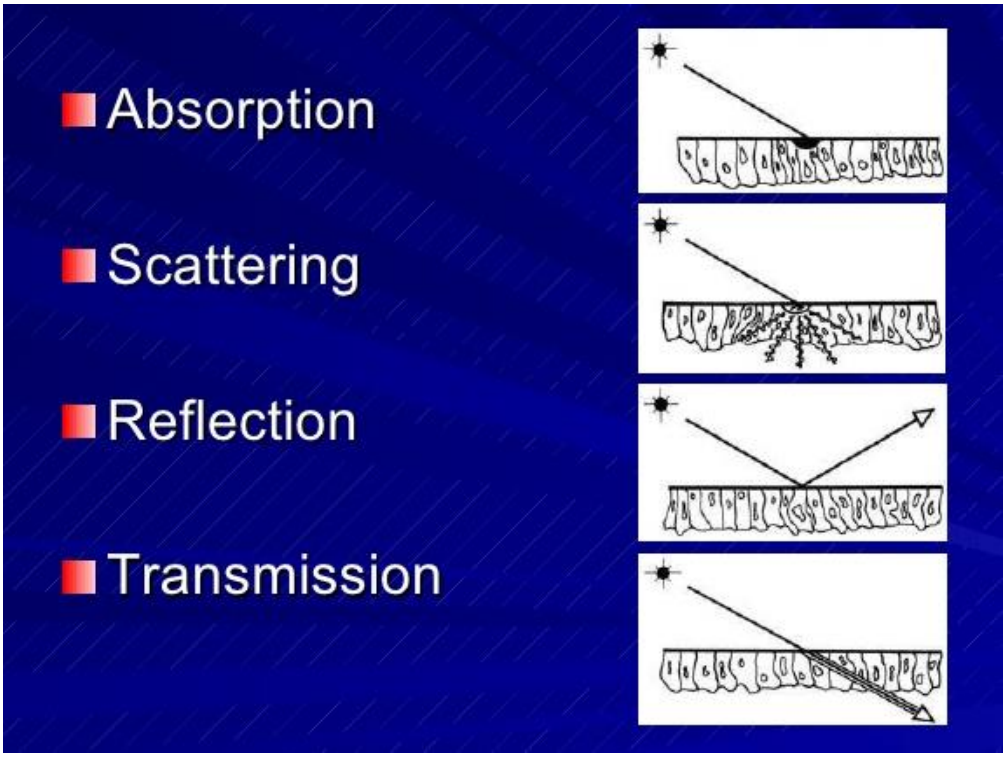
Laser Interaction With Tissue

Light-tissue interactions are essential for life. Humans depend on photochemical reactions, such as exposure to sun light, is vital for the production of vitamin D in the skin. However, light can also have undesirable effects such as causing cancers. Different types of lasers react differently with tissue. Interaction depends on:

- **The wavelength (λ) of the laser.**
- **Power density and exposure time.**
- **Optical property of the tissue being irradiated.**
- **Laser beam size on the tissue.**
- **If exposure is CW or pulsed wave radiation.**

When laser light reaches the biological interface, an interaction between laser and the tissue is occurred. The nature of interaction of all lasers light with biological tissue (as shown in figure below) can be described in terms of the following:



1. **Reflection:**

   If the laser beam is reflected from the surface of the tissue with no penetration or interaction, no energy is absorbed (i.e. the laser has no effect).

2. **Transmission:**

   If the laser beam is transmitted through the tissue, the laser has no effect or very minimal effect.

   The laser energy can pass through superficial tissues to interact with deeper areas. Retinal surgery is an example; the laser passes through the lens to treat the retina.

3. **Scattering:**

   Once the laser light enters the target (tissue) it will scatter in various directions. This phenomenon is usually not helpful and the laser effect will be more diffused and weakened.

4. **Absorption:**

   A laser light is absorbed by a small volume of tissue and exerts its effect within this tissue. Specific molecules in the tissue known as chromophores absorb the photons. The light energy is then converted into other forms of energy to perform work.

Absorption is the most important interaction. Each wavelength has specific chromophores that absorb their energy. This absorbed energy is converted into thermal and and/or mechanical energy that is used to perform the work desired.

The Optical Absorbers:

The optical absorbers in tissue are different for different wavelengths.

1. **In the UV region (200-350 nm), protein and DNA dominate absorption.**
2. **In the visible spectrum (400-700 nm), Oxyhaemoglobin and melanin are absorbers that occur naturally in tissue.**
3. **In the IR region (> 2000 nm), water is the chief absorber.**
4. **Wavelength interval (600-1300 nm), form a window of low optical absorption.**

Examples:

a. **Intraocular structure:**

Laser of wavelength between (380-1400 nm) may be used to treat intraocular structures by delivery through the pupil.

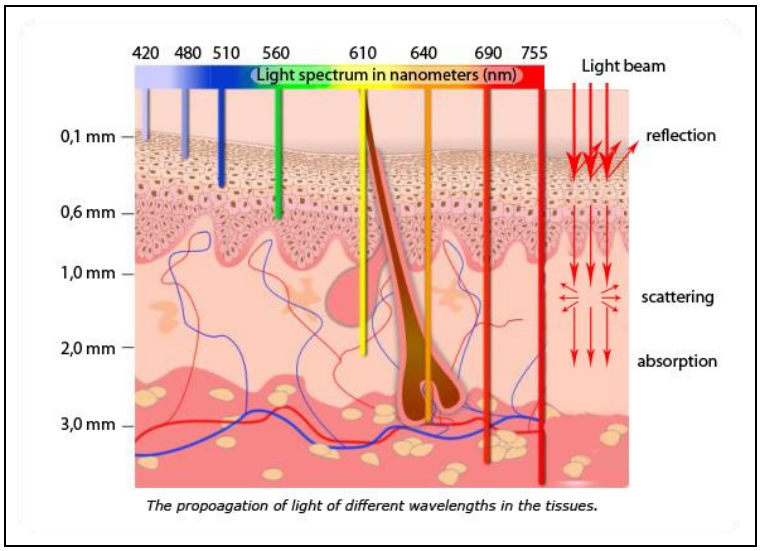
At wavelength << 380 nm, UV absorbing properties of the lens and cornea limit retinal exposure.

At wavelength >> 1400 nm, water absorption sharply limited transmission.

b. **Skin**

Darker skin absorbs larger ratio of the falling radiation energy than for the white skin.

The surgeon must select the appropriate laser system for a particular application.



The propoagation of light of different wavelengths in the tissues.

Types of effects:

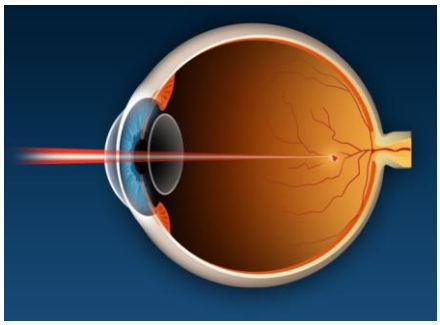
There are many important types of biological effects that can occur once the laser photons enter the tissue: photothermal, sonic (ionizing), and photochemical effects.

1. Photothermal effects:

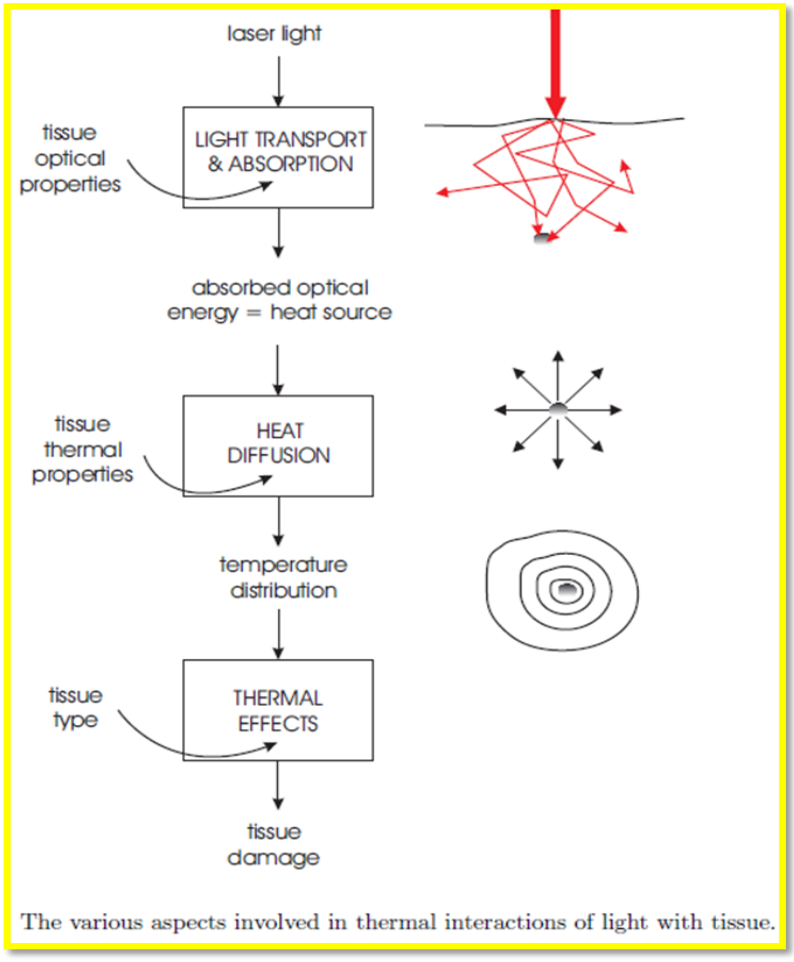
Photothermal effects occur when the chromophores absorb the laser energy, then the laser light is converted to heat. This causes the tissue to heat up and vaporize, and the heat may also be used for blood coagulating.

There are many different and varied medical applications that use a thermal interaction, from vaporization of tumors, to welding gastrointestinal ulcers, and the removal of skin marks such as port wine stain, birthmarks or tattoos. During these procedures a great care must be taken to avoid thermal damage to the tissues.

Photocoagulation **is defined as heating a blood vessel to the point where the blood coagulates and block the vessels.**



Photoevaporation **it is the rapid transfer of heat from the laser beam to the cell (thermal effect) when the laser energy is increased. The cellular water will be vaporized when the heated tissue reaches 100º C.**



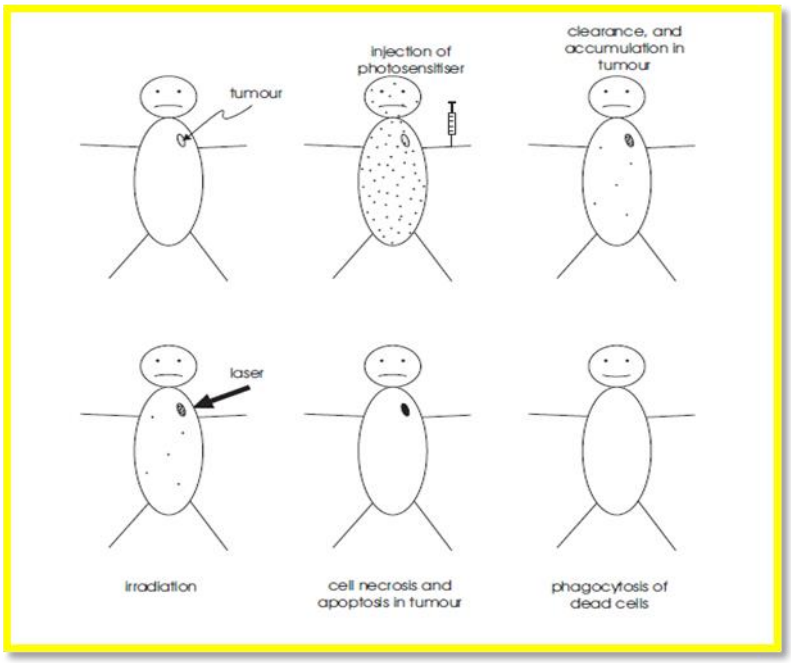
The various aspects involved in thermal interactions of light with tissue.

2. Photochemical effects:

A chemical reactions can be made to occur by intense laser energy (i.e. if the energy of photons is high enough to cause a chemical reaction).

For humans, the production of vitamin D3 from cholesterol in the skin is an important photochemical reaction. Vitamin D3 most important role is to promote bone formation; it also has other uses, such as enhancing calcium transport. A lack of sunlight can lead to problems with bone mineralization causing rickets and osteomalacia.

Photochemical effect of laser radiation has been used with photosensitizer to aid in diagnostic of certain tumors, such as Hematoporphyrin derivative (HPD), {(HPD) is photosensitizers}, its capable of localizing in malignant tissue. The tissue containing HPD will fluoresce when illuminating with short wavelength of UV-light.



Lasers in Medicine (Advantages & Disadvantages of Laser in Medicine, Laser Hazards, & Laser Safety Precautions)

Advantages of laser in medicine:

- **Non-contact technique.**
- **Dry surgical field with sterilization of the operative site.**
- **Reduce blood loss.**
- **Reduce pain and edema.**

- **Limited fibrosis and stenosis.**
- **Limited damage of the adjacent tissue.**
- **Precision.**
- **No causing genetic damage or cancer.**

Disadvantages of the laser:

- **High cost.**
- **Complexity of the laser surgical unit.**
- **Safety problems.**

Laser Hazards:

laser hazards can be classified into:

1. **Radiative hazard:**

   The main hazard in the eye and skin.

The eye	The skin
The laser beam might cause a thermal damage to the eye. (partial or total loss of vision).	Is much less sensitive to laser than the eye.
The energy of highly collimated beam might burn cornea or it concentrated on the retina.	The amount of reflected, absorbed, and transmitted radiation depends on the wavelength and the pigments in the tissue.

2. **Electrical hazard:**

   The electrical hazards involve electrical shocks (the effect of an electrical shock is not the voltage but the amount of current flowing through the body). The electrical shock depends on the skin conditions (moist or dry), and the point of contact.

   The physiological effects of current flow in the body vary from mild sensation to painful for low current (I=10 mA), and muscular paralysis for (I=40 mA).

3. **Explosive hazard:**
    - **Occurs in flash lamps and capacitors.**
    - **Chemical solvents can cause hazards.**

4. **Toxic hazard:**

   Toxic hazards result from rapid heating and vaporization of targets (substances, food, liquids, … , etc.) as they exposed to high power laser beams. It depends on the target.

Laser safety precautions

1. **Training is the most important factor in safe use of any laser. This applies to surgeons, specialist operating room personnel.**
2. **Warning sign should be placed on all entries to the surgical suite before the laser is operated.**
3. **The number of persons in controlled area should be kept to a minimum and no one should over look into laser beam.**
4. **Protective eyewear should be provided.**
5. **Window must be covered with light tight shades.**
6. **Store chemicals in cabinets away from laser radiation.**