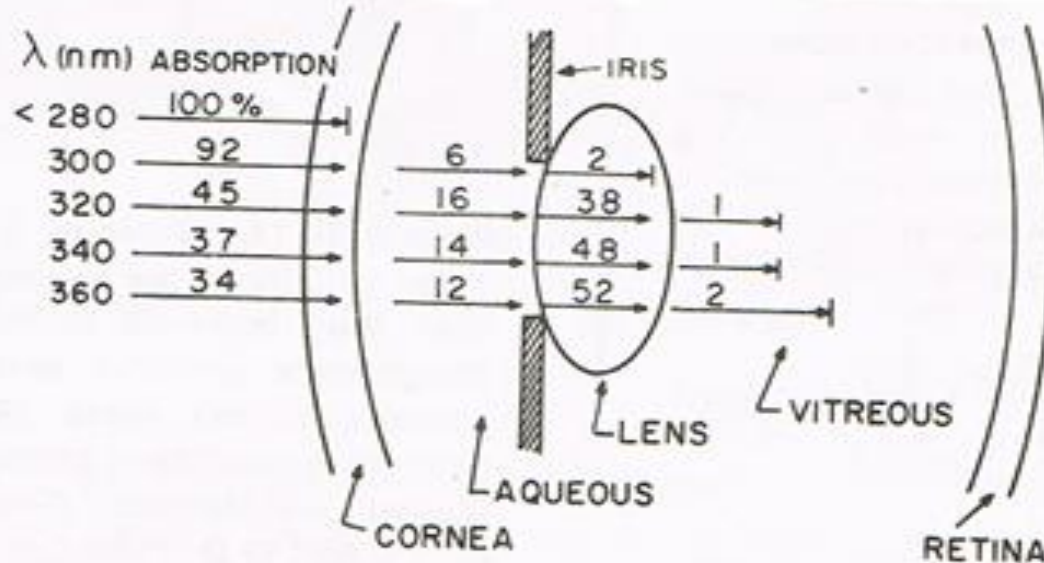


Figure Percentages of UV light of different wavelengths absorbed by the various components of the eye.

UV light

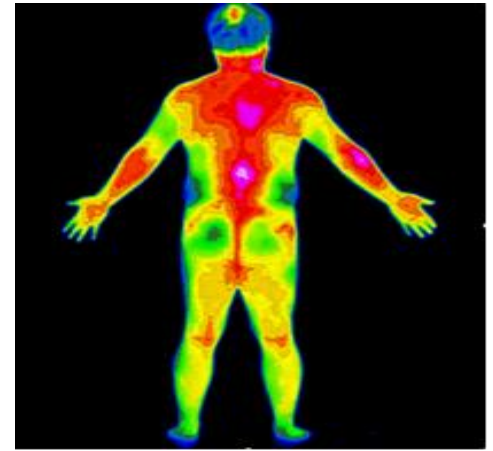
- ❖ The large percentage of near-UV light absorbed by the lens may be the cause of some cataract (opacities of the lens). Individual who have had the lens of an eye removed because of a cataract are able to see into the near -UV region because the major absorber is no longer present.



IR light

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

Two types of IR photography are use 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 thermography



IR light

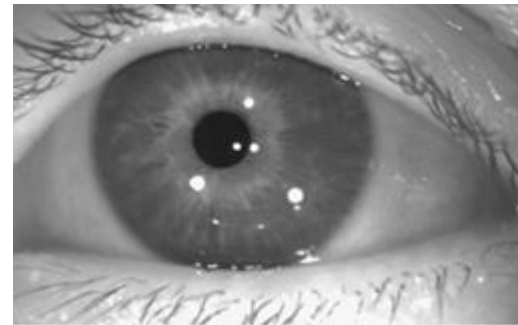
- ❖ We discuss here reflective IR photography. Which uses wavelengths of 700-900 nm to show the patterns of veins just below the skin. Some of these veins are visible to the eye, but many more can be seen on a near-IR photograph of the skin.



- ❖ Cancer and other diseases can cause changes in the venous pattern

IR light

- ❖ Also a layer of fat beneath the skin can reduce the appearance of the venous pattern.. Nevertheless, IR photography can be used to follow changes in the venous pattern.
- ❖ Infrared can also be used to photograph the pupil of the eye without stimulating the reflex that changes its size.



Raw infrared image captured by the EyeSeeCam video-oculography system. The bright white spots on the pupil and iris are reflections of infrared light emitting diodes.

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 other near it (coherent light).
- ❖ **L**aser is an acronym for **L**ight **A**mplification by **S**timulated **E**mission of **R**adiation.
- ❖ 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 as an intense pulse

Laser in medicine

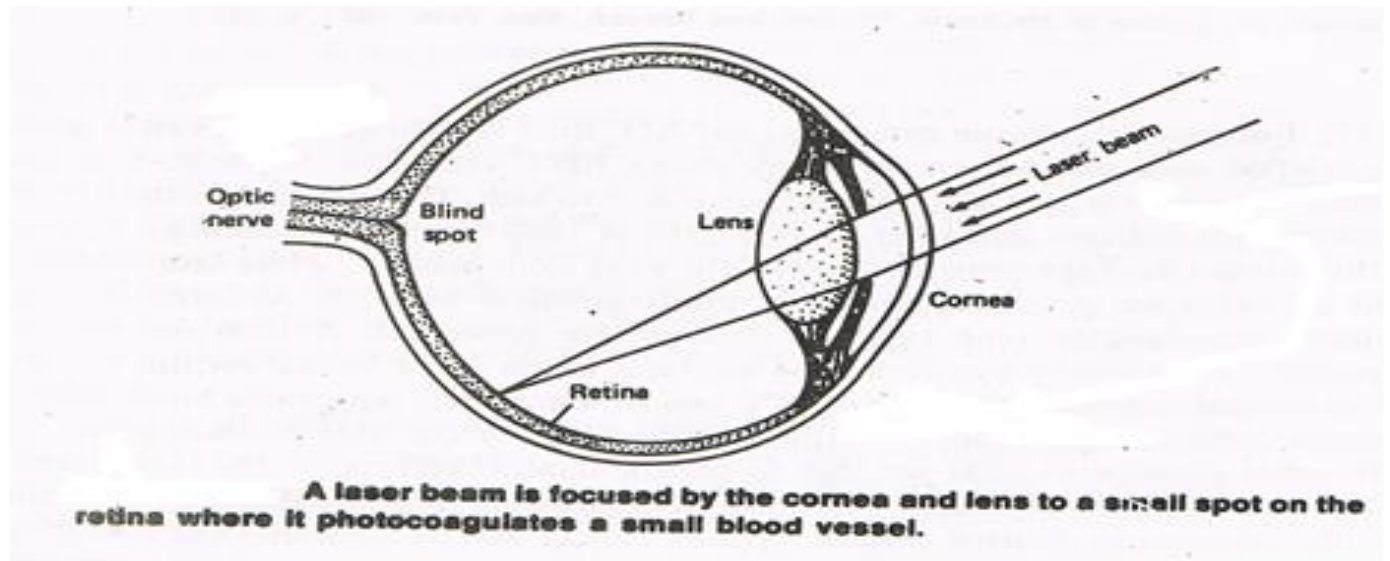
- ❖ **A laser beam can be focused to a spot only a few microns in diameter. When all of the energy of the laser is concentrated in such a small area, the power density (power per unit area) becomes very large**
- ❖ **The total energy of a typical laser pulse used in medicine, which is measured in milli joules (mJ), can be delivered in less than a microsecond, and the resultant instantaneous power may be in mega watts.**

Laser in medicine

- ❖ Since in medicine lasers are used primarily to deliver energy to tissue, the laser wavelength used should be strongly absorbed by tissue. The short wavelengths (400 to 600 nm) are always absorbed better than the long wavelengths (~700 nm).
- ❖ Laser energy directed at human tissue causes a rapid rise in temperature and can destroy the tissue. The amount of damage to living tissue depends on how long the tissue is at the increased temperature. For example, tissue can withstand 70°C for 1sec. However, not all laser damage is due to heat. It also produces noticeable damage due to photochemical effects

Laser in medicine

- ❖ The laser is routinely used in clinical medicine in ophthalmology. Its effectiveness in treating certain types of cancer and its usefulness as a "bloodless knife" for surgery.
- ❖ 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



Laser in medicine

Photocoagulation

prior to retinal detachment. When the retina is completely detached, the laser is of no help.

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). For example, The MRD for 50 μ m spot in the eye is about 2.4 mJ delivered in 0.25 sec., The typical exposure for photocoagulation are 10 to 50 times the MRD (e.i., 24 to 120 mJ for a 50 μ m spot in 0.25 sec.).

Laser in medicine

- **Laser are also being used in medical research for special three-dimensional imaging called holography.**



- **Protective glasses must be worn in medical laser areas to protect the eyes of the patient and the workers. Since the laser energy is concentrated in a narrow beam for long distances, even a reflected beam can be a hazard; thus the walls and other surfaces in a laser installation should have low reflectivity (e.g., flat black paint).**
- **The area should have adequate warning signs and a system that prevents outsiders from entering while lasers are in use.**

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).

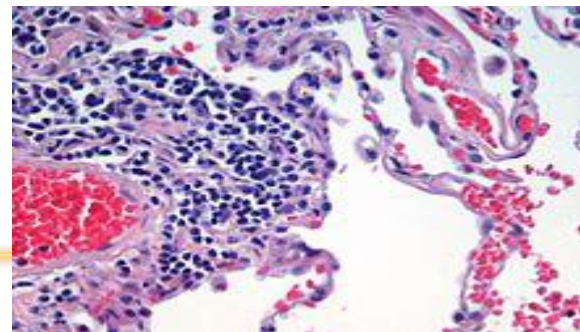


APPLICATIONS OF MICROSCOPES IN MEDICINE

- 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 wavelengths of visible light range from 400 to 700 nm (0.4 to 0.7Mm), the smallest object that can be resolved is about 1Mm in diameter. Since most cells are 5 to 50 Mm in diameter, this type of microscope is adequate for resolving all but subcellular objects.

APPLICATIONS OF MICROSCOPES IN MEDICINE

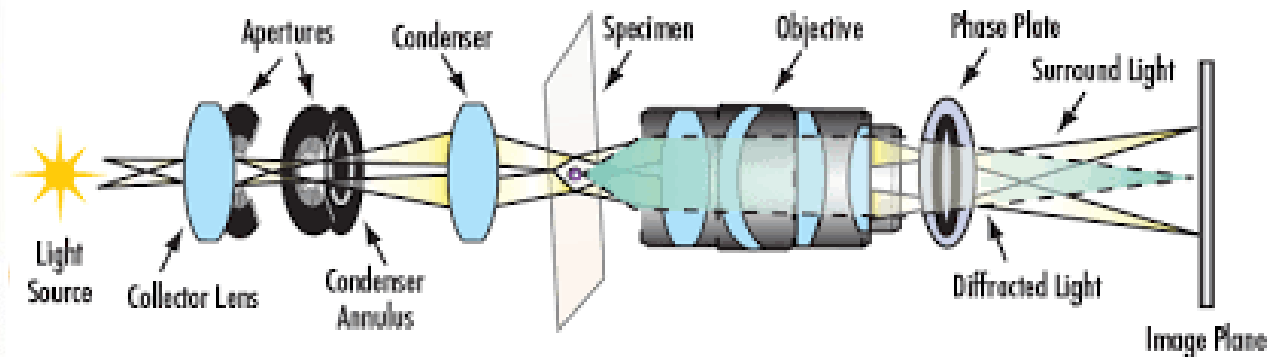
- ❖ If you put a thin slice of tissue under a microscope you will not see much because most cells are transparent to all wavelengths of visible light -red blood cells are an exception.
- ❖ In order to distinguish different cells it is usually necessary to stain them with a chemical that strongly absorbs certain visible wavelengths.



APPLICATIONS OF MICROSCOPES IN MEDICINE

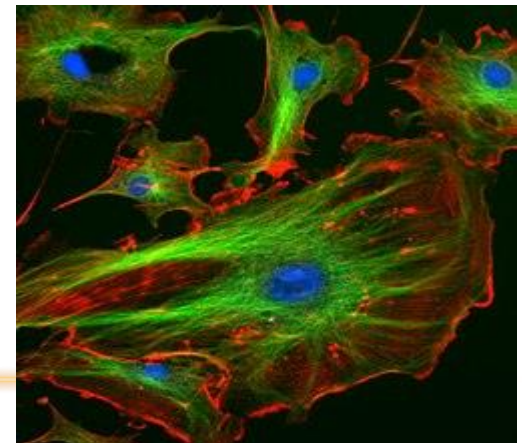
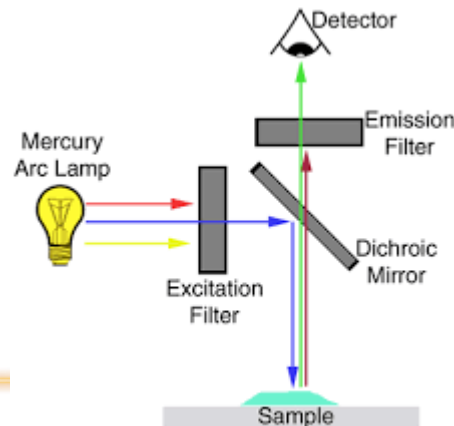
- ❖ Other techniques in addition to staining are useful in microscopy. One technique takes advantage of the different indexes of refraction of different cell parts.
- ❖ Since light travels at different speeds in the various part of a cell, the phase relationships of the light waves change in passing through a specimen. The phase-contrast microscope takes advantage of this phenomenon to allow cell structures to be seen without the use of stain.

Phase Contrast Microscope



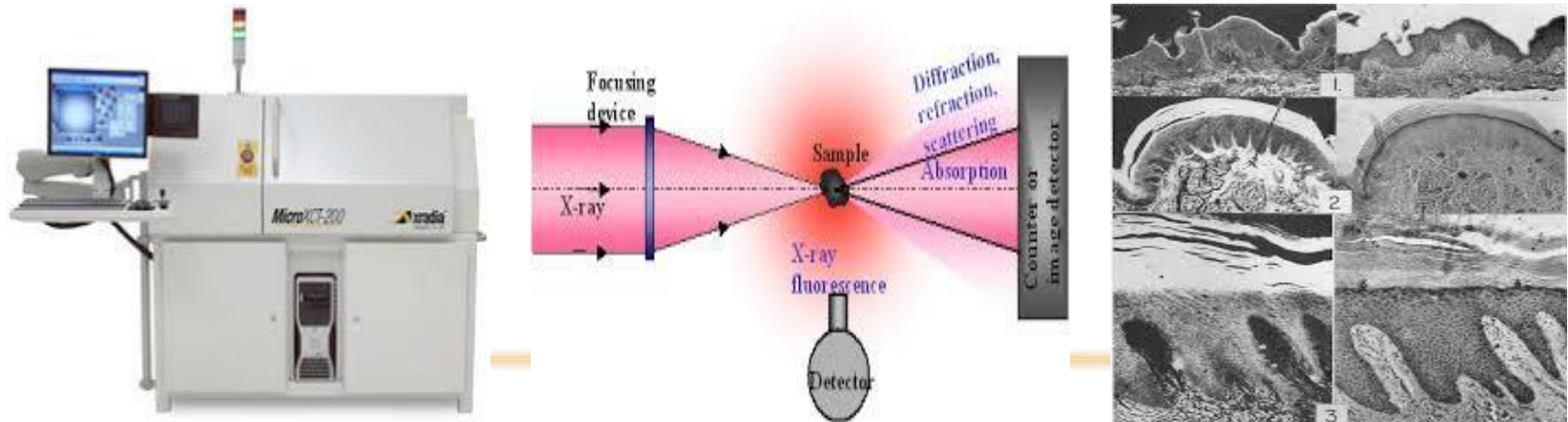
APPLICATIONS OF MICROSCOPES IN MEDICINE

- **Ultraviolet light is used in fluorescent microscopy. The tissue sample is stained with a dye that fluoresces when it is irradiated with UV light in a fluorescent microscope.**



APPLICATIONS OF MICROSCOPES IN MEDICINE

- Low-energy x-rays are used in a microscopy technique called **historadiography**. Historadiography is often used to study **bone samples** that have been cut in thin slices (~0.1mm).

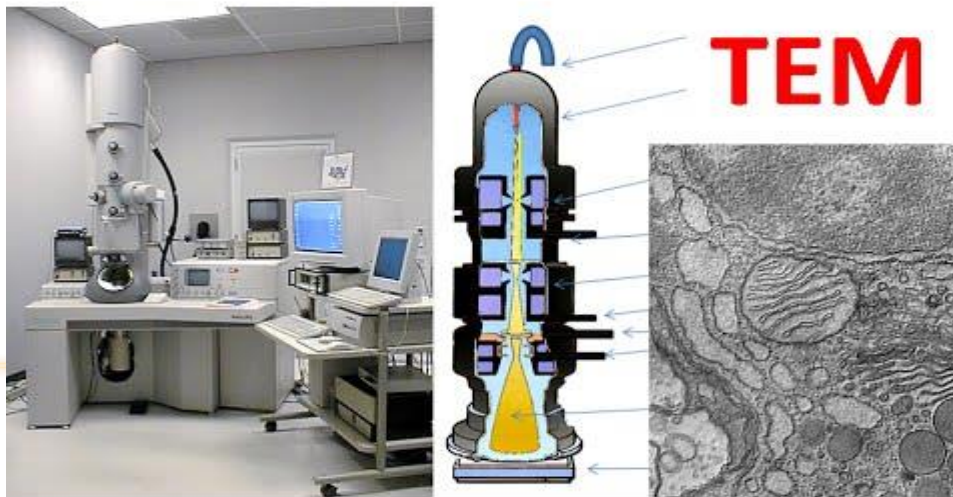


APPLICATIONS OF MICROSCOPES IN MEDICINE

- **Several microscopy techniques used primarily in research involve electron beams. Electrons can be focused by electric and magnetic lenses, much like light is focused by glass lenses, to form an image.**
- **The wavelengths of electrons depend on their energy but are usually very short compared to those of visible light.**
- **As a result, electron microscopes can show details much better than light microscopes. Magnifications of up to 250.000 times have been obtained in electron microscopy, while the maximum in conventional light microscopy is about 1000 times.**

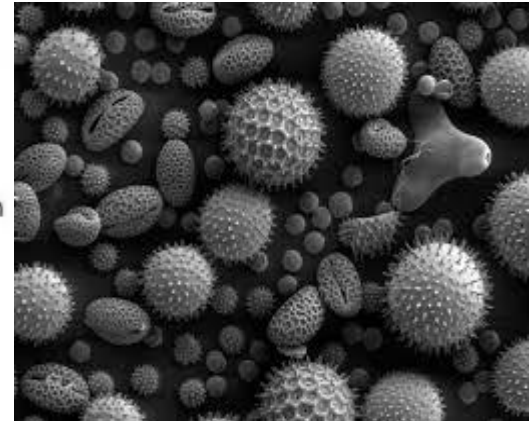
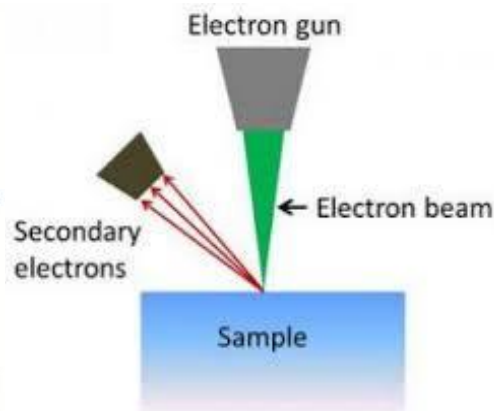
APPLICATIONS OF MICROSCOPES IN MEDICINE

- **Electron microscopes (TEM)**
- **In transmission electron microscopy (TEM) exceedingly thin specimens must be used so that the electrons can pass through them. It is also usually necessary to evaporate a very thin layer of a heavy metal on each sample to act as a stain.**



APPLICATIONS OF MICROSCOPES IN MEDICINE

- **Scanning electron microscopy (SEM)**
- In scanning electron microscopy (SEM) a finely focused beam of electrons scans the surface of the specimen and a detector measures the number of scattered electrons from each point on the surface. This information is used to control the intensity of an electron beam in a TV tube to make an image of the surface of the specimen.



A close-up photograph of a bouquet of white tulips. The flowers are in various stages of bloom, with some fully open and others still in bud. The green leaves are long and pointed, some showing signs of being eaten or damaged. The background is a soft, out-of-focus white.

Thank you