PHOTOTHERAPY

LIGHT – SKIN INTERACTION

Light – Skin Interaction

Automatically generated and predictable images of organic materials such as human skin:

- creating convincing pictures of organic materials, such as human skin, is usually an art entirely left to designers and animators
- these processes affect not only skin appearance, but also its health
- light propagation (transport) and absorption in skin tissues
- recent advances in the biophysically-based rendering of human skin
- computer graphics models used to simulate these natural phenomena

translucency of skin tissues varies with levels of melanin pigmentation.

Left: moderately pigmented specimen.

Right: heavily pigmented specimen.

An Introduction to Light Interaction with Human Skin
Gladimir V. G. Baranoski
Aravind Krishnaswamy
Natural Phenomena Simulation Group, School of Computer Science, University of Waterloo, Canada

Light – Skin Interaction

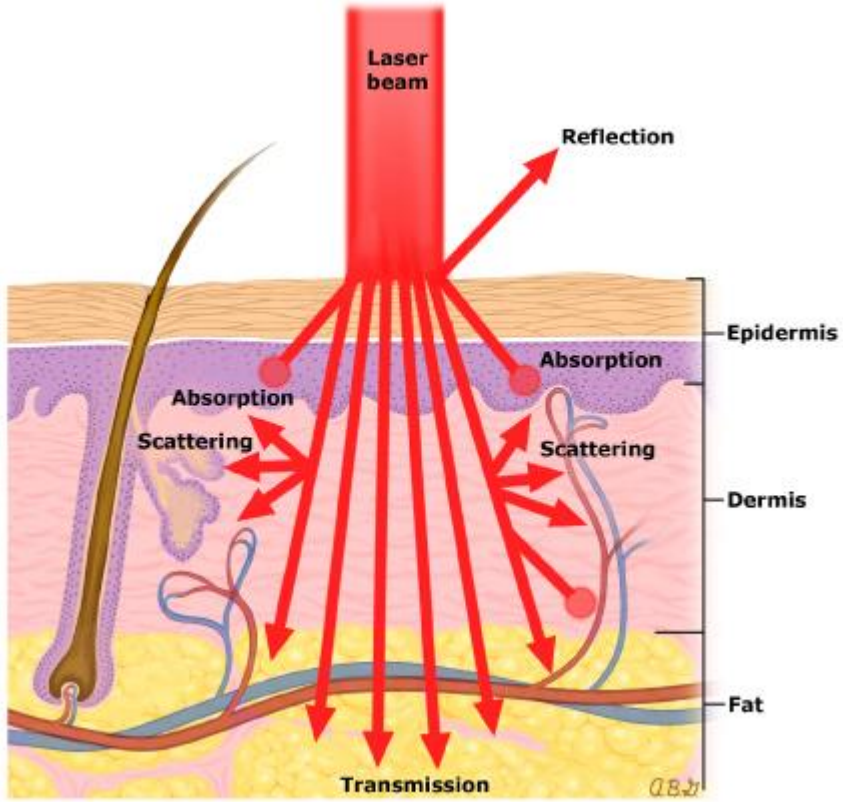
Light that reaches the skin surface can be

(i) reflected away from the skin

(ii) absorbed by light absorbing molecules (chromophores) within the skin

(iii) scattered in various directions within the skin, or

(iv) transmitted through the skin to underlying tissues.



Light – Skin Interaction

The group of measurements necessary to **characterize** both the color and surface finish of a material is called the **measurement of appearance** of the material:

- spectral energy distribution of the propagated light (**reflectance and transmittance**) >> **spectrophotometers**
- spatial energy distribution of that light, measured in terms of **BRDF** (bidirectional reflectance distribution function) and **BTDF** (bidirectional transmittance distribution function) >> **Goniophotometers**

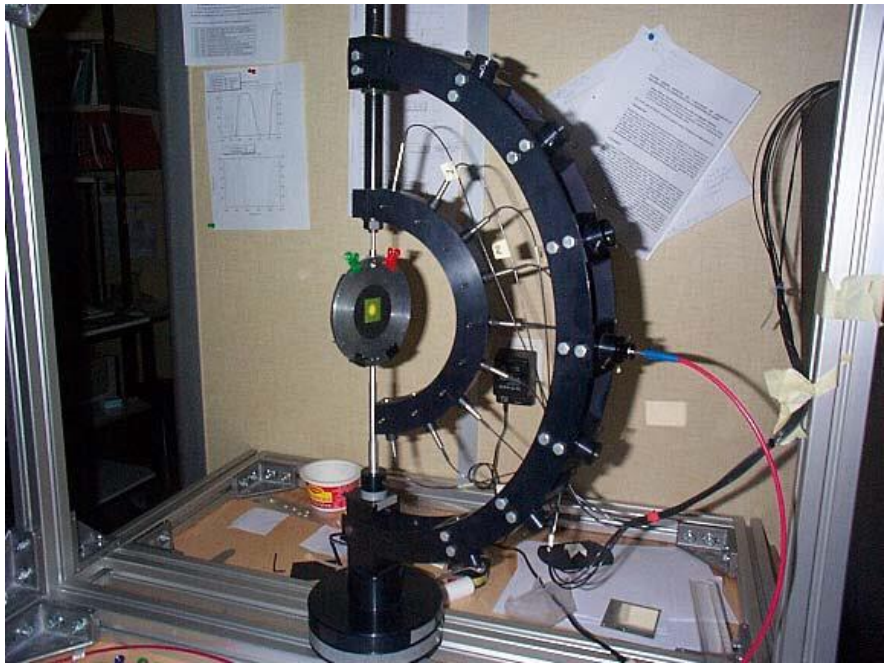
Spectrophotometry is defined as the quantitative measurement of reflection and transmission properties as a function of wavelength

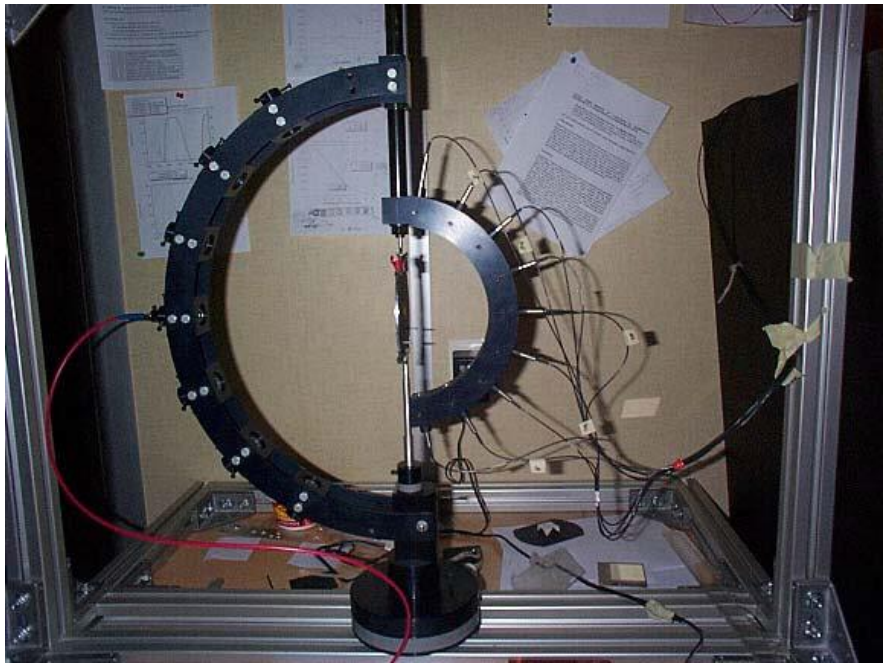
Spectrophotometers can also be used to determine the absorption characteristics of an object as a function of wavelength.

Goniophotometry is defined as the measurement of the directional light distribution characteristic of sources, media and materials, and a goniophotometer is defined as an instrument that measures flux (power) as a function of angles of illumination and observation

Goniophotometry

Figure - Photographs of a goniophotometer showing different set-ups for BRDF (left) and BTDF (right) measurements.





Skin Structure – Spectral Properties

Stratum corneum - a stratified structure approximately 0.01-0.02 mm thick

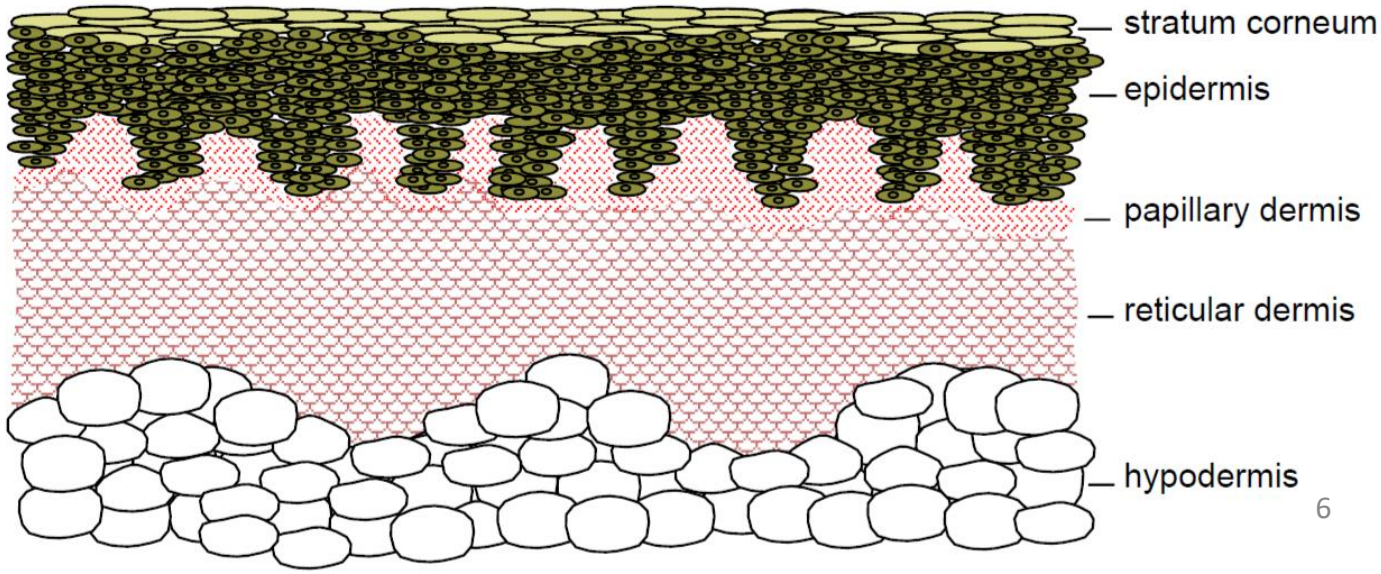
Epidermis - a 0.03-0.15mm thick structure composed of four layers (stratum basale, spinosum, granulosum and lucidum).

The **dermis** is a 0.6-3mm thick structure which also propagates and absorbs light.

The **hypodermis** is an adipose tissue characterized by a negligible absorption of light in the visible region of the spectrum.

composed mainly of dead cells, called *corneocytes*
Light absorption and light scattering (diffusion) are low in this tissue
Sometimes considered as part of the epidermis

The epidermis propagates and absorbs light; *melanin*: two types, the red/yellow *phaeomelanin* and a brown/back *eumelanin*
Skin color is mostly associated with eumelanin.
Melanin is produced by *melanocytes* in the stratum basale, and accumulated in membranous particles called *melanosomes*. Volume fraction of melanosomes in epidermis varies from 1.3% (lightly pigmented specimens) to 43% (darkly pigmented specimens).



Skin Structure – Spectral Properties

stratum corneum - a stratified structure approximately 0.01-0.02 mm thick

epidermis - a 0.03-0.15mm thick structure composed of four layers (stratum basale, spinosum, granulosum and lucidum).

The **dermis** is a 0.6-3mm thick structure which also propagates and absorbs light.

The **hypodermis** is an adipose tissue characterized by a negligible absorption of light in the visible region of the spectrum.

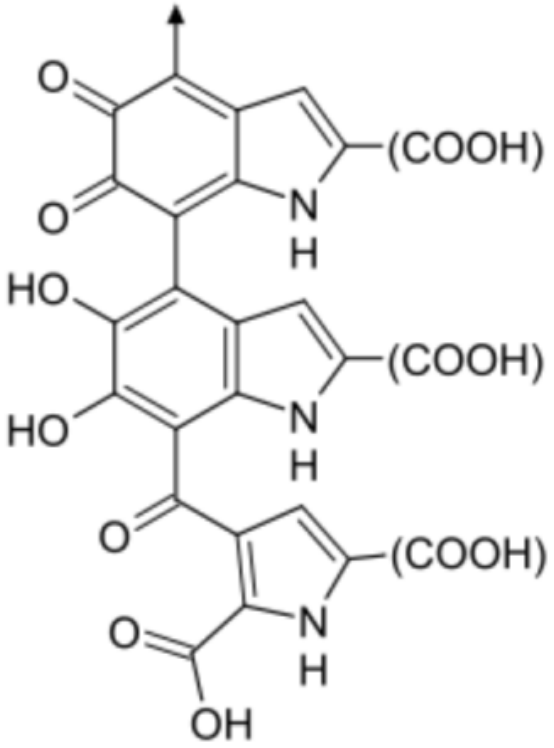
two layers: *papillary* dermis and *reticular* dermis. Primarily composed of dense, irregular *connective tissue* with *nerves* and *blood* vessels (smaller ones in the papillary, and larger ones in the reticular dermis, volume fraction ranging 0.2-7%). Here we find another natural chromophore, *hemoglobin* (134 and 173g/L). Two other blood borne pigments are found in the dermis, *bilirubin* and *β-carotene*, which contribute to the yellowish or olive tint of human skin.

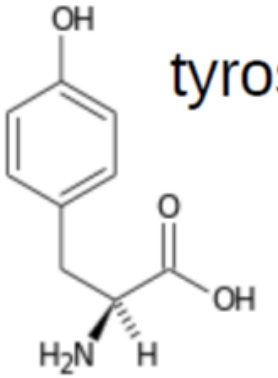
usually not considered part of the skin, variable size (up to 3cm thick in the abdomen, absent in the eye lids). *White fat*, whose cells are grouped together forming clusters. Most of the visible light is scattered and reflected back to the upper layers.

Melanin

most common form is a polymer derived by metabolism of aminoacid tyrosine

Non-structured absorbance in the whole spectrum from UV to NIR

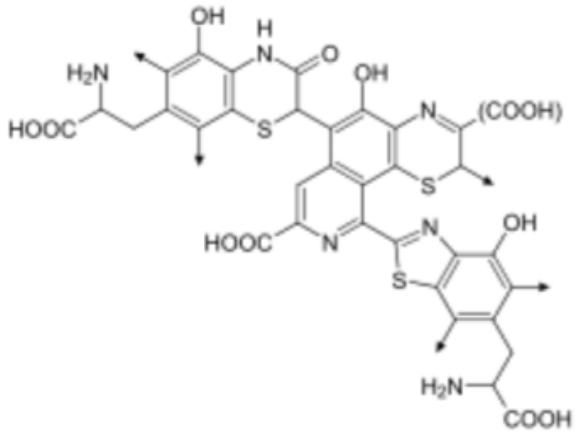




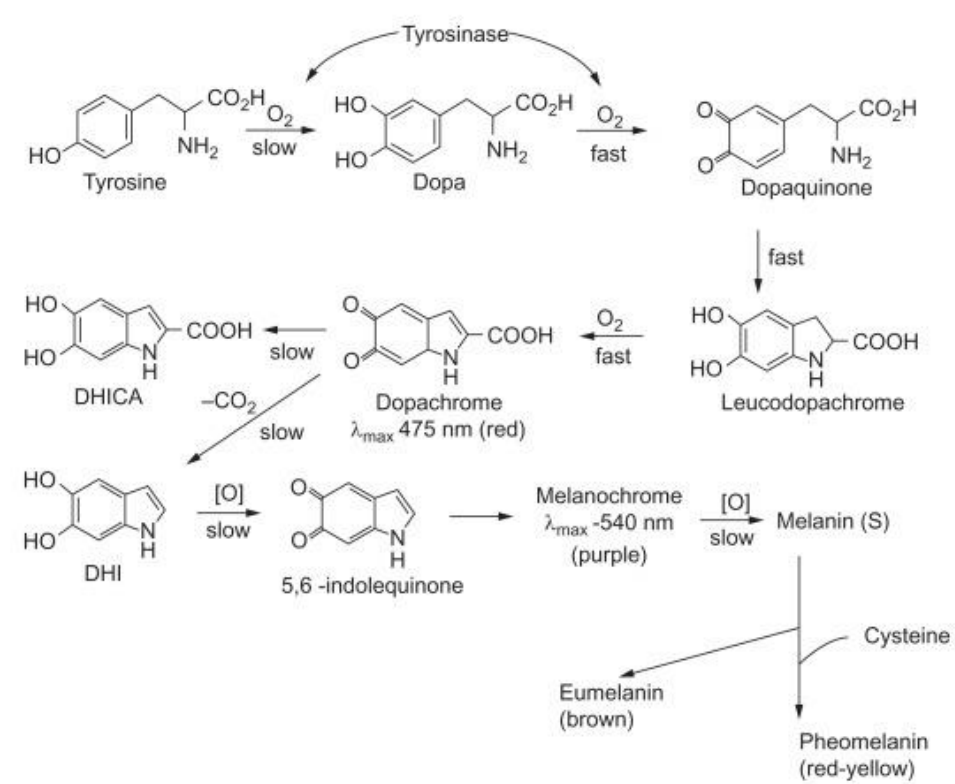
tyrosine

eumelanin

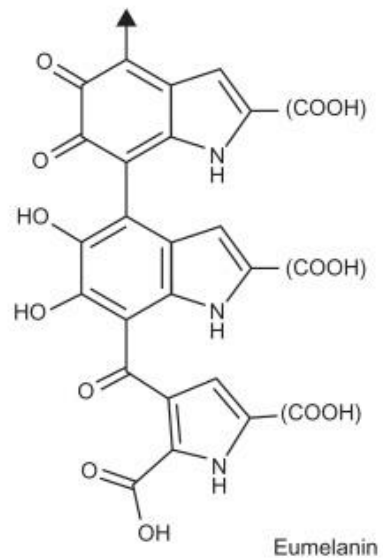
pheomelanin



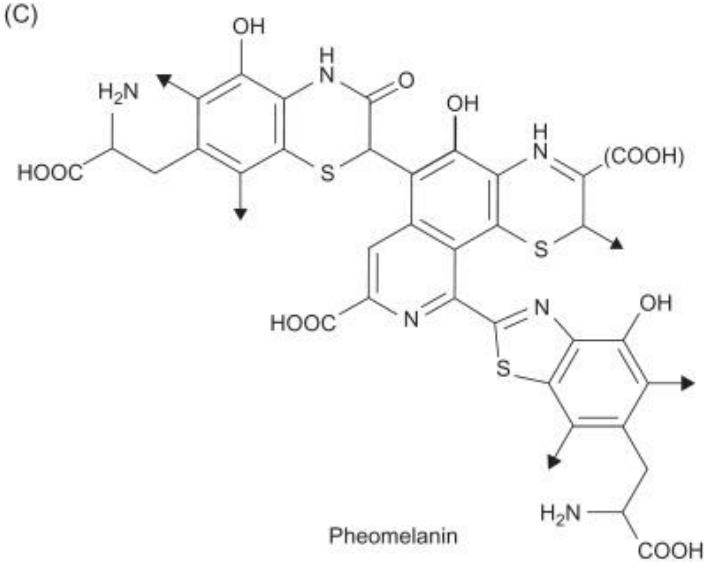
(A)


Tyrosinase
Tyrosine
slow
Dopa
fast
Dopaquinone
fast
Leucodopachrome
fast
Dopachrome
λmax 475 nm (red)
slow
DHICA
–CO2
slow
DHI
[O]
slow
5,6 -indolequinone
Melanochrome
λmax -540 nm
(purple)
[O]
slow
Melanin (S)
Cysteine
Eumelanin
(brown)
Pheomelanin
(red-yellow)

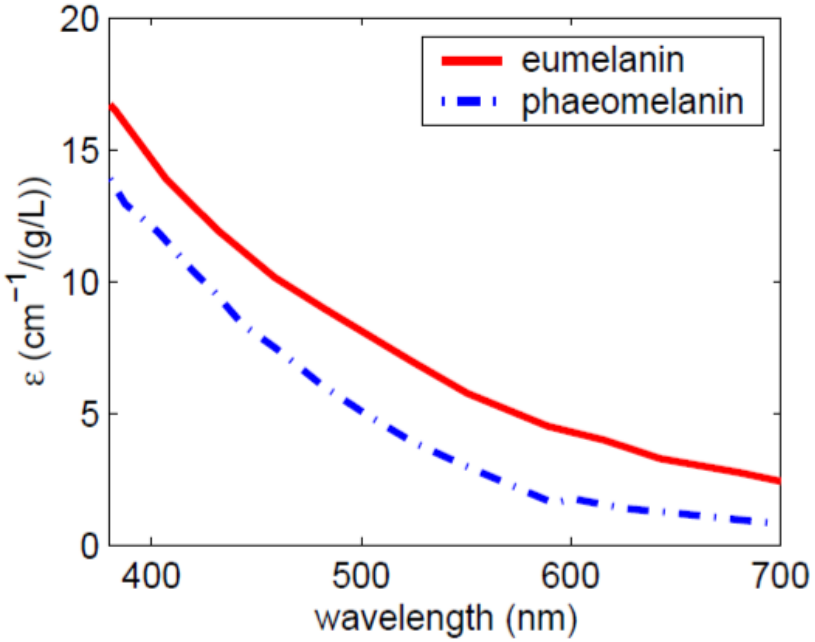
(B)

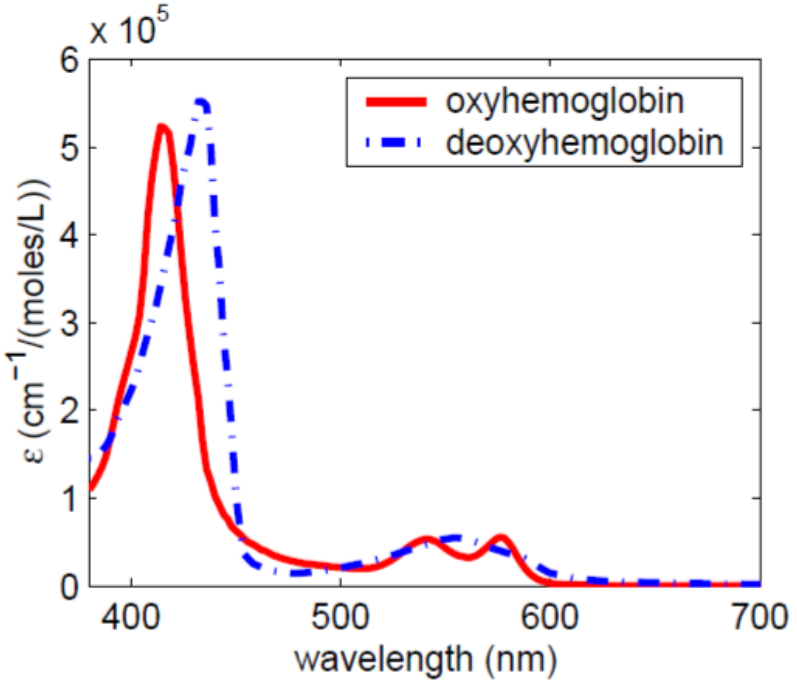

(COOH)
(COOH)
(COOH)
Eumelanin

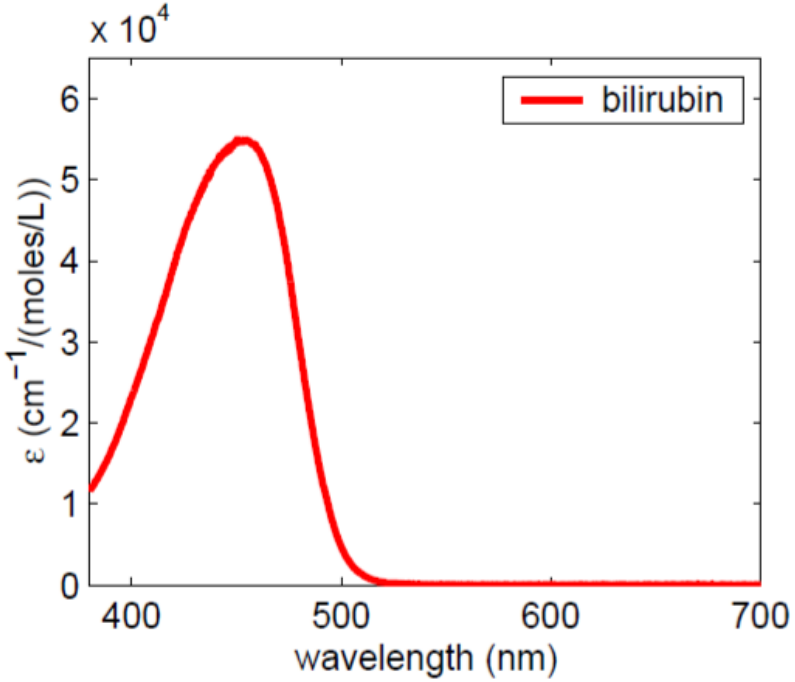
(C)

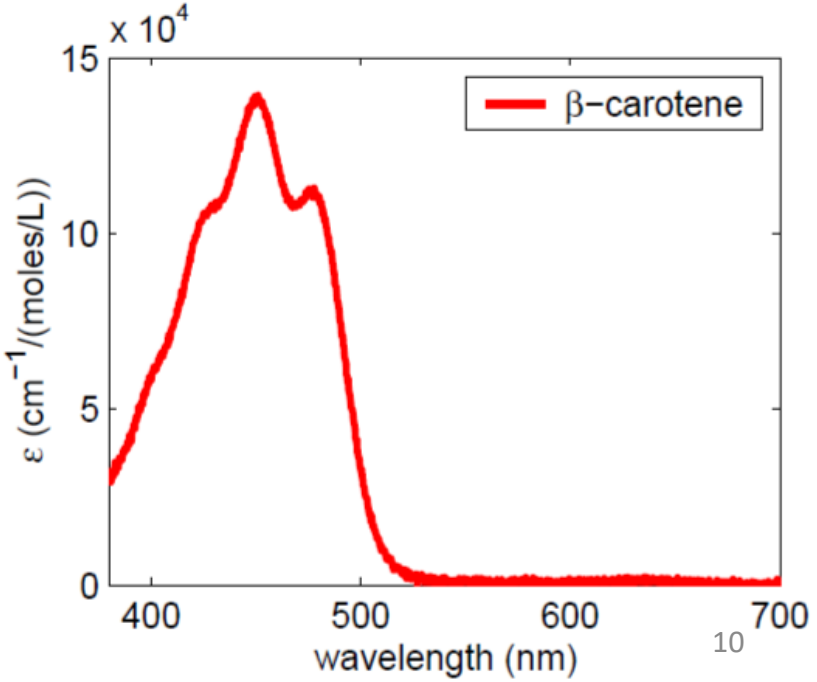

Pheomelanin

Spectral extinction coefficient curves for pigments present in skin tissues









Light scattering in human skin

The scattering profile of human skin has two main components: surface and subsurface scattering.

Approximately 5-7% of the light incident (over the entire spectrum) on the stratum corneum is reflected back to the environment (*reflective – refractive* scattering)

The **stratum corneum and the epidermis** are forward scattering media, due to the alignment of the fibers (stratum corneum) or to *Mie scattering* caused by nanometric particles (same size as light λ, e.g., cell organelles).

Inside the **dermis,** light gets scattered multiple times from larger structures such as vessels, nerves and connective tissue (*Rayleigh scattering*) before it is either propagated to another layer or absorbed. This means that the spatial *distribution of light quickly becomes diffuse* within the dermis.

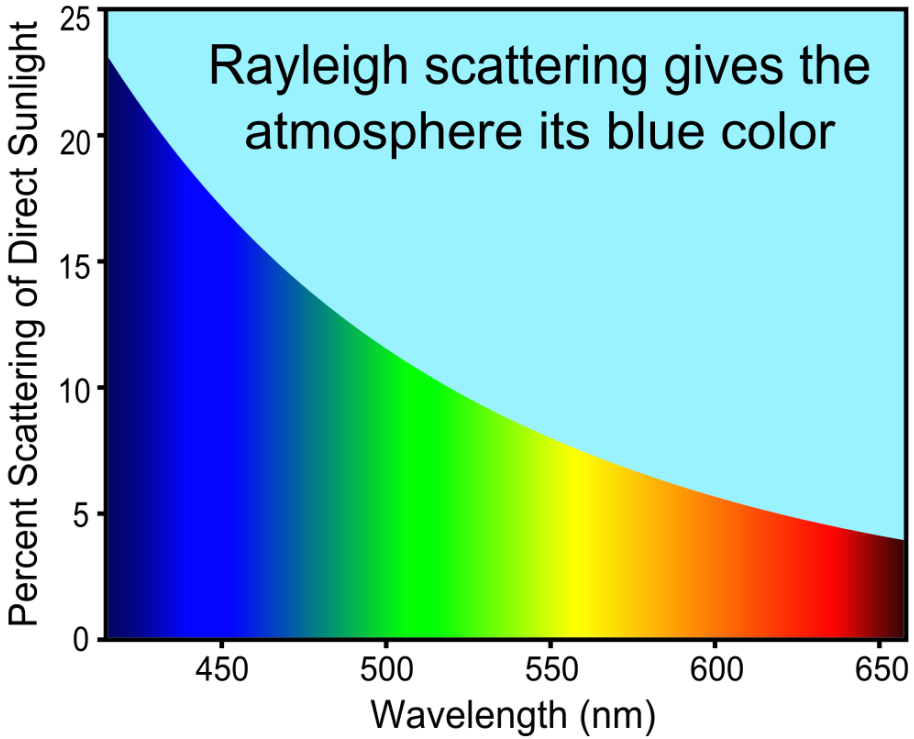
Light scattering in human skin

Scattering occurs when the incident light is forced to deviate from a straight trajectory by one or more localized non-uniformities in the medium through which they pass.

In the skin, **collagen fibrils cause most of the scattering**.

Scattering proportionately decreases with increasing wavelengths. Using longer wavelength can serve to reach deeper target tissues in the deeper dermis, e.g. hair follicles or dermal melanin.

The residual light, which has not been absorbed or scattered in the tissue, will be transmitted into the subcutaneous tissues. These are mainly beyond the 700 nm spectra.



$$I = I_0 \frac{\pi^2 V^2 \sigma_\epsilon^2}{2\lambda^4 R^2} \left(1 + \cos^2 \theta\right)$$

Wavelength selection

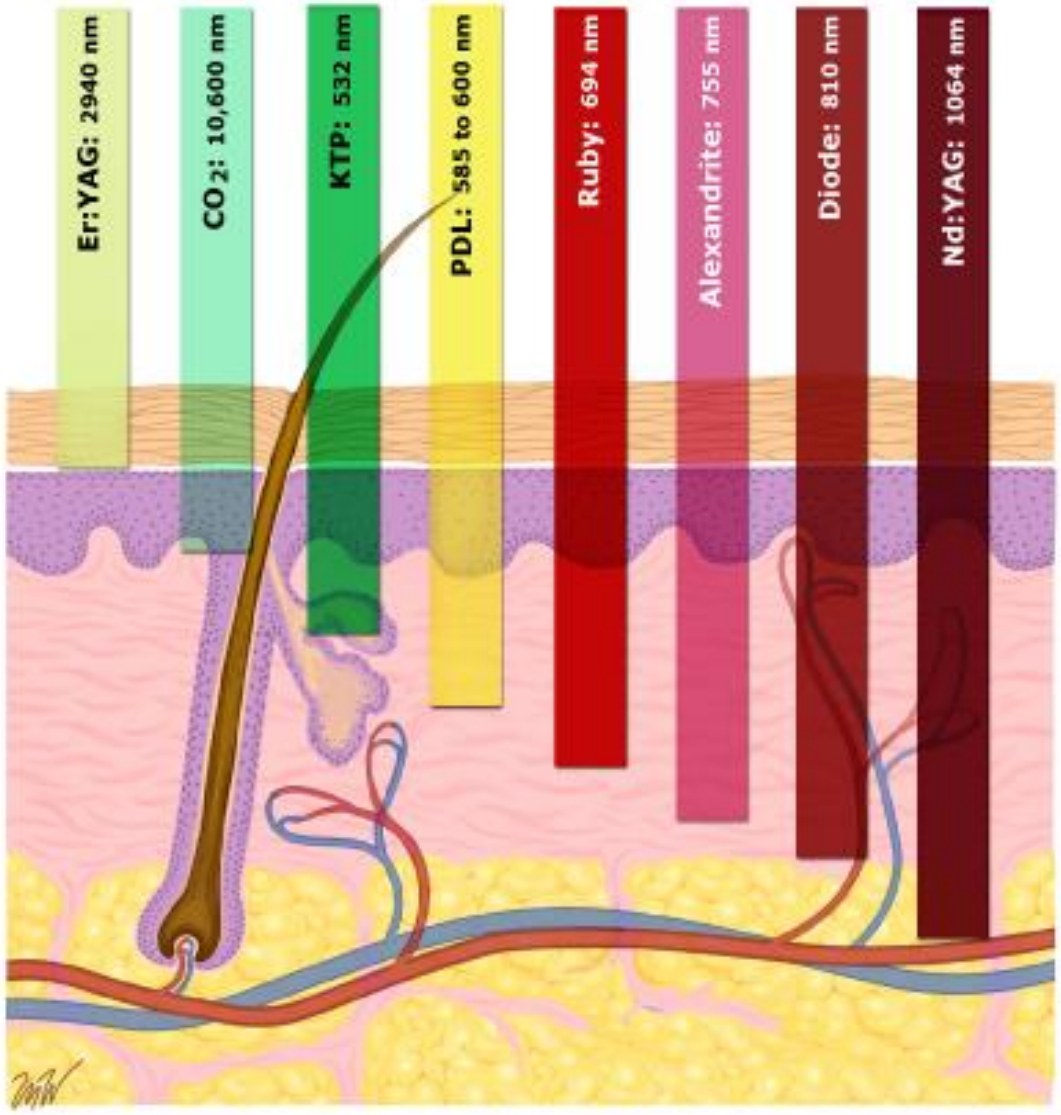
To select appropriate laser parameters, it is important to have an idea of the depth of the target structure:

< 1 mm depth: green or yellow light

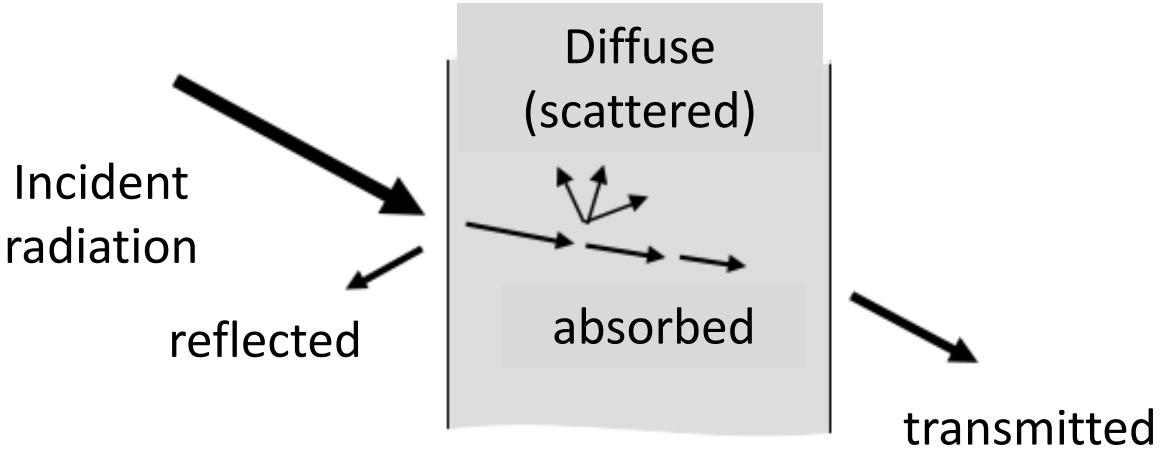
< 2 mm depth: red light

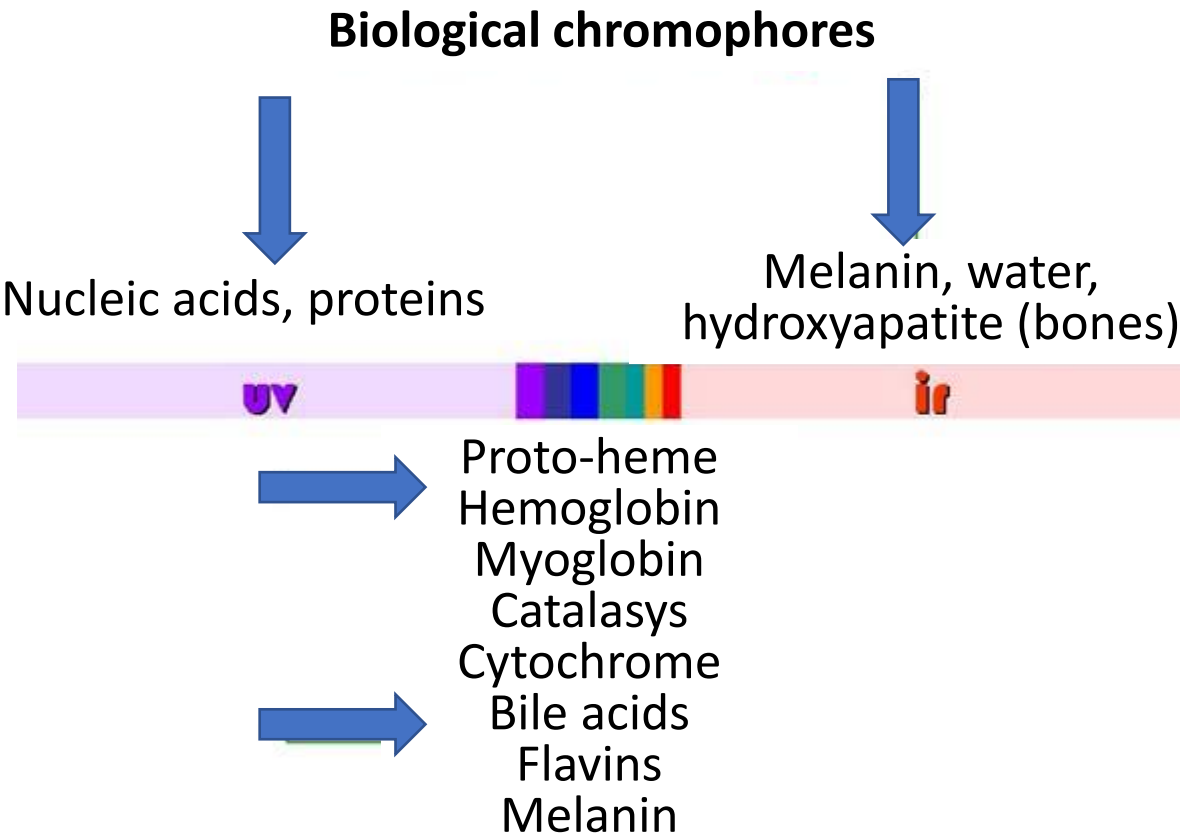
< 4 mm depth: near-infrared light

In the range of visible light and near infrared light (400 to 1200 nm), lasers that emit long wavelengths of light penetrate more deeply into the skin than lasers that emit shorter wavelengths of light. **Mid-infrared** (Er:YAG) and **far-infrared** (CO_2) lasers do not follow this rule. **Heavy absorption by water in the skin greatly limits the penetration of these lasers.**



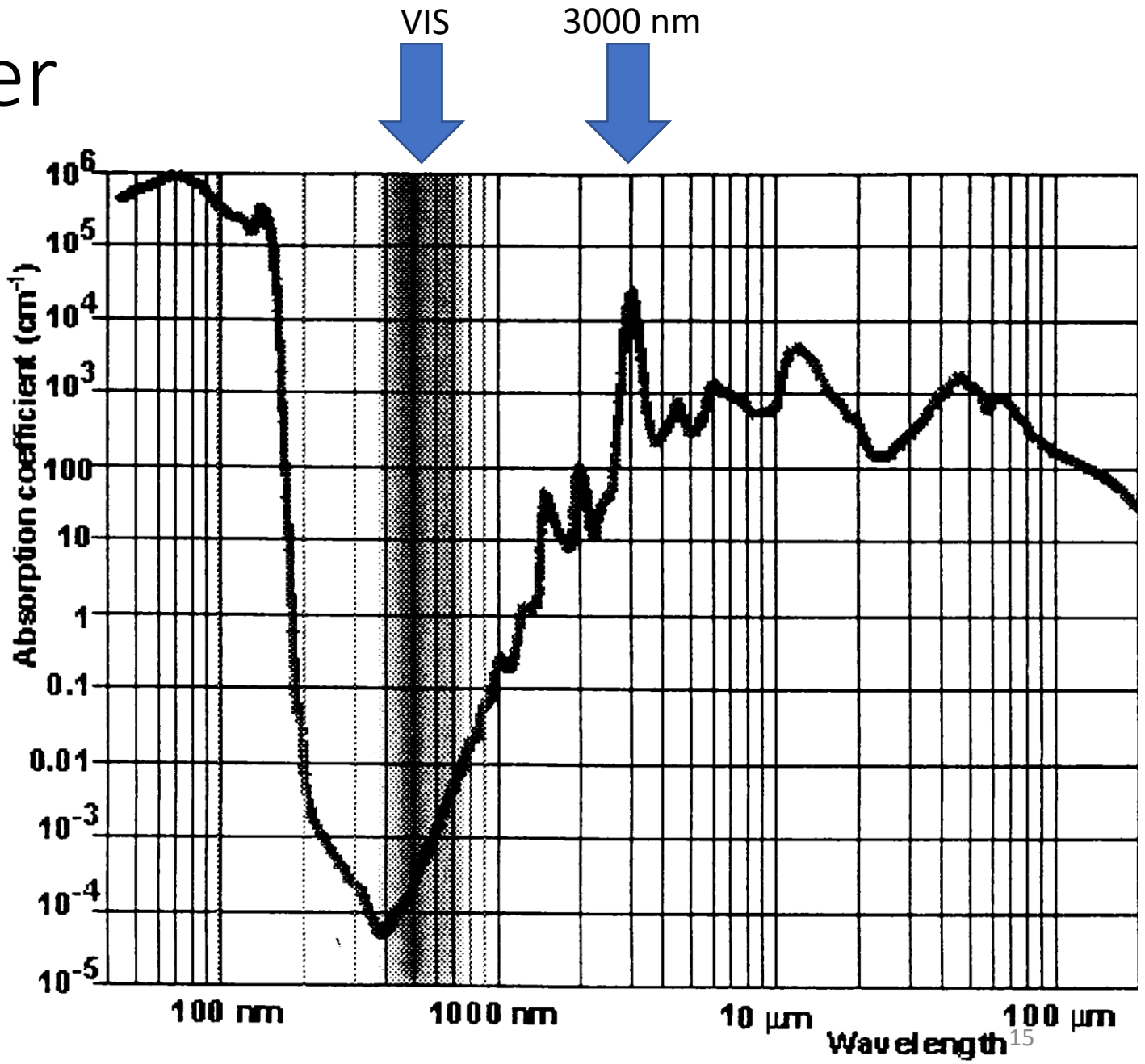
Light –skin interaction: ABSORPTION





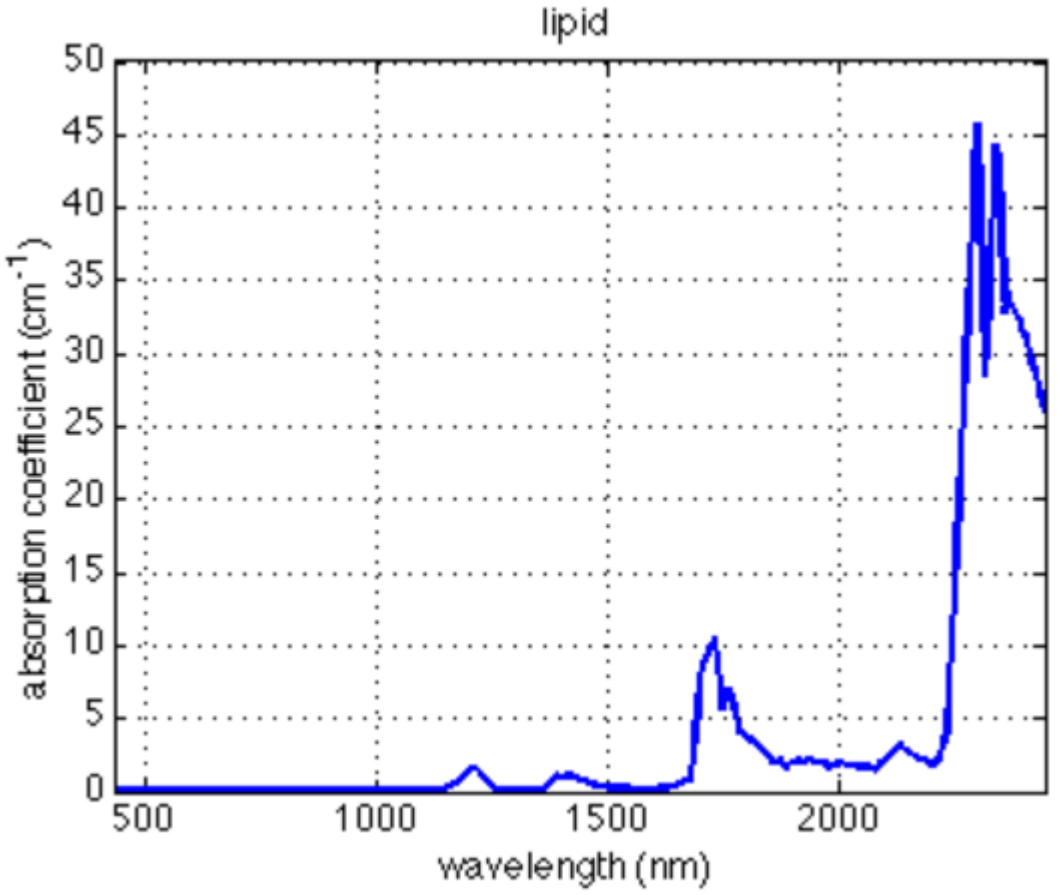
Absorption of Water

- high concentration > high absorbance even with low extinction coefficient
- absorbance peak at 3000 nm (stretching OH) and good absorbance in the whole IR spectrum.
- from 1000 nm and below sudden decrease, transparent in the visible spectrum.

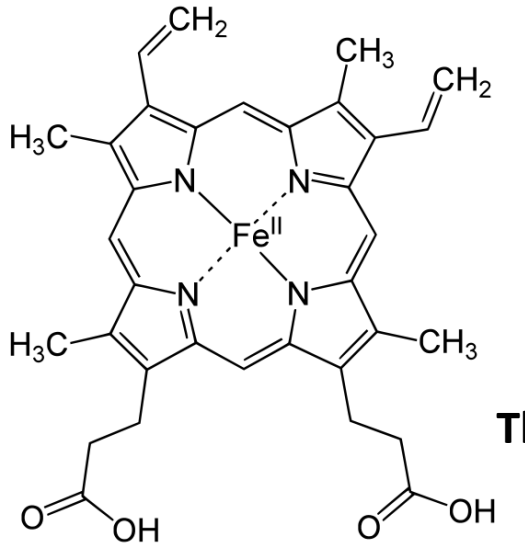


Absorption of Lipids

- suine fat, analogous to human fat with good approximation,
- Some NIR absorbance from 1000 to 2000 nm
- As water, low absorbance in the visible (but **high scattering due to refractive index contrast**)



Absorption of Hemoglobin Hb



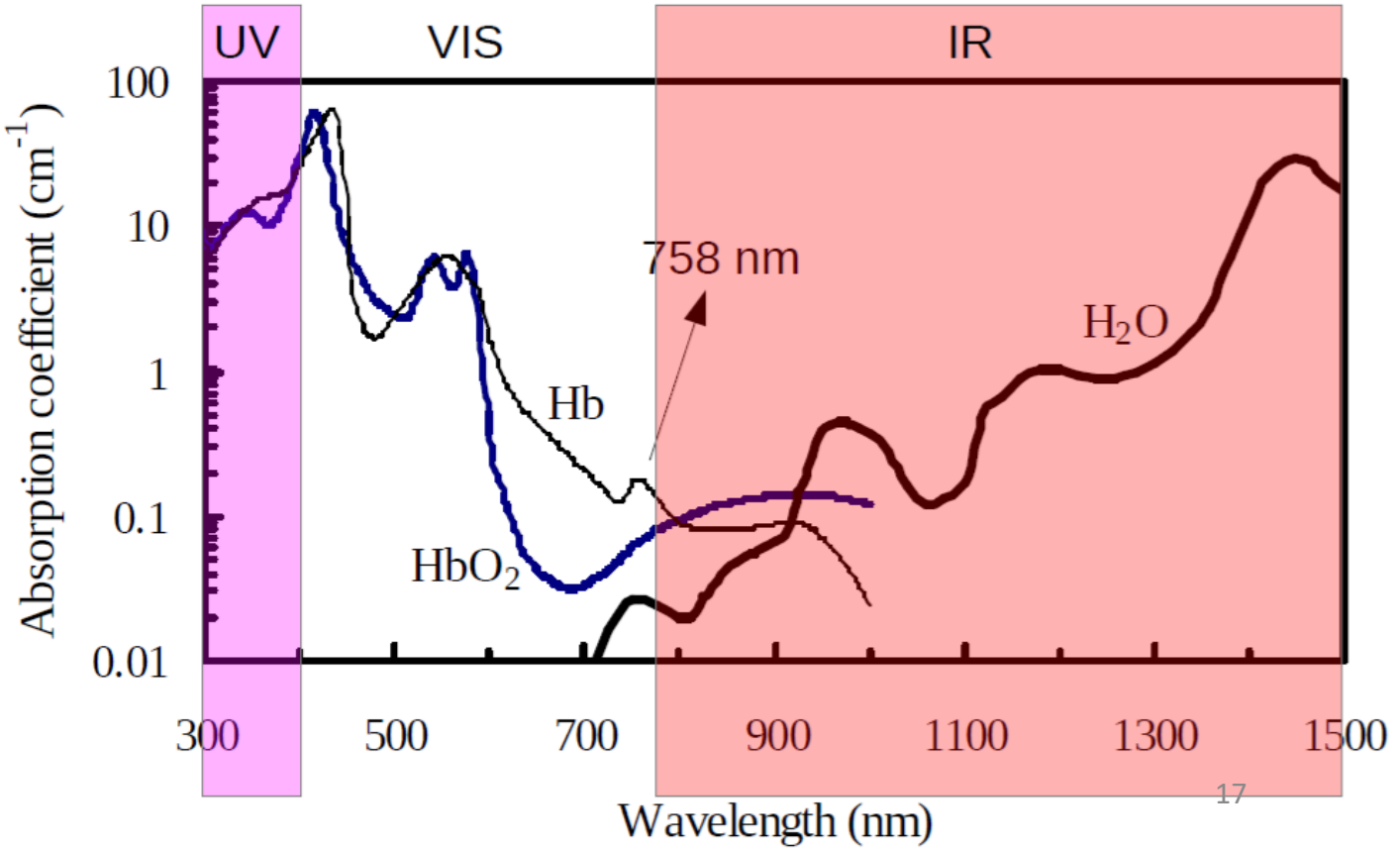
The HEME group

«respiratory pigment» of red blood cells

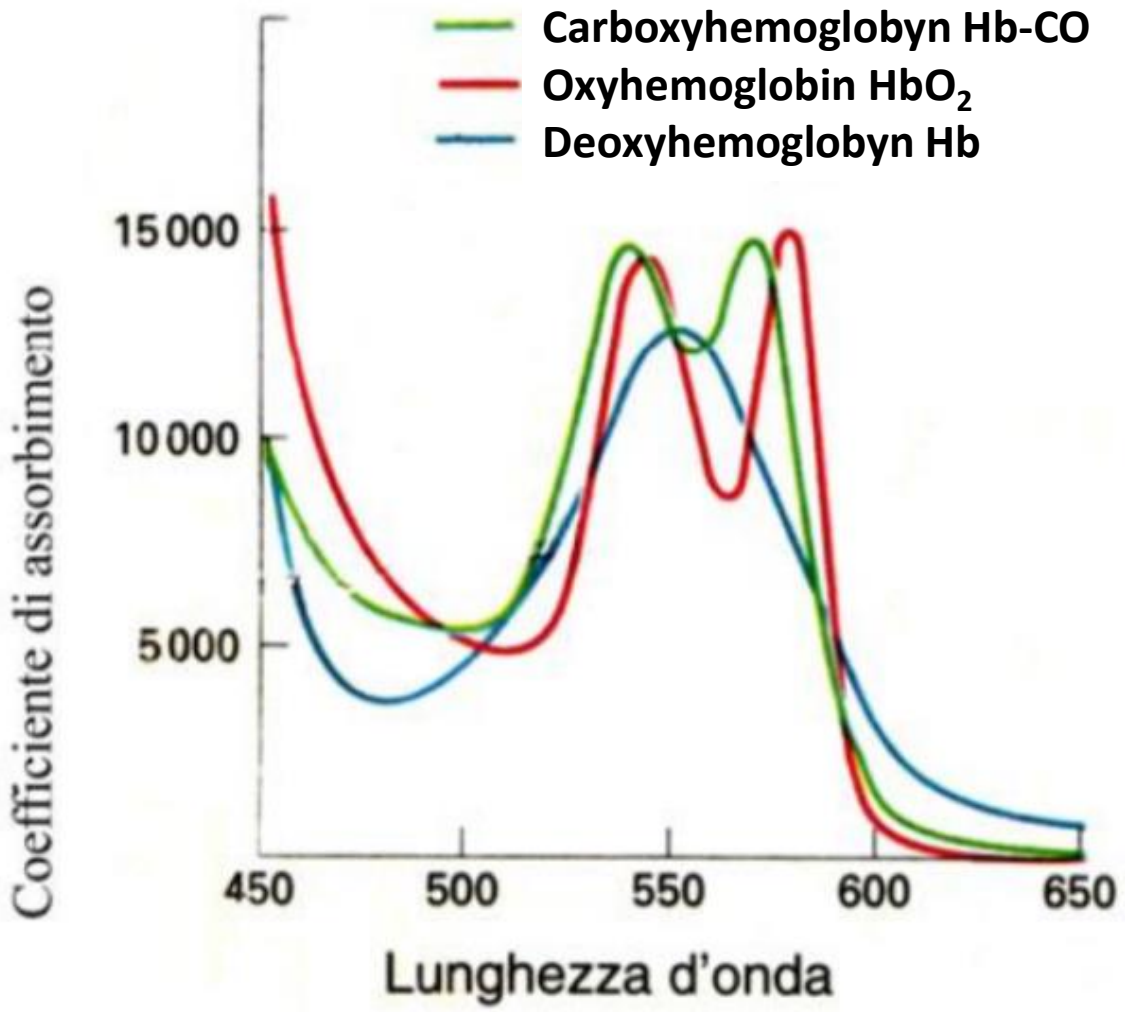
Composed of a proteic component (globulin) binding a prosthetic group (porphyrinoid) binding metal (Iron II)

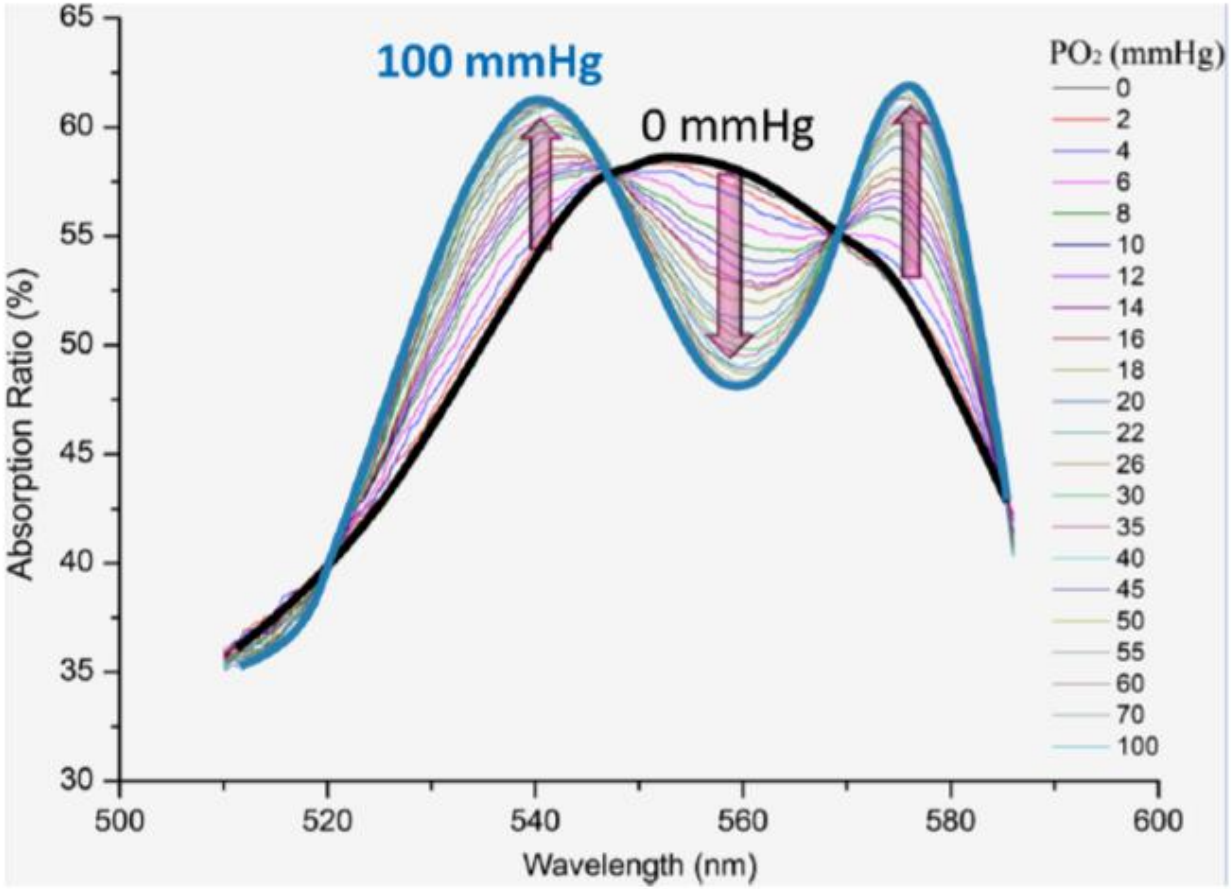
A "prosthetic group“ is a coenzyme that is tightly or even covalently, and permanently bound to a protein (e.g. myoglobin, catalasys, cythochrome)

Absorbance spectra of both Hb e HbO_2 high absorbance in the blue-green (Soret band) and yellow-orange (Q-bands, Hb > HbO_2) regions of the visible spectrum.



Absorption of Hemoglobin Hb





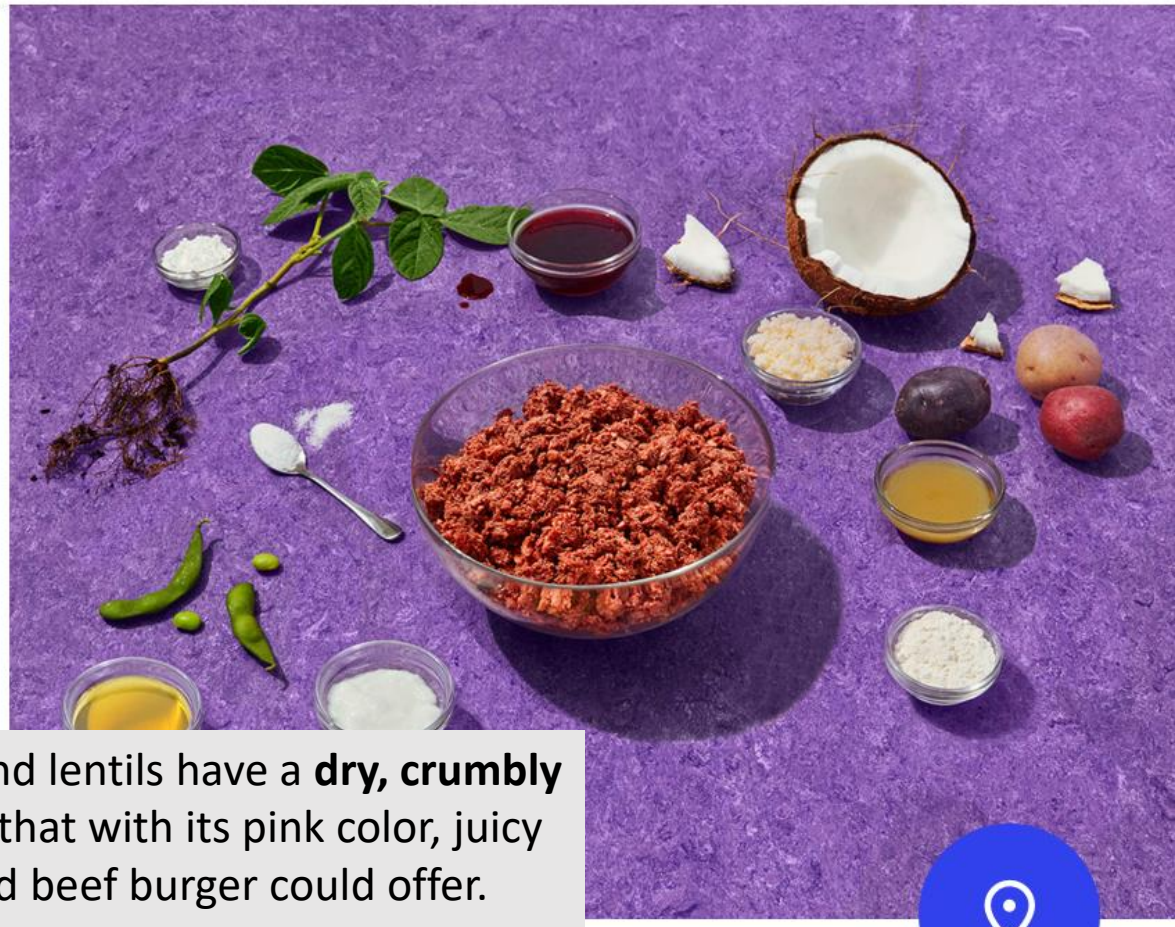
Hemoglobin Hb: appearance, and taste…!

FIND COOK SELL IMPOSSIBLE™ FOOD FOODSERVICE

(EAT THE IMPOSSIBLE™)

FOOD FOR THOUGHT

We started with a simple question. "What makes meat taste like meat?" Then we took everything we know and love about meat, and made it even better – using plants.



Traditional veggie burgers made from combinations of soy, beans and lentils have a **dry, crumbly texture** that's nothing like beef. The Impossible Burger has changed that with its pink color, juicy dribbles, smoky flavor and charred crust that previously only a grilled beef burger could offer. Oh, and this meatless patty **even bleeds like beef**.

(HOW IT HAPPENS)

FROM PLANTS TO MEAT

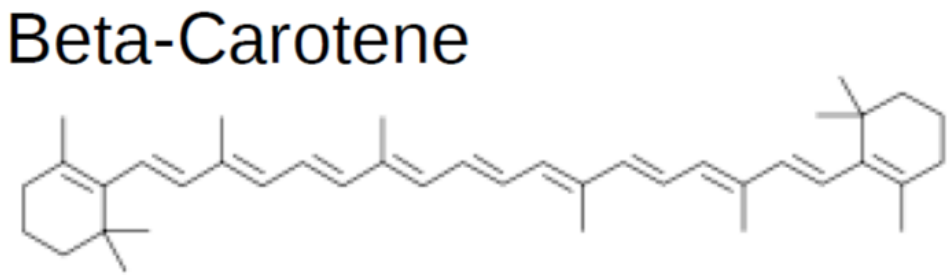
We started with a question: What if we could make meat better? Our approach: understand exactly what people love about meat, dairy, and fish, and then explore the plant world for specific ingredients that recreate those experiences — the flavor, the texture, the juicy sizzle. The result? Meat from plants. Good for people, and the planet.

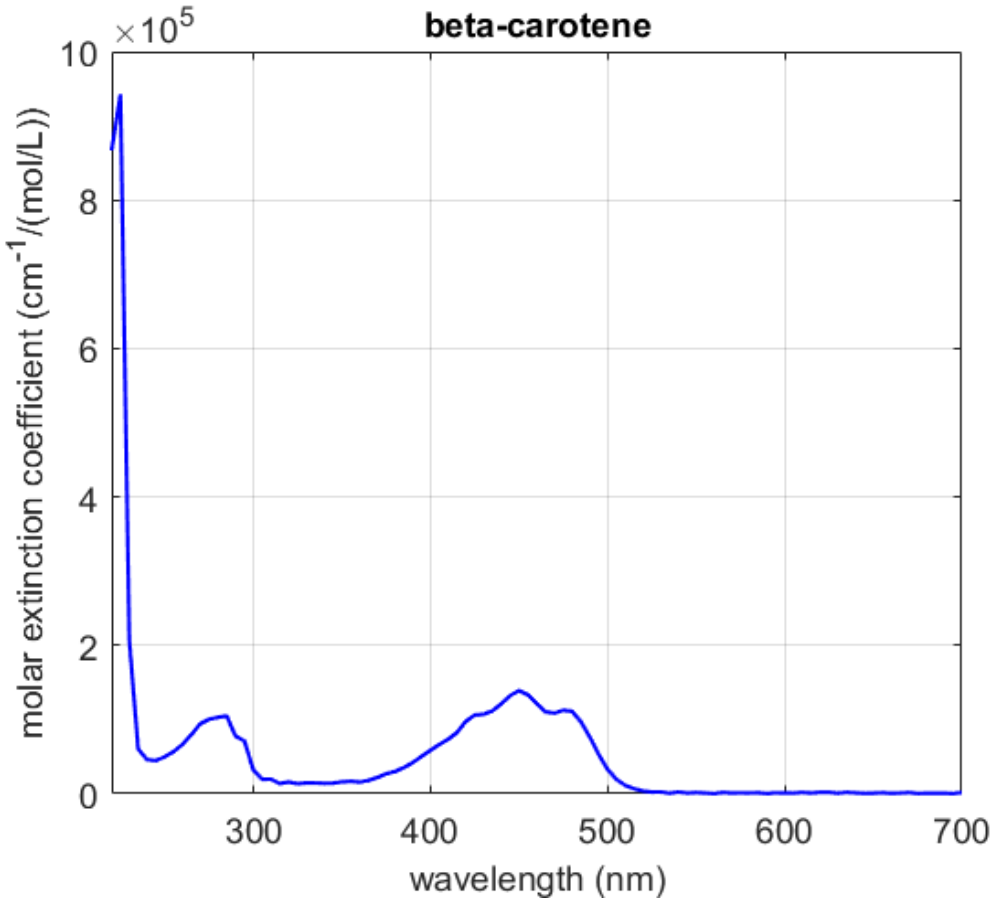
(OUR PROCESS)

MAKING HEME

We started by extracting heme from the root nodules of soybean plants, but we knew there was a better way. So we took the DNA from these soy plants and inserted it into a genetically engineered yeast. We ferment this yeast (very similar to the way Belgian beer is made) to produce heme. Why use genetic engineering? Read all about it on Medium.

Absorption of beta-Carotene



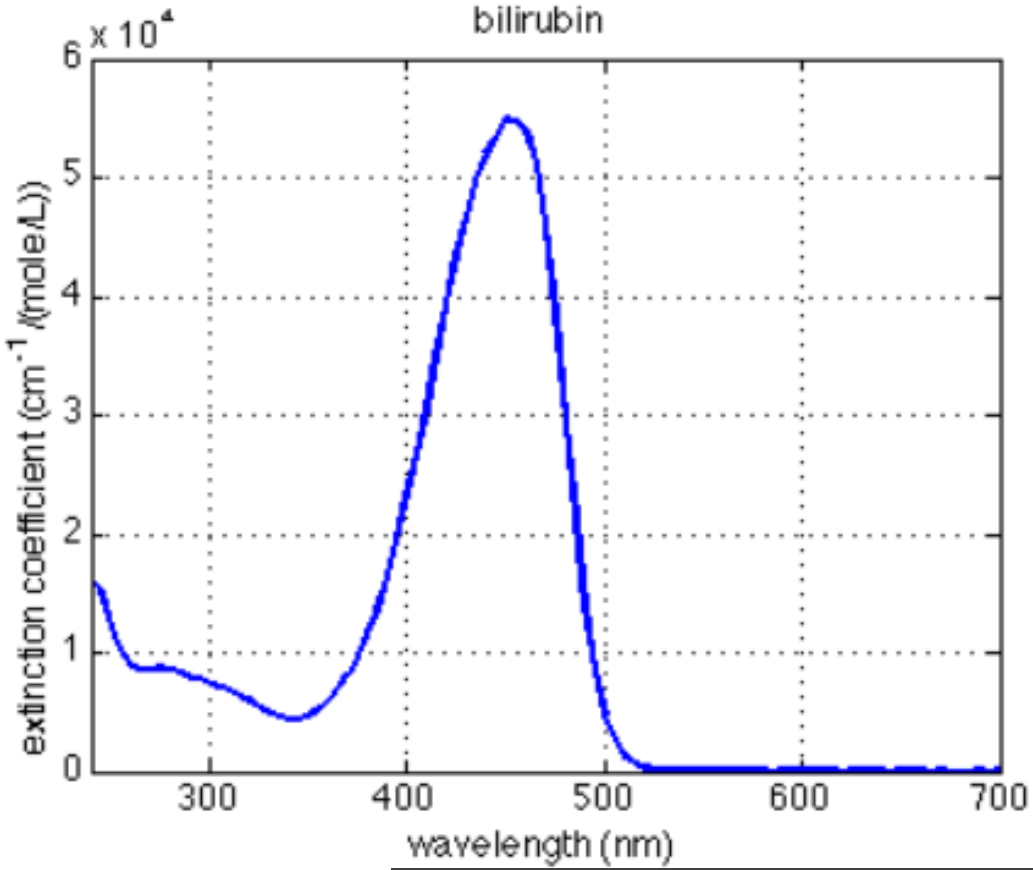


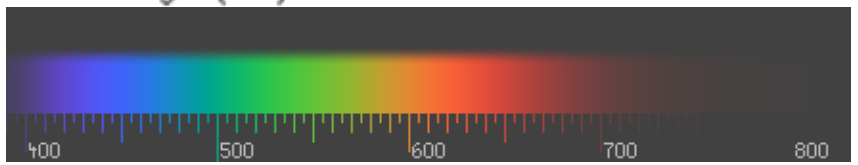
Absorption of Bile acids

Beside macrocyclic tetrapyrroles (as porphyrin in heme group) linear tetrapyrroles are found, constituting bile acids

Heterogeneous group of compounds differing in oxidation and poymerization grades

They feature various bands mainly in the UV and visible spectrum





Absorption of Nucleic acids and proteins

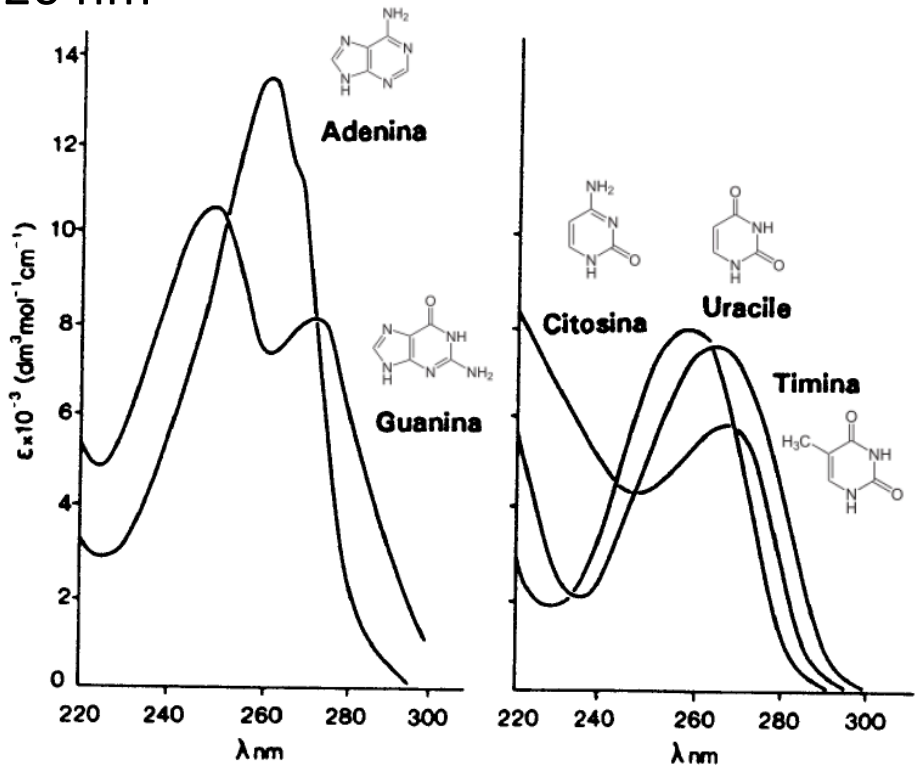
DNA, RNA: absorbance in range -> 250-270 nm

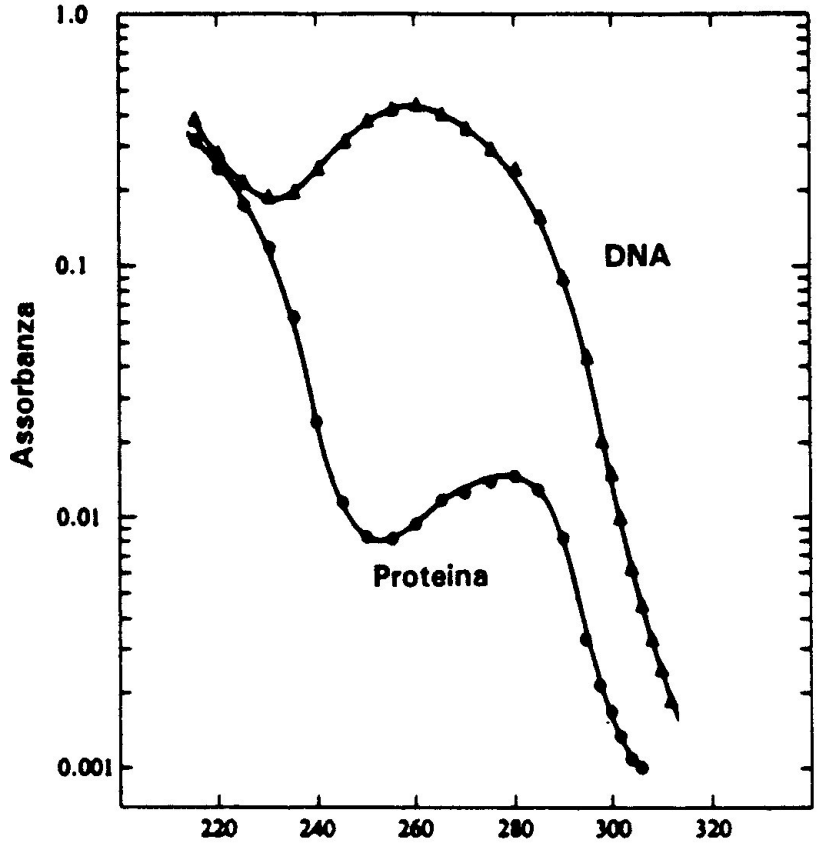
Aminoacids and Proteins: absorbance usually below 300 nm

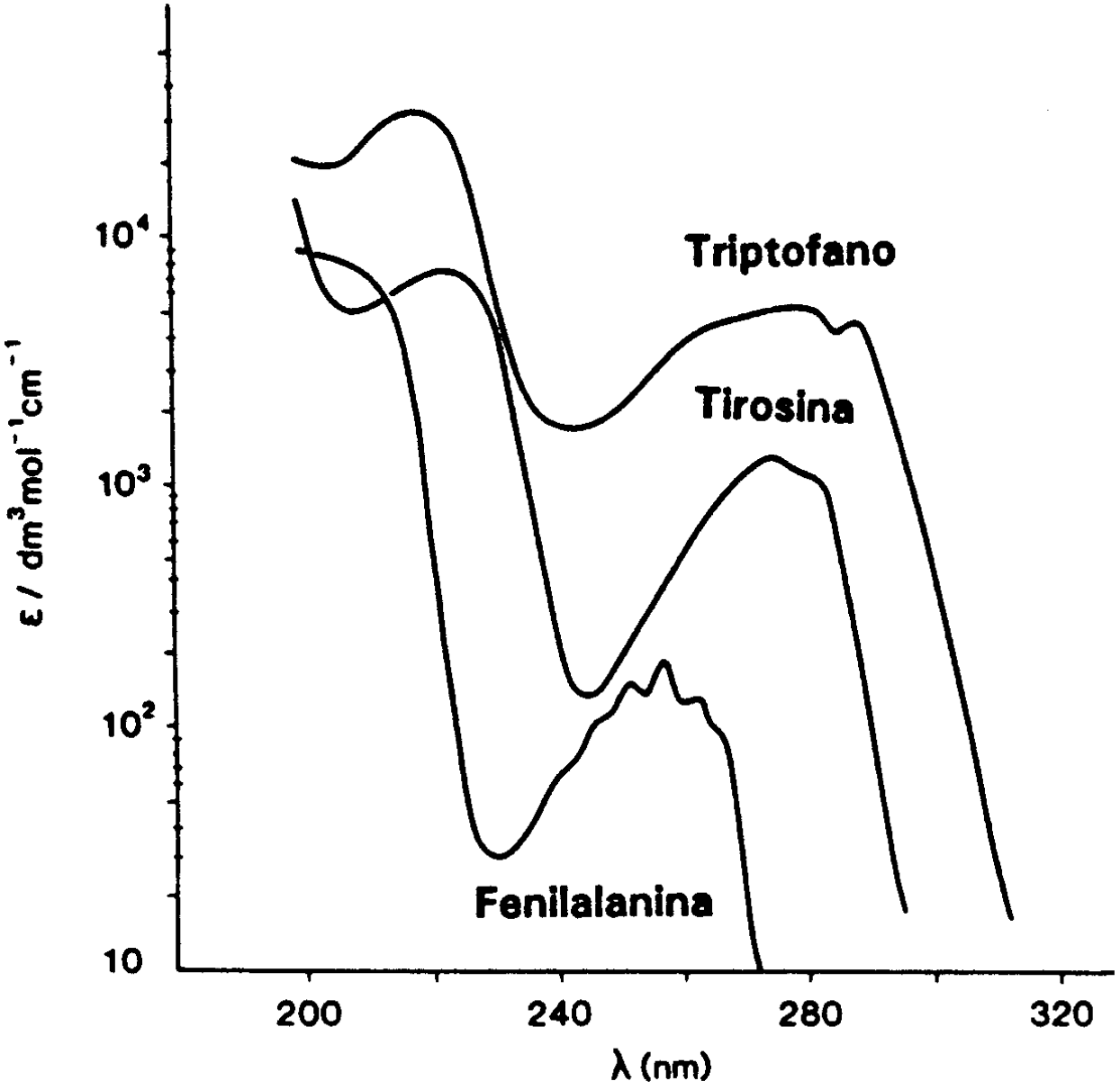
Peptidic bond:

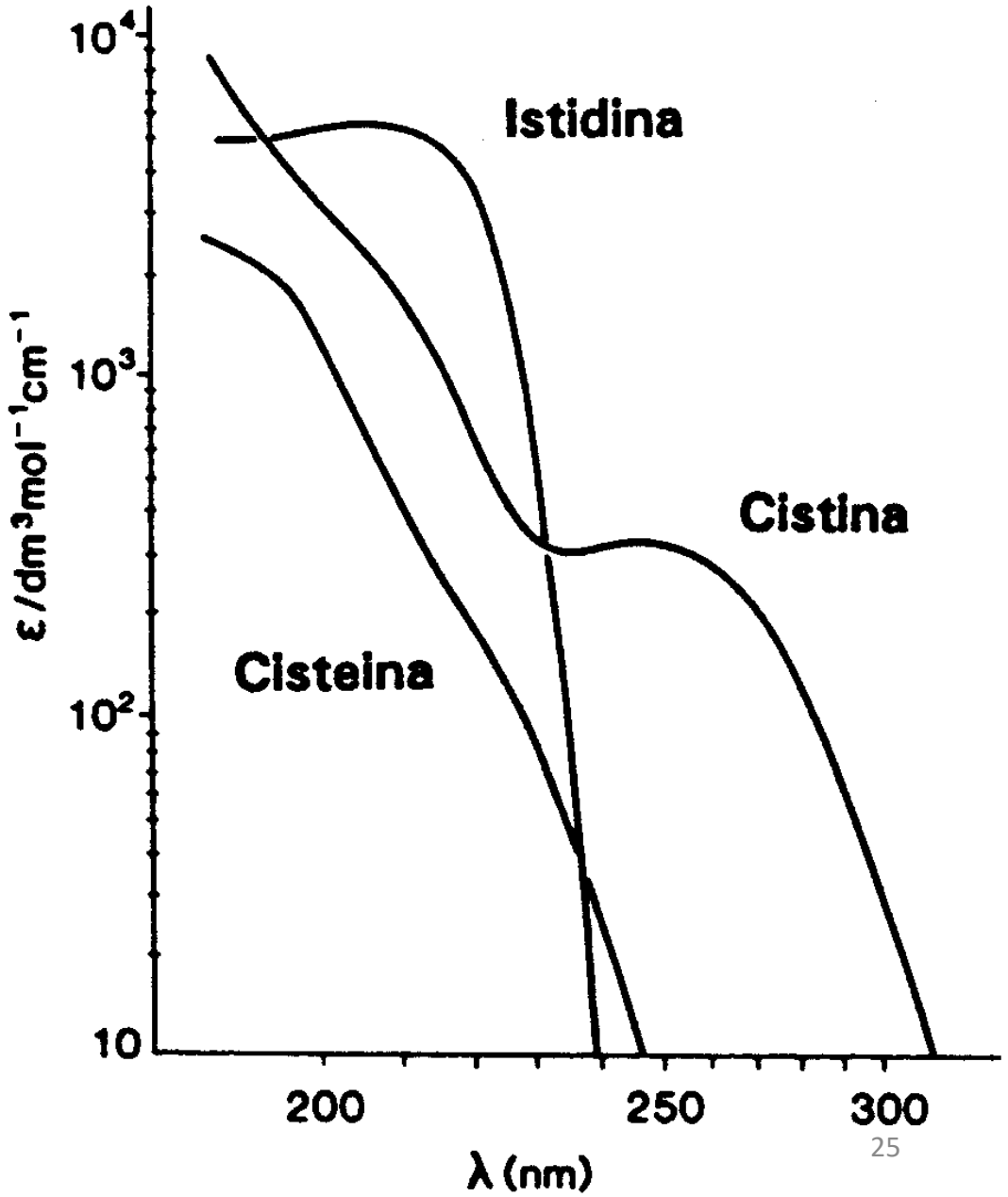
π-π* absorbance 190 nm

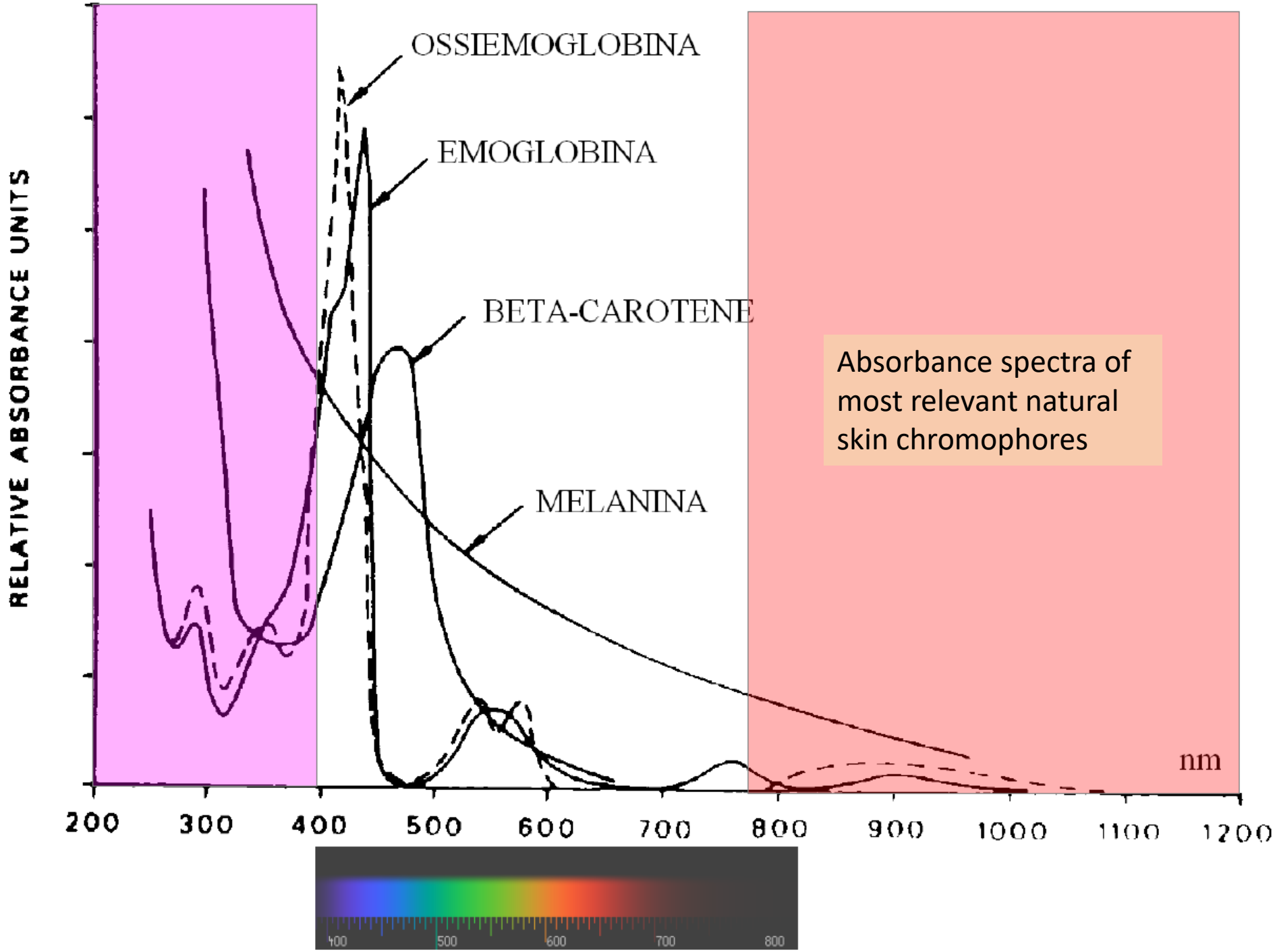
n-π* absorbance 210-220 nm






Triptofano
Tirosina
Fenilalanina
ε / dm³mol⁻¹cm⁻¹
10⁴
10³
10²
10
200
240
280
320
λ (nm)


Istidina
Cistina
Cisteina
ε /dm³mol⁻¹cm⁻¹
10⁴
10³
10²
10
200
250
300
λ (nm)



Absorbance spectra of most relevant natural skin chromophores

Use of lasers in skin therapy

- Soon following its invention in 1960, lasers have been used for medical purposes – both therapy and diagnostics
- Lasers substitute previous light and thermal (surgery) sources due to their superior properties:

- directionality

- monochromaticity

- power

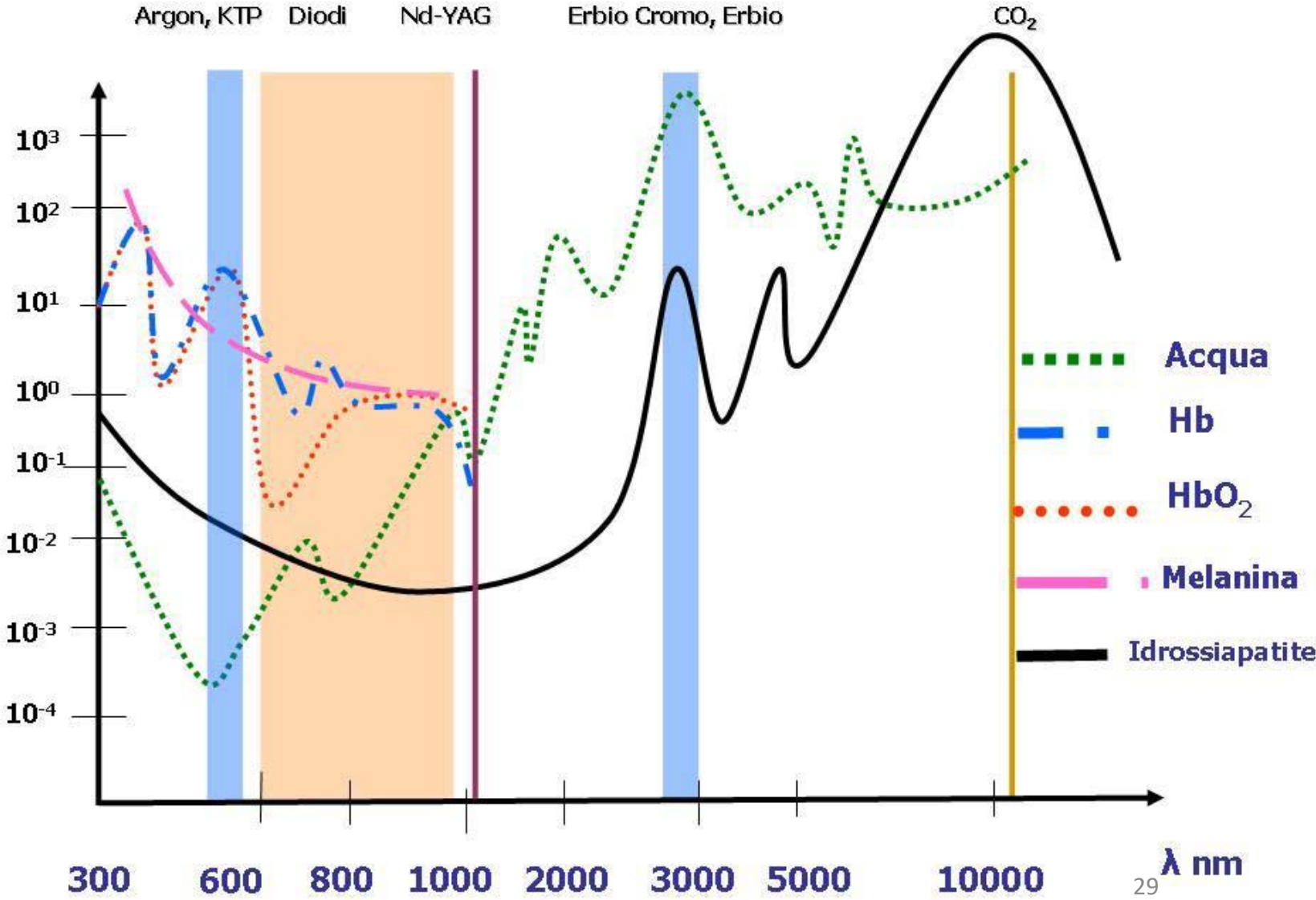
directionality

- laser light can be concentrated very tightly through focusing optics

- can be efficiently transported via fiber optics to reach internal organs in a non-invasive fashion

Monochromaticity

- specific action on the target object
- primary target is a chromophore
- target object may not be the primary target
- e.g. pigmented macula: then primary target is also the target object (extra melanin)
- e.g. coagulation (telangiectasias): primary target = Hb / HbO2; target object is the whole vessel to be cauterized (indirect effect due to thermal diffusion)



Power

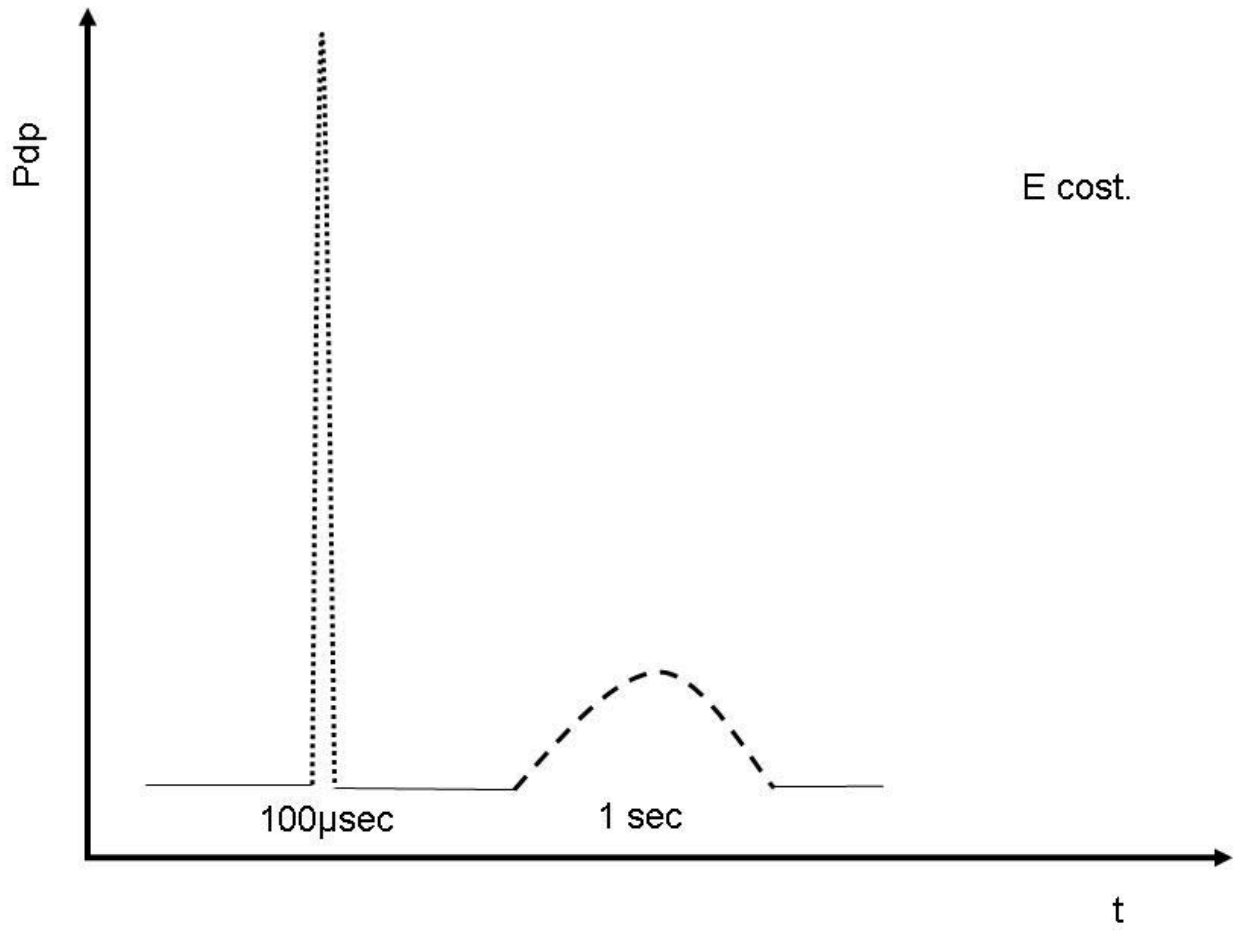
- Easy modulation of power
- Modulation of **pulse duration** (and peak power): range from ms to fs
- Pulse frequency range from 1 Hz to MHz, thus tuning the **time lag between following pulses** and the average power and energy
- Typically, shorter pulses > higher peak power

- Example: a laser with 150 mJ pulses, 20 Hertz frequency, will have average power 3 W

A single pulse of 150 mJ, with a duration of 10 ms, will have peak power of 15 W

The same energy, if confined in 10 ns, reaches peak power 15.000.000 W (15 MW)

>> no other existing sources allow for similar confinement of energy in a short time



Laser-tissue interaction

Complex response, depending on:

- wavelength
- Intensity
- Power
- Exposure time (total energy)
- Pulse duration
- **Absorbance** coefficient of the tissue (chromophores)
- Penetration depth (transparency: absorbance / scattering)

When light is absorbed, it gives up its photon energy to a target molecule termed a chromophore. The photon will cease to exist and this quantum of energy transferred excites the chromophore.
Without light absorption, there can be no effect on the tissue.
In the skin, the three main primary chromophores are melanin, water and hemoglobin.

By combining these and other parameters, it is possible to optimize the transformation of radiant energy in mechanical, thermal or chemical energy

Table 1.1.

Common Laser Terminology

Term	What it Means	Units
Chromophore	Substance that absorbs light	NA
Wavelength	The distance between one peak or crest of a wave of light and the next corresponding peak or crest.	nanometers (nm)
Pulse Duration/ width	The length of time that the laser is exposed to the skin	nanoseconds (ns) milliseconds (ms)
Fluence	The amount of energy delivered to a unit square area	J/cm^2
Power	The rate at which energy is delivered	W
Spot size	The diameter of the laser upon skin impact	millimeters (mm)

Table 1.2.

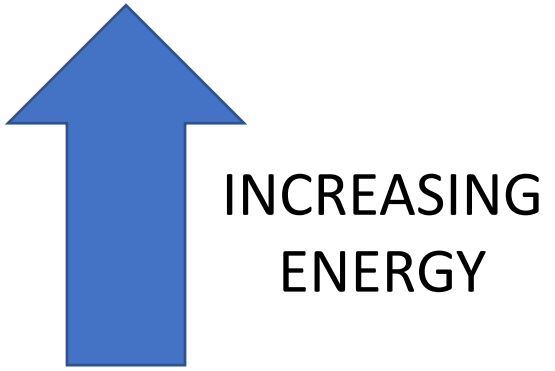
Selective Photothermolysis Targets

Chromophore	TRT	Pulsewidth	Laser
Tattoo/pigment	ns	ns	Q-switched
Blood vessel, Telangiectasia	ms	ms	Pulsed dye
Venule	sec (s)	ms	Long pulsed
Hair follicle	ms	ms	Long pulsed

Light Skin interaction

Depending on various parameters e.g. wavelength, fluence, power, spot size, pulse duration and cooling, the reaction of the tissue to light/laser irradiation is as follows:

1. Photomechanical Reactions
2. Photothermolytic Reactions
3. Photochemical/Photodynamic Reactions
4. (Photostimulatory Reactions)



1. Photomechanical Reactions

- These are induced mainly by **high power, short pulse lasers**.
- The generation of laser-induced **stress waves** can disrupt tissue, kill cells, decrease cell viability and increase the permeability of the plasma membrane.
- Additionally, it may cause **erythrocyte vaporization** and **mechanical vessel rupture** with hemorrhage.

1. Photomechanical Reactions

- Photoelectromechanical mechanism

When high energy dose is released in a small area, the local electric field is as intense as ionization energy (intermolecular coulombic field), inducing dielectric rupture with sparse formation of plasma and high density of free electrons

- Rapid expansion generates a spherical stress wave travelling ca. 30 µm (locally high T and high pressure – kbar range)
- Stress wave generates mechanical stress and consequent tissue laceration

2. Photothermolytic Reactions

Laser/light tissue interactions upon absorption produce **heat** which can **denature** various cells, e.g. melanocytes, keratinocytes or essential structures, e.g. collagen and blood vessels which make up the skin.

Each component within the skin has a **threshold for heat injury** before it denatures.

Thermal relaxation time (TRT) is the time required for the targeted heated tissue to lose half its heat. Therefore the key to successful laser treatment is to induce a thermal effect in the target tissue **quickly** and cause *damage to it before the heat is conducted* to the surrounding tissue.

2. Selective Photothermolysis

In other words, if we carefully select the laser/light wavelength, with an appropriate fluence and a pulse duration equal or less that the TRT of the target, focal selective destruction of the target occurs with little or no destruction to surrounding tissue. If the conditions are met, the heat generated should reside within the target until it is damaged without heat dissipating to the surrounding tissue. As a result this will only require minimum light/laser deposition and provide selective damage. This forms the basic concept of "**selective photothermolysis**."

Chromophores may also be used as subsurface heat sources to denature **nearby tissue** targets (**extended selective photothermolysis)**

This is best illustrated in the scenarios involving hair removal and the treatment of telangiectasias. In hair removal, the chromophore is the melanin in the hair shaft while the target structures like the stem cells within the bulge area have little melanin content. If a longer pulse width is utilized, the melanin laden hairshaft is heated up and significant heat diffusion damages the target stem cells. By the same reasoning, in the treatment of telangiectasias, the laser targets hemoglobin, heats it up and heat then diffuses to the blood vessel wall, coagulating it.

3. Photochemical/Photodynamic Reactions

- The process usually involves the administration of either a topical or systemic **photosensitizer** that is subsequently activated by a light or laser source to destroy targeted tissues.
- treatment of **superficial non-melanoma skin cancer** is based on the application of the agent (5aminolevulinic acid) to the tumor (Bowen's disease or superficial basal cell carcinoma) for 3–4 hours, and then irradiated with red light. The photochemical reaction takes place during illumination with **selective destruction and necrosis** of the tumor cells.

4. Photostimulatory Reactions

- Experimentally, it has been shown that **low energy** level laser **may be beneficial for wound healing**.
- Although the results suggest possible mechanisms by which the wavelength may potentially influence the cellular responses of injured cells, **more work has to be done** for a full mechanism efore the concept can be translated into clinical practice.

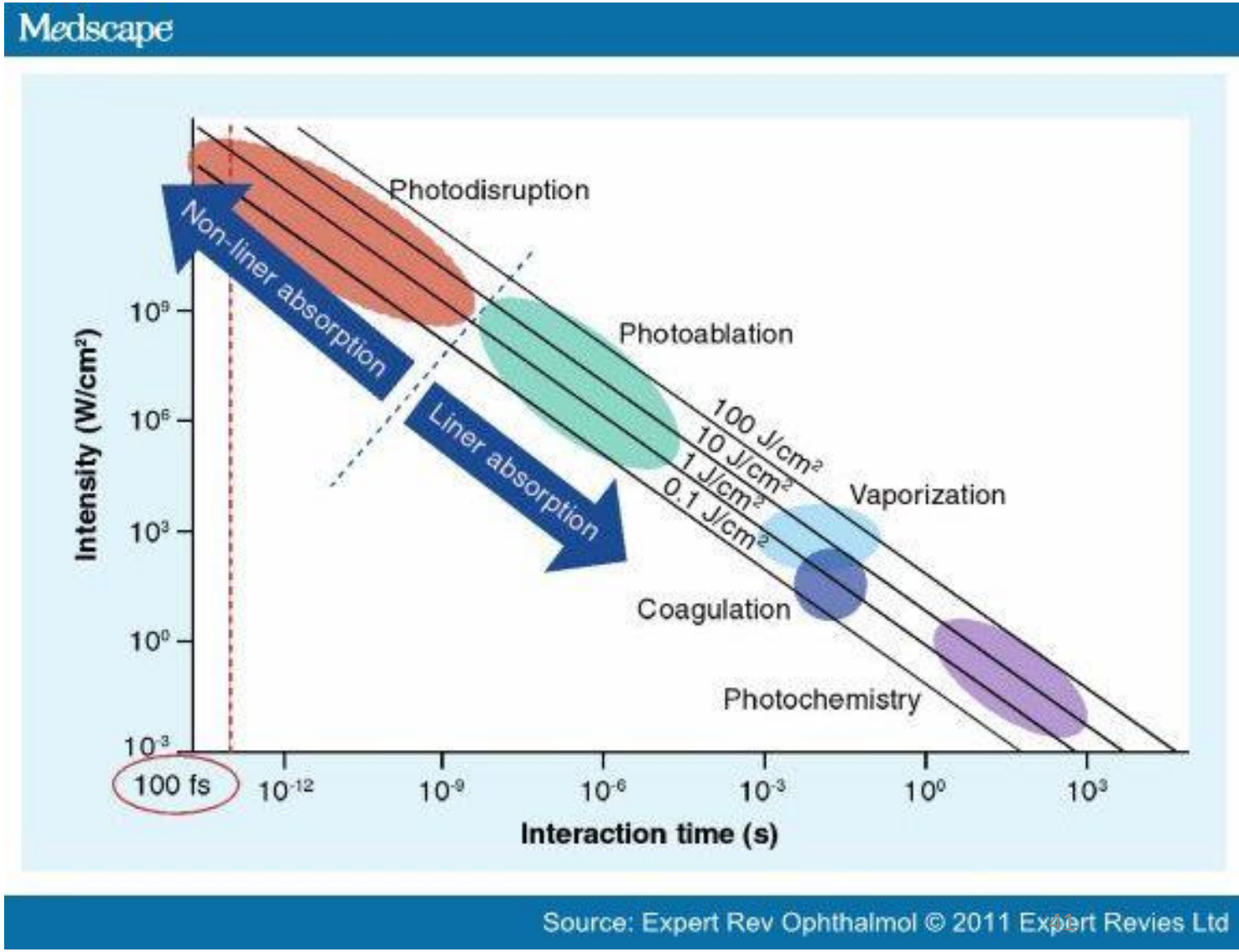
Medical laser interaction map – by power

Photodisruption:
High energy per surface unit (10 J/cm²)
laser Nd:YAG (Q-switching or mode-locked)

Photo-thermo-ablation
Pulsed lasers Δt=10 ns-100 µs
I~10^8 W/cm²

Photothermal effects
CW lasers, power density > 10 W/cm²
Pulsed lasers Δt >1 ms

Photochemical interaction
Long exposure to low intensity lasers



Photothermal effects

Surgery

- High intensity and high directional precision laser beams – cut and cauterization of pathological tissues in < 1s
- Low or no damage on surrounding health tissue
- Bones can be drilled (hydroxyapathite absorbing in the Mid-IR is the target)

Vaporization

- Extended irradiation raises local temperature to > 100°C with vaporization of water and surrounding biolical material

Selective necrosys of tissues

- With relatively low power (1 W) a tissue can be heated to ca. 45°C, with consequent necrosys

Temperature effects

- 43-45°C: Hyperthermia (cell death / necrosys) – Conformational changes of cells
- 50°C: Enzyme activity reduction
- 60°C: Protein coagulation – Denaturation of biomolecules (proteins, collagen, lipids, hemoglobin) – Membrane Permeabilization
- 80°C: Carbonization – Collagen disruption
- 100°C: Water evaporation – formation of vapor vescicles trapped in tissues – Tissue compression and mechanical stress

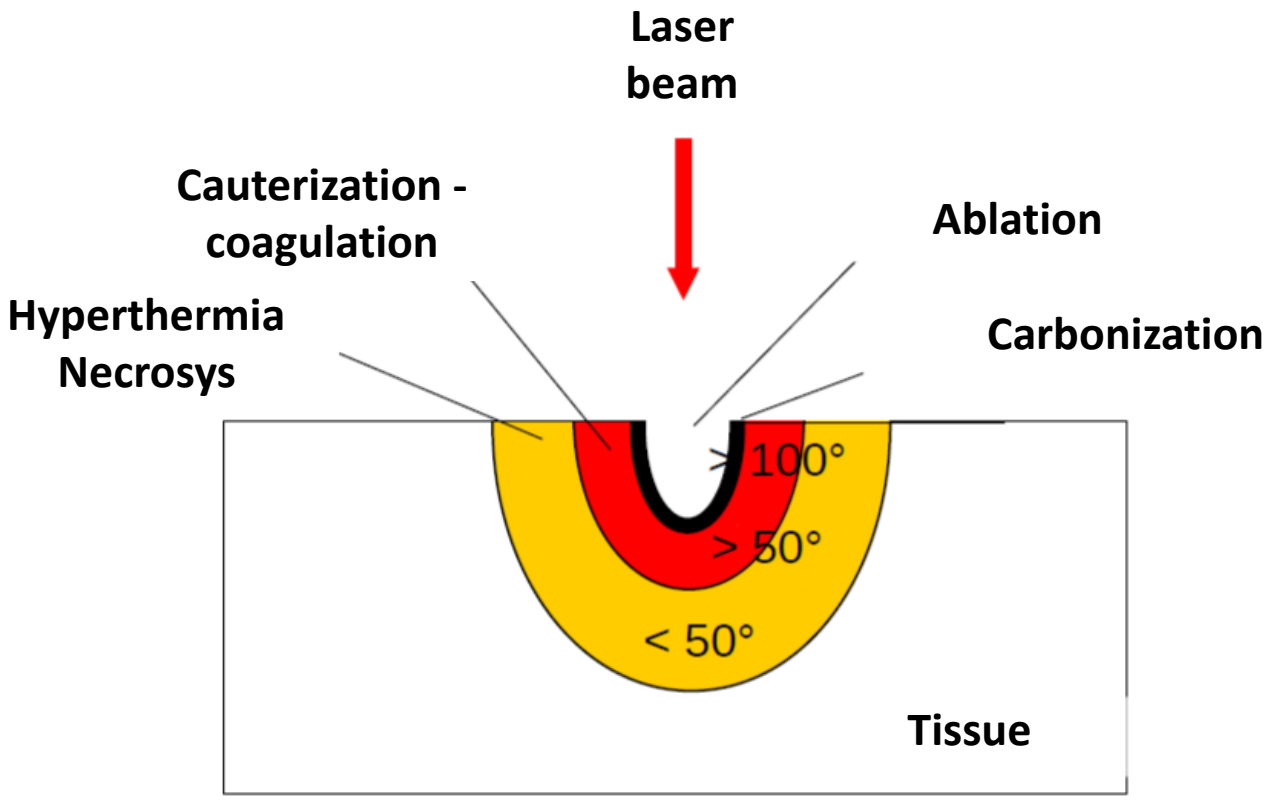
(The irradiated layer remains at ca 100 °C until all water is vaporized)

- > 100°C: Rapid vapor expansion – Vescicle membranes are broken, formation of large bubbles – Bubble expansion until explosions (pop-corn effect) – Vapor exits tissues with temprary surface cooling, formation of surface craters – Tissue dehydration

N.B. Water loss limits thermal conductiveness, heat remains trapped for longer time

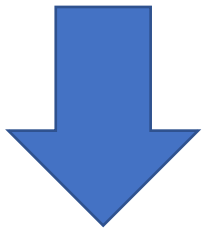
- 300-1000°C: After water vaporization, T rapidly increases to 300°C (burning tissue, carbonization) > photo-thermo-ablation of tissue

Localization of photothermal effects in biological tissues



Exposure time

- long exposure may damage surrounding healthy tissues
- **relationship between exposure time and heat localization?**



HEAT DIFFUSION THEORY

Heat diffusion theory

- Length “L” travelled by heat in the exposure time τ :

$$L^2 = 4 K \tau$$

K = thermal diffusivity coefficient

Specific of each material

- Water: K=0.143 mm²/s

Hence, in a second, heat travels in water:

L=2√(Kτ)=2√(0.143*1)=0.7563 mm≈0.8 mm

In 1 ms heat travels 0.8 µm in water

Material	K (mm²/s)	L (mm/s)
Copper at 25 °C	111	21.1
Silicon	88	18.8
Iron	23	9.6
Air (300 K)	19	8.7
Quartz	1.4	2.4
Sandstone	1.15	2.1
Glass, window	0.34	1.2
Water at 25 °C	0.143	0.8
Wood (Yellow Pine)	0.082	0.6
Paraffin at 25 °C	0.081	0.6
PVC (Polyvinyl Chloride)	0.08	0.6
Alcohol	0.07	0.5

Thermal relaxation time

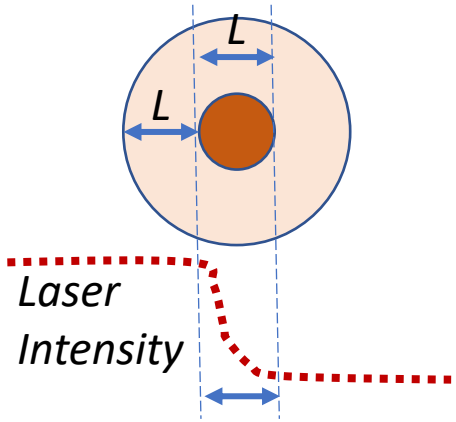
- Thermal relaxation time (TRT) indicates the time needed to trasfer the absorbed energy to adjacent tissues

TRT = $(L_{extinction})^2/(4K)$

= $1/(4K\mu_a^2)$

$$L = \frac{1}{\mu_a}$$

Spatial distribution of intensity within the tissue:
absorption length (extinction length) *(inverse of absorption coefficient)*



The absorption length measures the distance, along the beam axis z, at which the intensity has dropped to 1 / e of its incident value

- Where $L_{extinction}$ is a length of «optical extinction» (absorption of 90% radiation)

(NB sometimes TRT is defined as the time needed for an object to cool down to half its temperature >> «functional» definition, for specific purposes)

Localization of photothermal effects

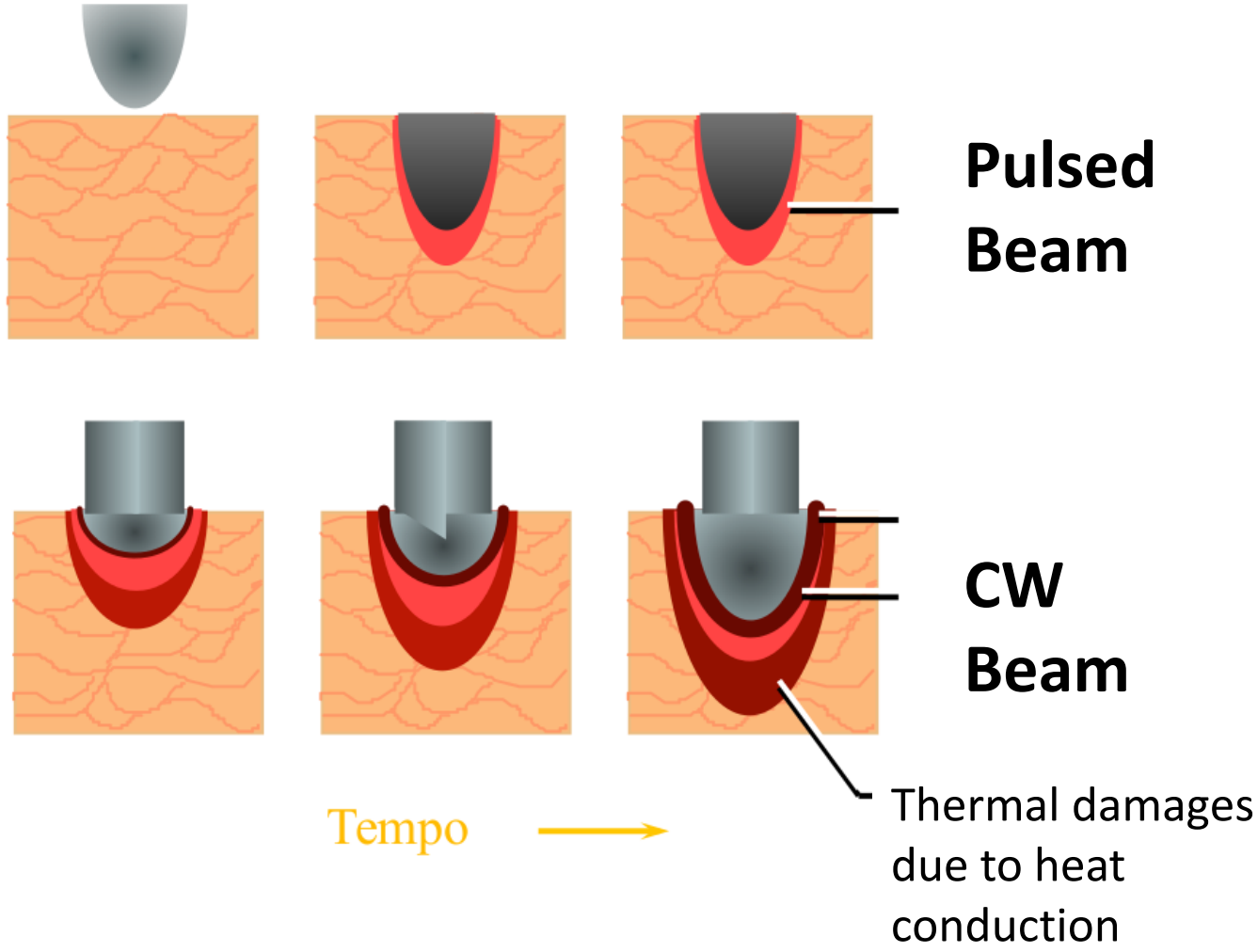
τ(pulse) < TRT

● Fast pulse (shorter than TRT) > heat confinement in the region given by:

Irradiated surface (or «voxel»)* Lext

High local and confined heating

● By tuning energy and frequency local Temperature can be controlled below the threshold



Example- photocoagulation

Selective photocoagulation of a vessel with diameter d

- select wavelength of laser:

  $L_{extinction} = d$

- select pulse duration:

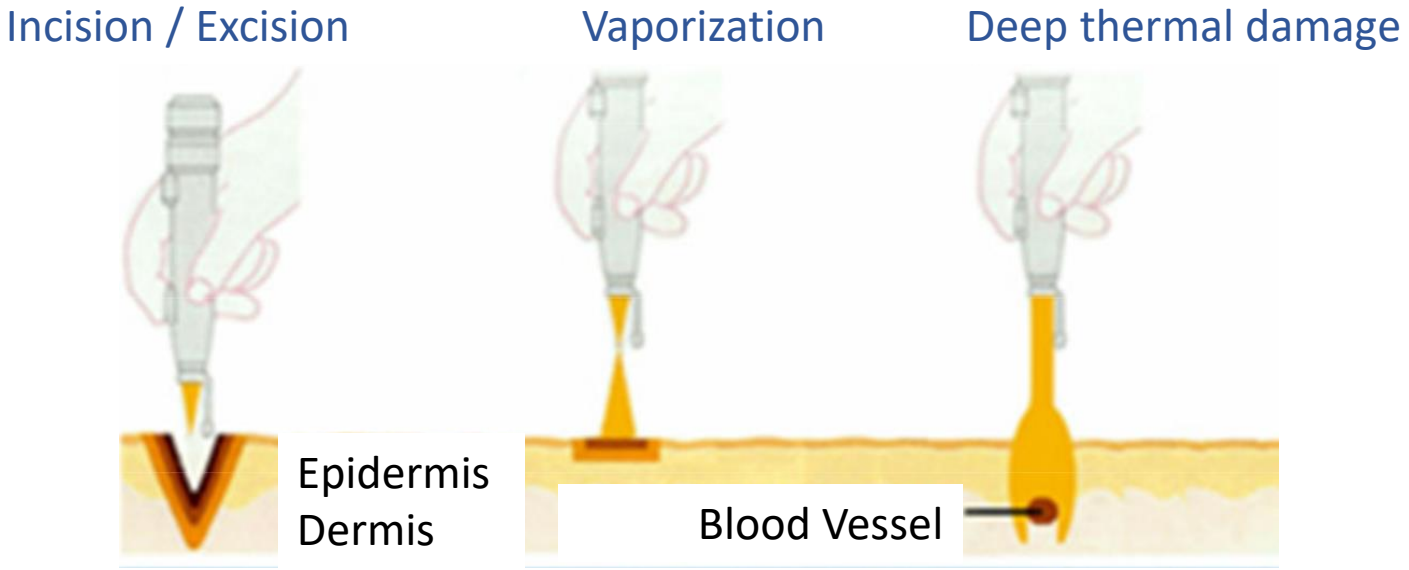
  $t_{pulse} << TRT$

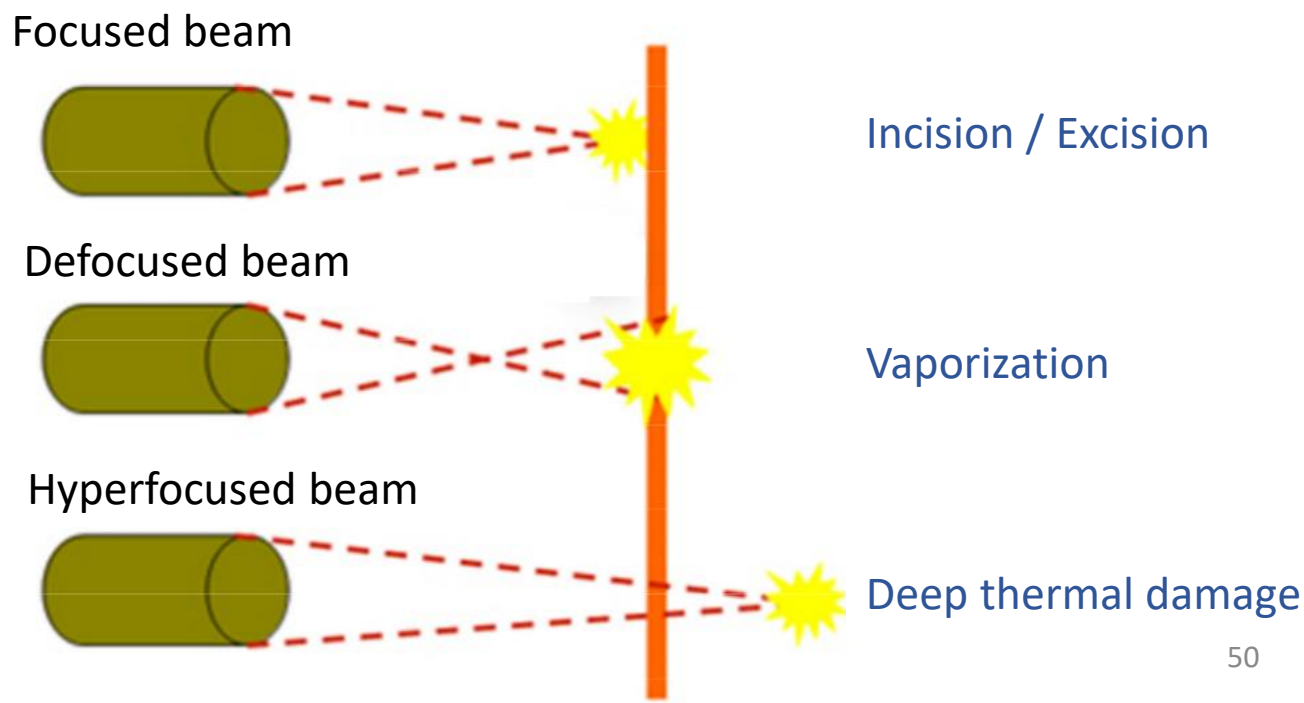
- select energy of the pulse:

Coagulation Temperature should be reached

Focalization of light
the beam spot size

- Focused beam: incision / excision
- Defocused beam: tissue vaporization
- Hyperfocalization: deep thermal damage





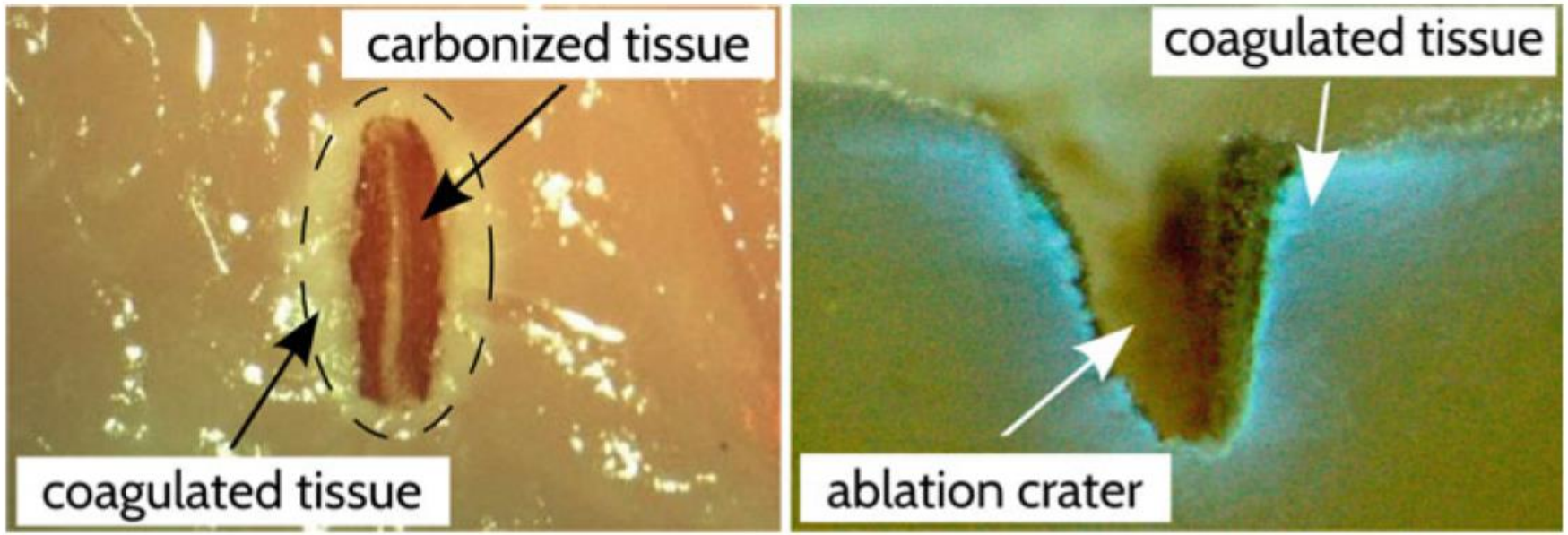


Fig. 2.11 Thermal effects of CO_2 laser radiation on soft tissue. Here, the same tissue specimen is shown from a top view (*left*) and cross-section (*right*) perspective. Material ablation can be observed in correspondence with the laser incision line. Dark areas on the edges of the ablation crater indicate that temperatures over 100 °C have been reached, resulting in the carbonization of tissue. Coagulation can be also be observed, in the surroundings of the laser incision site.The volumetric extent of coagulation has been highlighted in the cross-section image through the use of a fluorescent light source

Non selectivity: Tissue Cooling

Tissue cooling is of paramount importance and has been incorporated into many laser systems. During laser treatment of vascular lesions and hair removal, it is inevitable that **epidermal melanin** may become an **undesired target chromophore**.

Although this may not be an issue in fairer skin individuals, **pigmented skin types** may suffer pigmentary side effects or blistering with scar formation.

The use of tissue cooling minimizes this risk of epidermal heat accumulation and damage.

1. **Cold Air Convection -** cooled air at − 30°C using a closed loop cooling circuit before targeting with laser treatment. It may also minimize pain during laser treatments.

2. **Contact Cooling -** chilled liquid between transparent plates (laser must pass through); Sapphire is used as it is a much better conductor than glass (thermal conductivity approaching that of metals).

3. **Dynamic Cryogen Cooling -** bursts of cryogen impacts on the skin, allowing evaporative cooling to take place milliseconds before the laser pulse. This method is able to achieve cooling of the tissue up to a depth and temperature of 1 mm and − 20°C, respectively.

LASER SAFETY

Laser safety encompasses several areas:

1. Adequate training
2. Medical surveillance
3. Laser Hazards Analysis
4. Provision of safe environment
5. Personal protective equipment

Table 2.2.

Biological Effects of Light of Different Wavelengths

Photobiological Spectrum	Effect on Eye	Effect on Skin
Ultraviolet B (280–315 nm)	Photokeratitis	Skin burn Accelerated skin aging Increased pigmentation
Ultraviolet A (315–400 nm)	Photochemical cataract	Pigment darkening Skin burn
Visible (400–780 nm)	Photochemical and thermal retinal injury	Photosensitive reactions
Infrared A (780–1400 nm)	Cataract, retinal burn	Skin burn
Infrared B (1400–3000 nm)	Corneal burn Aqueous flare Cataract	Skin burn
Infrared C (3000–10,000 nm)	Corneal burn	Skin burn

Laser Hazards

High-power laser beams may cause *skin burns, ignite flammable materials,* and heat materials that release *hazardous fumes, gases, or debris*. Increased risk of *carcinogenesis*, although not yet clinically proven, is an issue to consider with use of ultraviolet and near-ultraviolet wavelengths (e.g. 308 nm XeCl Excimer laser).

Laser hazards cathegories:

Beam-related hazards relate to the effects of the laser beam on the eye and skin. Acute exposure of the eye to lasers of certain wavelengths (e.g. 1064 nm Nd:YAG and 10,600 nm CO_2 laser) and power can cause corneal retinal burns or macular injury. Chronic exposure to excessive levels of laser light in the ultraviolet, visible, or infrared range may cause corneal opacities, cataracts, or retinal injury.

Non-beam hazards include electrical hazards, chemical hazards, fire hazards, and health hazards from inhalation of the *laser plume* generated while using ablative lasers, e.g. CO_2 or Herbium:YAG lasers. *Fire* hazard arises when all three elements of the fire triad are present: *fuel, oxidizer, and ignition*. Alcohol-based disinfectants and antiseptics are flammable. Oxygen provided during general anesthesia increases the risk. High-voltage pulse or flash lamps may cause ignition. Flammable materials may be ignited by direct beams or reflections from mirror-like surfaces

Laser emission wavelengths

Common Lasers and their Wavelengths

Laser Type	Examples	Wavelength	Target Chromophore
Carbon dioxide (CO_2)	Sharplan™ Ultrapulse™ SmartXide DOT™ Mixto SX™ Fraxel Re:pair™ Deep FX™	10,600 nm	Water
Erbium:YAG	Sciton Profile Contour™	2940 nm	Water
Erbium-doped fibre	Fraxel Re:store™	1550 nm	Water
Erbium-Glass	Lux1540 Fractional™ Mosaic™	1540 nm	Water
Q-switched Nd:YAG	Medlite™	1064 nm 532 nm (frequency-doubled)	Melanin Epidermal melanin
Long pulsed Nd:YAG	CoolGlide™ Sciton Profile Clearscan™ Gentle-YAG™	1064 nm	Melanin, hemoglobin
Diode	SmoothBeam™ ELOS e-Laser™	1450 nm 900 nm	Water Hemoglobin, melanin
Pulsed dye	V-Beam™	585, 595 nm	Hemoglobin, melanin

CO_2 laser surgery

Water in the target tissue absorbs the laser energy, heats up, boils, and vaporizes, taking the surrounding tissue with it.

$\mathbf{L_{extinction}}$ = 20-30 µm Approximately 90% of CO_2 laser energy is absorbed in the initial 20–30 µm of the skin. The **TRT** for 20–30 µm of skin tissue is approximately 1 ms.

Ablation threshold ≈5 J/cm^2 to vaporize tissue (energy fluence density)

Can one pass of the CO_2 laser will vaporize about 20–30 µm of skin?

Beyond zone of vaporization is a zone of necrosis due to heat conduction from the laser beam, reaching 1 mm CW or 40–120 µm for pulses.

1. **CW** In this mode, the laser acts as a **vaporization device** . CW mode is commonly used to ablate skin lesions such as epidermal nevi and viral warts.
2. **Pulse wave** The peak power per pulse is 2–10 times that of the continuous wave CO_2 laser but the average power over time is similar. In this mode, the laser acts as an **excision or cutting device** . The zone of necrosis is thinner compared to the continuous wave mode. Different laser companies use different terms for the pulse wave. The Ultrapulse TM (Coherent Medical) and Tru-Pulse TM (Palomar Medical) deliver 500 mJ at a pulse duration of 600 and 60 µs respectively ($t_{pulse} < TRT_{skin} \approx$ 1ms for minimal damage). The pulse mode may be selected to treat small skin lesions such as syringomas, small melanocytic nevi, excision of skin tissue and in skin resurfacing

CO_2 laser surgery

Side Effects and Complications

Post-inflammatory Hyperpigmentation

This tends to occur in the darker skin phototypes. Treating a test spot on a less conspicuous area on the body may help determine if this is likely to occur. Measures that can be taken to minimize this effect include pre- and post-treatment with broad-spectrum sunscreen, hydroquinone, tretinoin, and avoidance of sun exposure. Post-inflammatory hyperpigmentation tends to subside over a course of 4–6 months.

Epidermal Lesions

Epidermal nevus
Seborrheic keratosis
Viral warts — verruca vulgaris, plane warts

Dermal Lesions

Angiofibroma
Keloid
Rhinophyma
Melanocytic nevus — junctional, compound
Sebaceous hyperplasia
Syringoma
Xanthelesma

CO_2 laser surgery

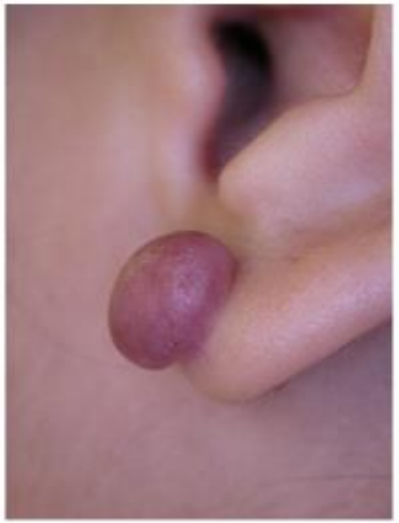


Figure 3.4.
Case 2. Keloid left earlobe.

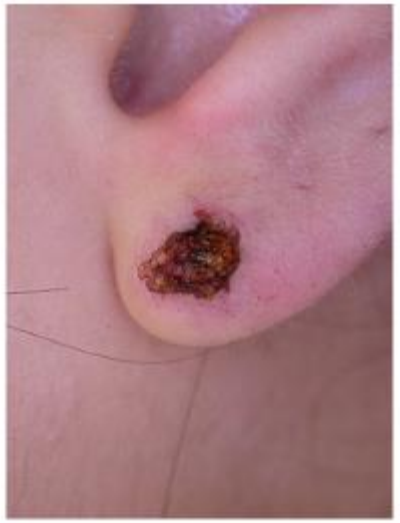


Figure 3.5.
Immediate post-operation.

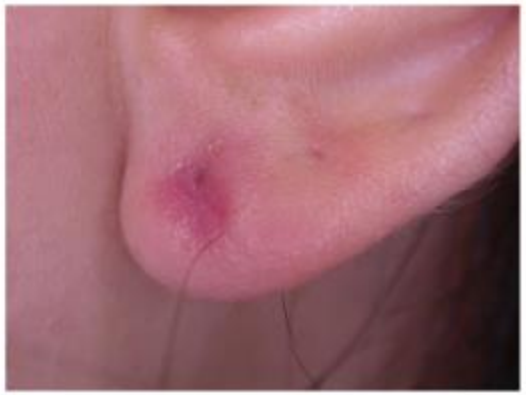


Figure 3.6.
One month post-operation.

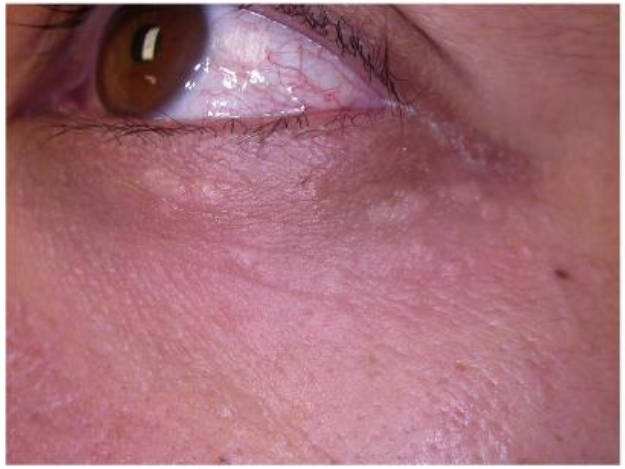


Figure 3.14.
Case 5. Syringomas left periorbital area.

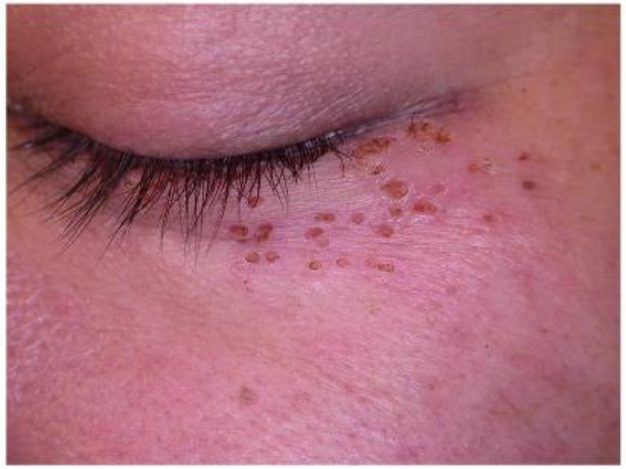


Figure 3.15.
Immediate post-operation.

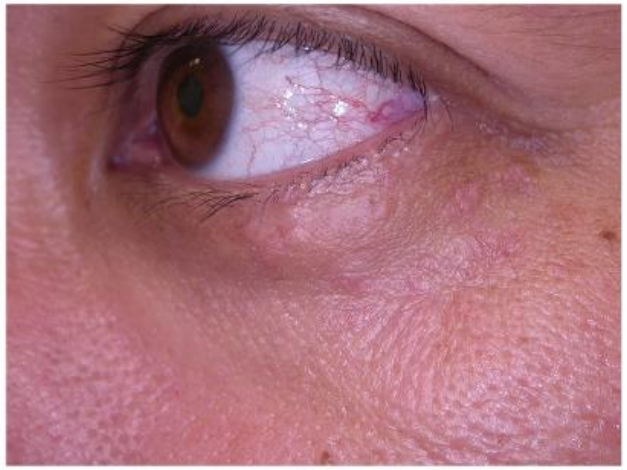


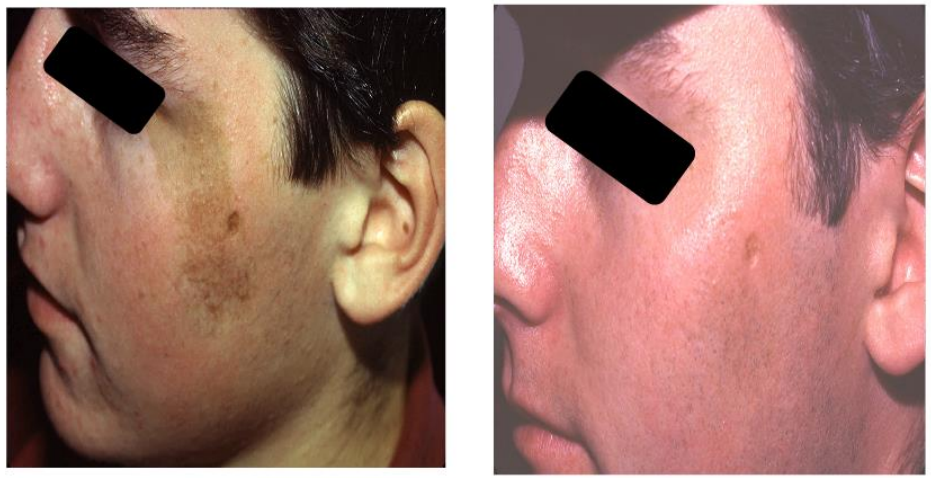
Figure 3.16.
One month post-operation.

Treatment of Pigmented Lesions

Various laser systems can be used to remove pigmented lesions. Melanin is the main chromophore and melanosomes, the organelle in which melanin is stored, are the primary target of laser-induced damage.

A selective window for targeting melanin lies between 600 and 1100 nm, where there is good skin penetration and greater absorption of melanin over oxyhemoglobin.

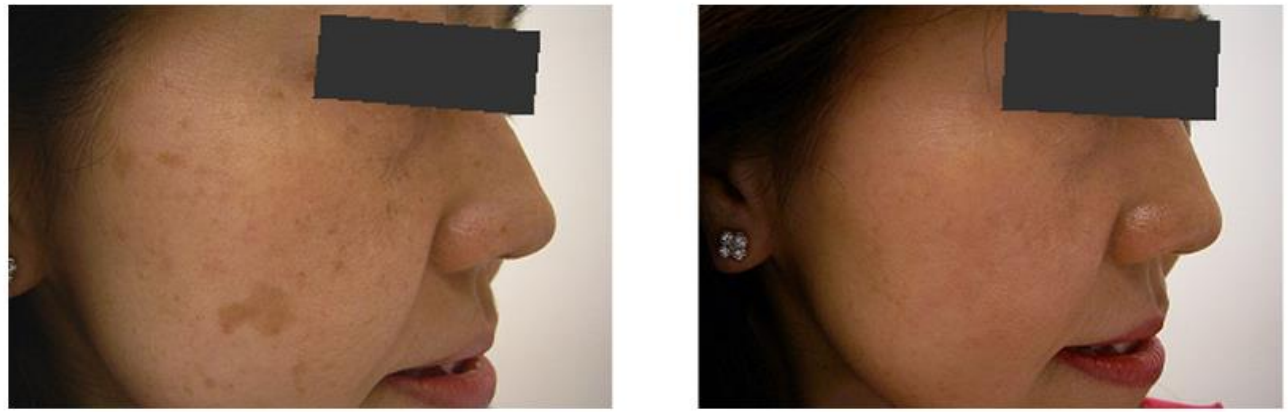
The thermal relaxation time of a melanosome is about 0.5–1 μs. According to the theory of selective photothermolysis, $t_{pulse} < TRT_{skin} \approx 1ms$ for confined injury. The Q-switched lasers, with their nanosecond pulse duration, can selectively target melanosomes and tattoo particles.



(a) (b)

Figure 5.5.

Case 5. Café-au-lait patch. (a) Before treatment. (b) After 5 treatments showing clearance: QS alexandrite laser: 3 m
7–9 J/cm^2. (Courtesy of Morelli JG, MD, Denver, USA.)



(a) (b)

Figure 5.2.

Case 2. Lentigines. (a) Before treatment. (b) After (QS 532 nm Nd:YAG laser).

Categories of Tattoos

Professional tattoos
- applied by registered artists using a tattoo machine or a tattoo gun
- composed of one or several colors of organometallic dyes (multiple pigments)
- large amounts of ink are uniformly injected into the dermis to create a sharp and clear image

Amateur tattoos
- made by individuals / friends jabbing ink, charcoal, or ashes under the skin with a pin (single pigment)
- usually appears gray or blue-black in color - not as sharp as a professional tattoo
- usually require fewer laser treatments to remove

Cosmetic tattoos
- performed in beauty parlors
- black, brown, and red inks employed as “permanent make-up” to create lipliner, eyeliner, and eyebrows, etc.

Traumatic tattoos
- occur during mechanical penetration of the skin by foreign body particles such as carbon-containing material, dirt, or other materials
- The ease of removal depends on the depth of the penetration of the substance.

Tattoo ink composition

Pigment bases

- Manufacturers are not required to reveal their ingredients (recipes are proprietary)
- Professional inks: iron oxides (rust), insoluble metal salts, or plastics. Homemade / traditional tattoo inks: pen ink, soot, blood, etc.
- Heavy metals used for colors include mercury (red); lead (yellow, green, white); cadmium (red, orange, yellow); nickel (black); zinc (yellow, white); chromium (green); cobalt (blue); aluminium (green, violet); titanium (white); copper (blue, green); iron (brown, red, black); and barium (white).
- Metal complexes used include ferrocyanide and ferricyanide (yellow, red, green, blue).
- Organic chemicals used include azo-chemicals (orange, brown, yellow, green, violet) and naptha-derived chemicals (red). Carbon (soot or ash) is also used for black.
- Other elements used as pigments include antimony, arsenic, beryllium, calcium, lithium, selenium, and sulphur.

Tattoo ink composition

Carriers

- A carrier acts as a solvent for the pigment, to “carry” the pigment from the point of needle trauma to the surrounding dermis. Carriers keep the ink evenly mixed and free from pathogens, and aid application.
- Ethanol (or methanol, rubbing alcohol, propylene glycol, and glycerine) also disinfects the skin and increases skin's permeability

Glow in the dark ink and blacklight ink

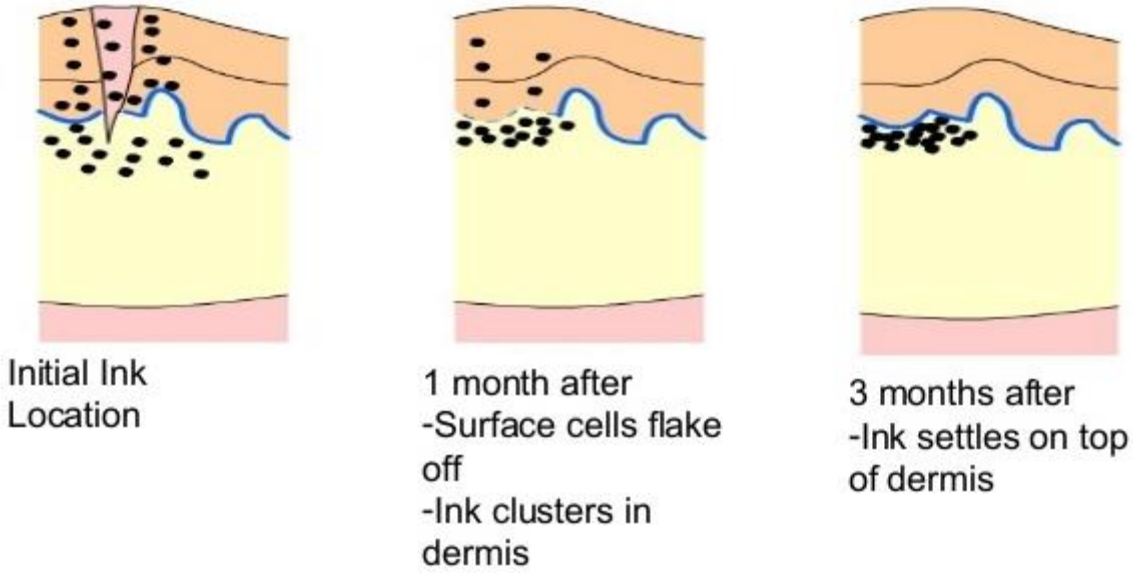
- Glow in the dark tattoo ink absorbs light and emit with very long lifetime (*long phosphorescence*, $minutes^{-1}$) to glow in darkened conditions.
- Blacklight ink emit via fluorescence (fast decay) does not glow in the dark.
- Photoactive materials (dye 2.5%) are embedded in PMMA microspheres for longer stability

Permanent Makeup

- Permanent Makeup or Semi-Permanent Makeup tattoos are cosmetic tattoos meant to alter pigmentation in the facial features.
- For medical conditions, such as to cover up scars or vitiligo
- For aesthetic reasons like tattooing eyeliner, lip color or eyebrows.
- Newer machines are needle-less which should result in less painful procedures, safer and more sterile.
- The needle-less device is also capable of inserting the pigment deeper into the skin than machines that use needles.

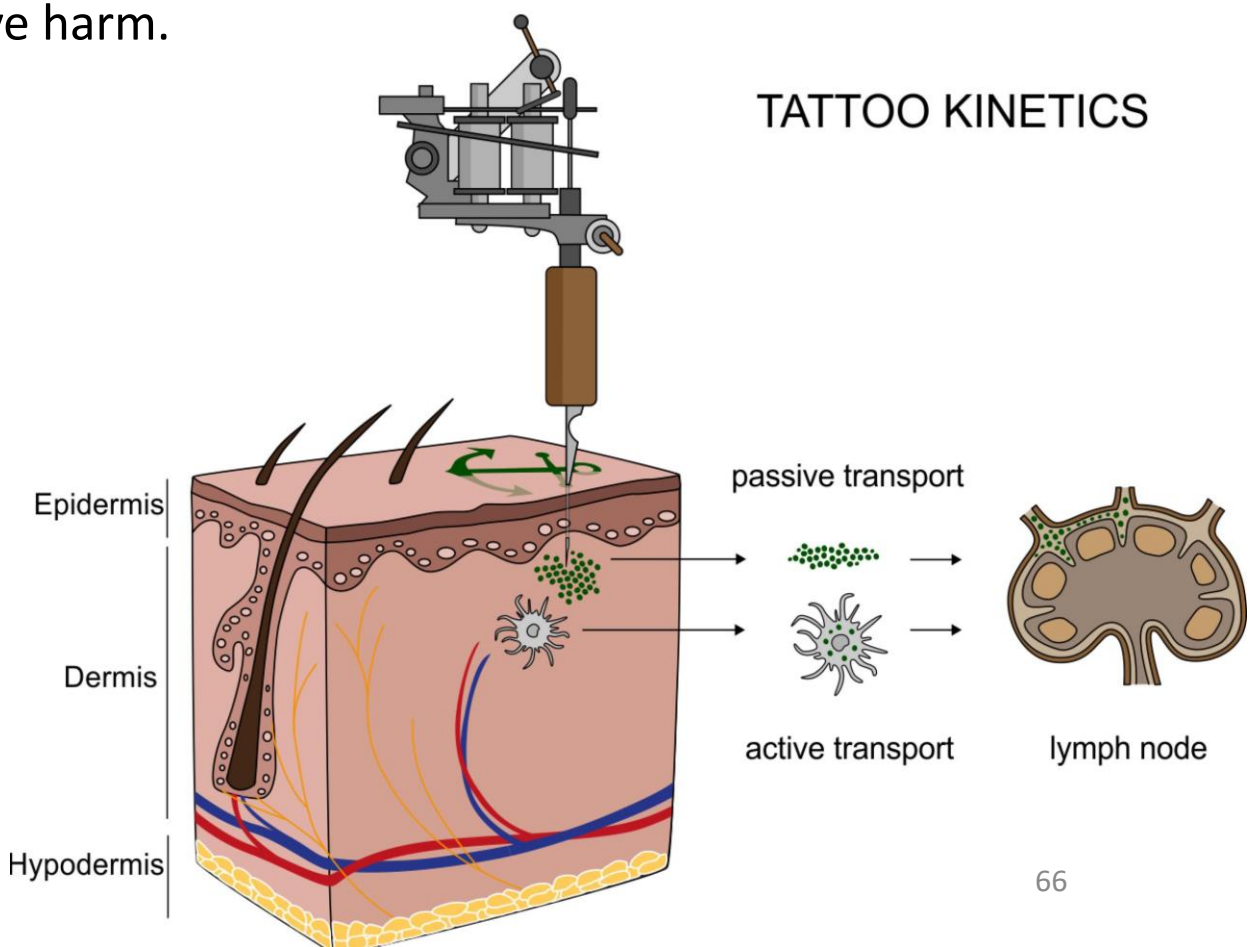
Physiological process of tattooing

- Tattooing involves the placement of pigment into the skin's dermis, the layer of dermal tissue underlying the epidermis.
- After initial injection, pigment is dispersed through the epidermis and upper dermis, the presence of foreign material activates the immune system's phagocytes to engulf the pigment particles.
- As healing proceeds, epidermis flakes away eliminating surface pigment, while deeper in the skin granulation tissue forms, later converted to connective tissue by collagen growth.
- Pigment remains trapped within fibroblasts, ultimately concentrating in a layer just below the dermis/epidermis boundary.
- In the long term (decades) pigment migrates deeper into the dermis (old tattoos degradation)



Health concerns

- A variety of medical problems, though uncommon, can result from tattooing
- Tattoo parlors in California must warn their patrons that tattoo inks contain heavy metals known to cause cancer, birth defects, and other reproductive harm.
- While care is often paid to the use of sterile needles, little attention is dedicated to the chemical composition of the colors
- The elements that make up the ink in tattoos travel inside the body in micro and nanoparticle forms and reach the lymph nodes



BEILSTEIN JOURNAL OF NANOTECHNOLOGY

Large deposits of dark ink particles distributed in a clumped manner in the dermis

Tattoo ink nanoparticles in skin tissue and fibroblasts

Colin A. Grant[*1,§], Peter C. Twigg[1], Richard Baker[2] and Desmond J. Tobin[2]

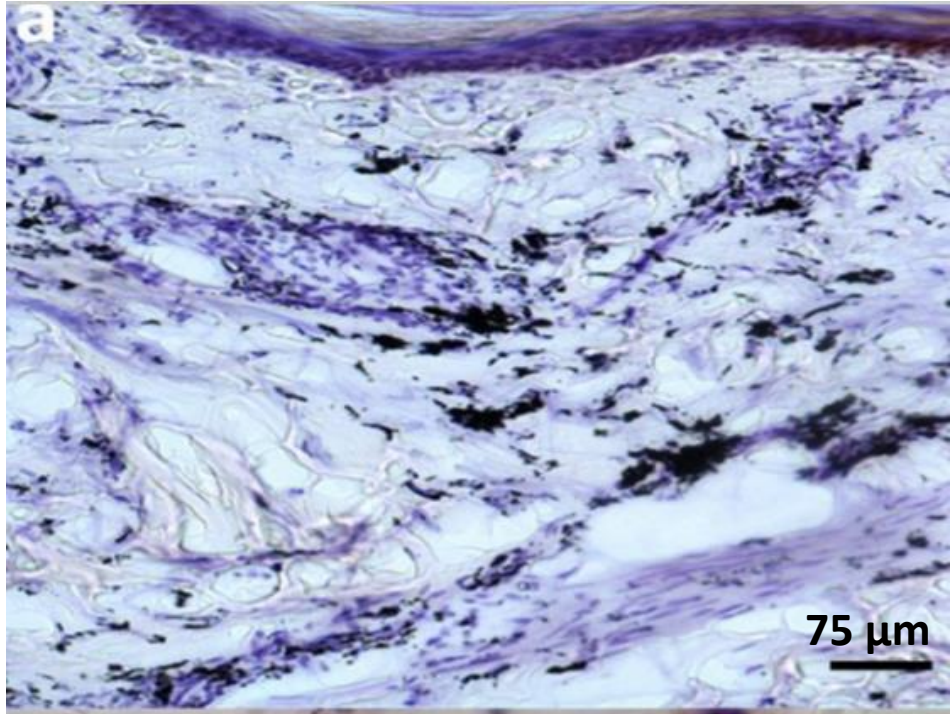
Tattoo ink suspensions unquestionably contain pigments composed of **nanoparticles**, i.e., particles of sub-100 nm dimensions.

It is widely acknowledged that nanoparticles have **higher levels of chemical activity** than their larger particle equivalents.

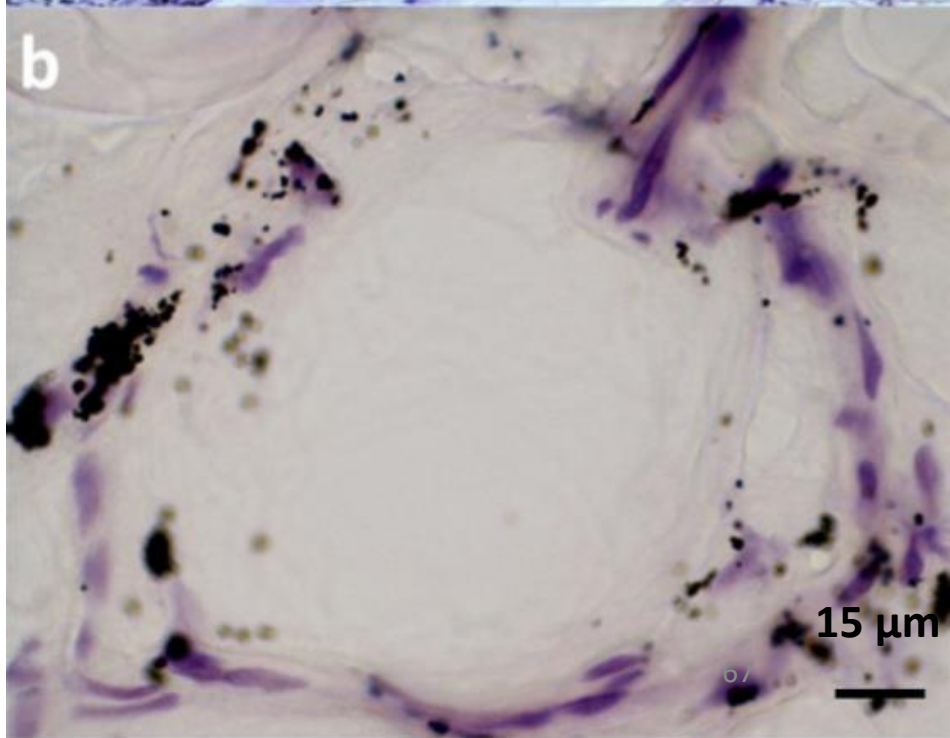
However, assessment of the toxicity of tattoo inks has been the subject of little research and ink manufacturers are not obliged to disclose the exact composition of their products.

This study examines tattoo ink particles by use of **atomic force microscopy and light microscopy**, to examine cryosections of tattooed skin, exploring the collagen fibril networks in the dermis that contain ink nanoparticles.

Light microscopy view of stained adult human tattooed arm skin



A deep dermal vessel with aggregations of ink particles in/around vessel wall and inside some associated cells.



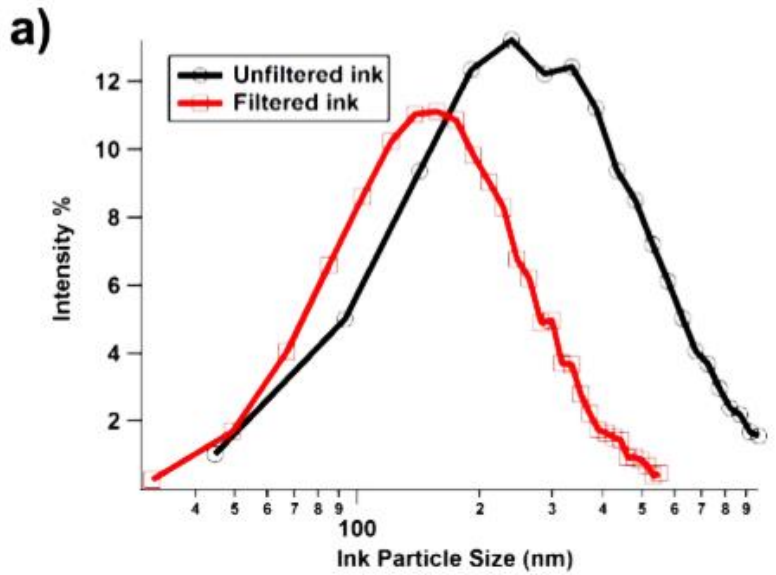


Figure 1: (a) Particle size distribution of filtered vs unfiltered commercially available tattoo ink, showing data ranging between 30 to 600 nm (filtered) and 40 to 970 nm (unfiltered). (b) Amplitude image of tattoo ink particles showing single and agglomerated particles adhered to a glass substrate.

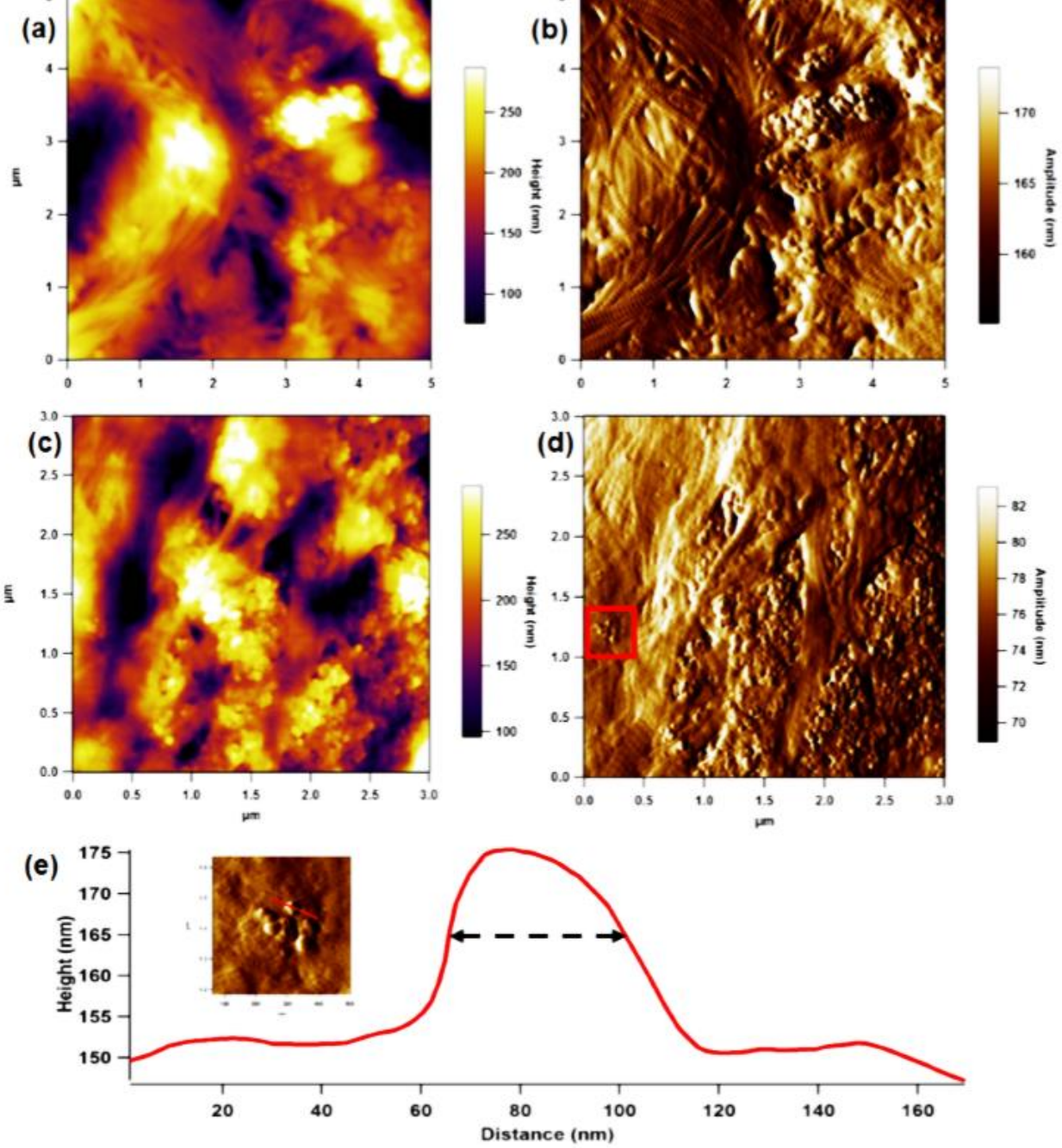
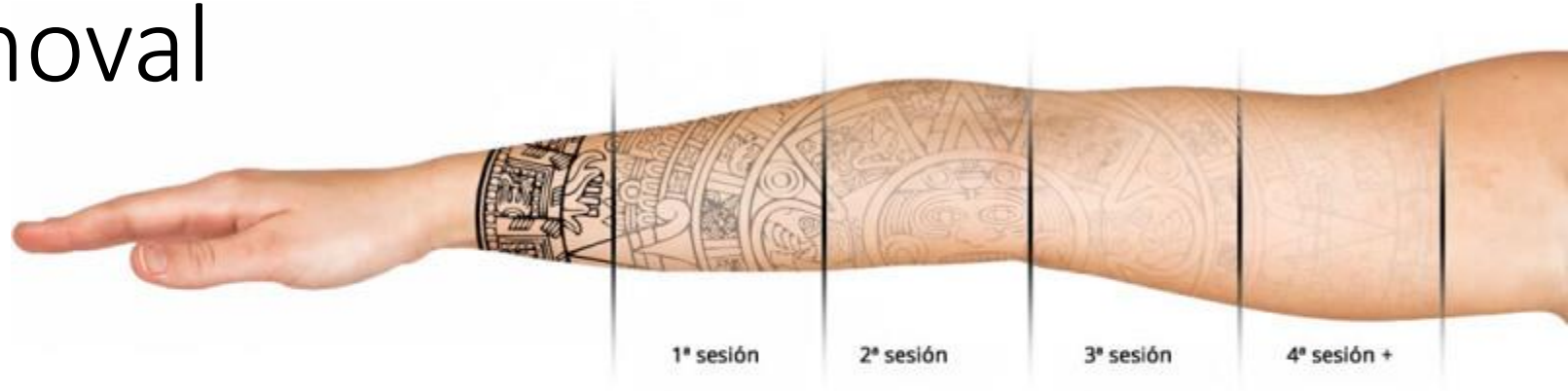
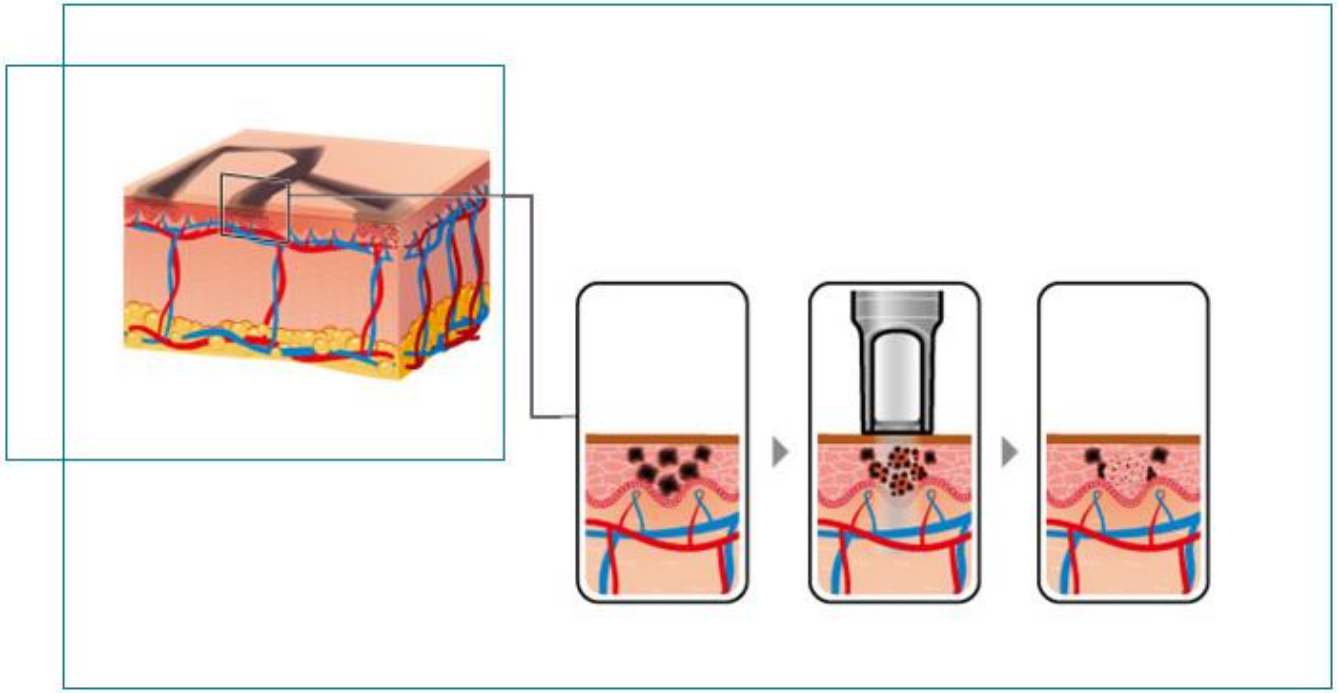


Figure 4: Height (a & c) and amplitude (b & d) images of disperse ink particles in the dermal collagen network. (Inset of (e)) 500 nm image of small cluster of ink particles from the solid red square (e) Line profile showing a particle of 37.5 nm width at half height.

Laser tattoo removal



The target for laser light consists of small particles of tattoo ink that are scattered extracellularly throughout the dermis.
These particles are too large to be removed from the skin.
Laser treatment causes tattoo pigment particles to heat up and fragment into smaller piecese, which can then be removed via normal body processes.



Tattoo Categorization

Tattoo Types	Pigment Type	Ink Concentration	Pigment Depth
Professional	Organometallic dyes	Dense	Deep
Amateur	India ink (carbon)	Sparse	Variable
Cosmetic	Iron or titanium oxide	Sparse	Superficial
Traumatic	Carbon, metals, dirt	Variable	Variable
Medicinal	India ink (carbon)	Sparse	Superficial

Laser Treatment Options for Various Tattoo Inks

		Response			
Laser Type	Parameters	Black Ink	Green Ink	Red Ink	Flesh-toned Ink
QS Ruby	694 nm 25–50 ns	Excellent	Good	Poor	Usually blackens
QS Alexandrite	755 nm 50–100 ns	Excellent	Excellent	Poor	Usually blackens
QS Nd:YAG	1064 nm 10 ns	Excellent	Fair	Poor	Usually blackens
Frequency-doubled Nd:YAG	532 nm 10–40 ns	Poor	Poor	Excellent	Usually blackens

Adapted from Alster TS, Lewis AB. (1996) Dermatologic laser surgery: A review. *Dermatol Surg* **22**, 797–805.

Laser Hair Removal

- Principle of selective photothermolysis
- Selective targeting of chromophore: melanin 600-1100 nm
- λ selection: long λ = higher penetration >> Q-switched Nd:YAG (1064 nm)
- Competing chromophores: **hemoglobin** (poor absorption), **epidermal melanin** (adverse effects > dependence on skin type)
- Hair cycle: Anagen phase – melanin production in the growing follicle

Skin color scale

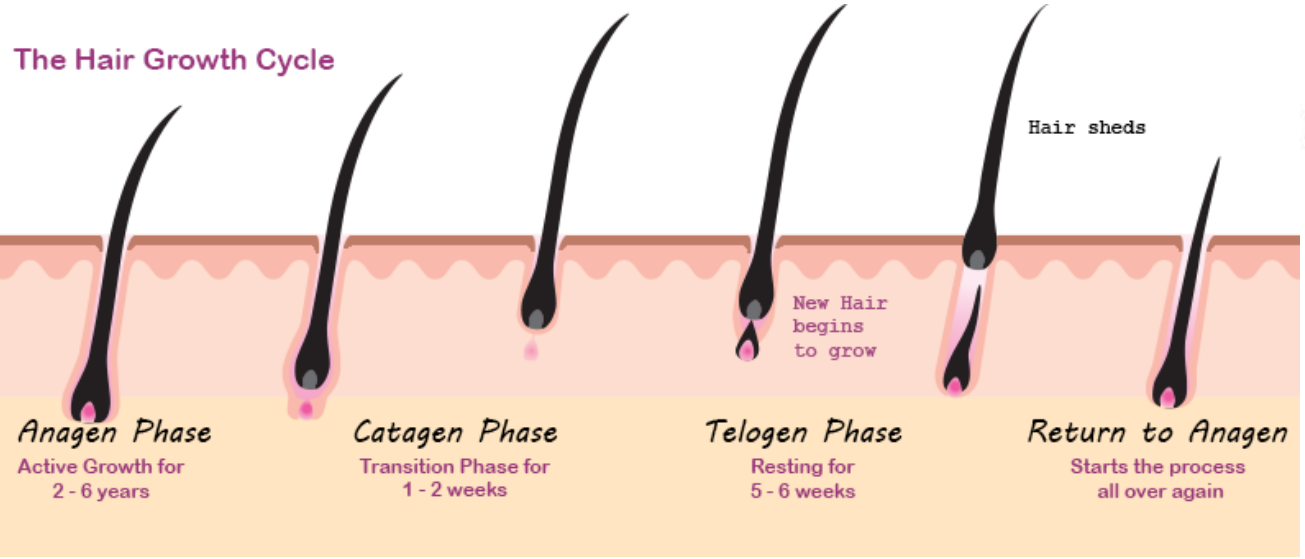
Fitzpatrick skin phototypes

Skin type	Unexposed skin color	Reaction to sun exposure*
I	White	Always burns, never tans
II	White	Always burns, minimal tan
III	White to olive	Burns minimally, gradually tans
IV	Light brown	Burns minimally, tans well
V	Brown	Very rarely burns, tans profusely
VI	Dark brown to black	Never burns, tans deeply

Note: Slight variations on the definitions of the phototypes appear in the literature.

* After the first one hour of sun exposure on untanned skin on the first day of spring.

Hair cycle



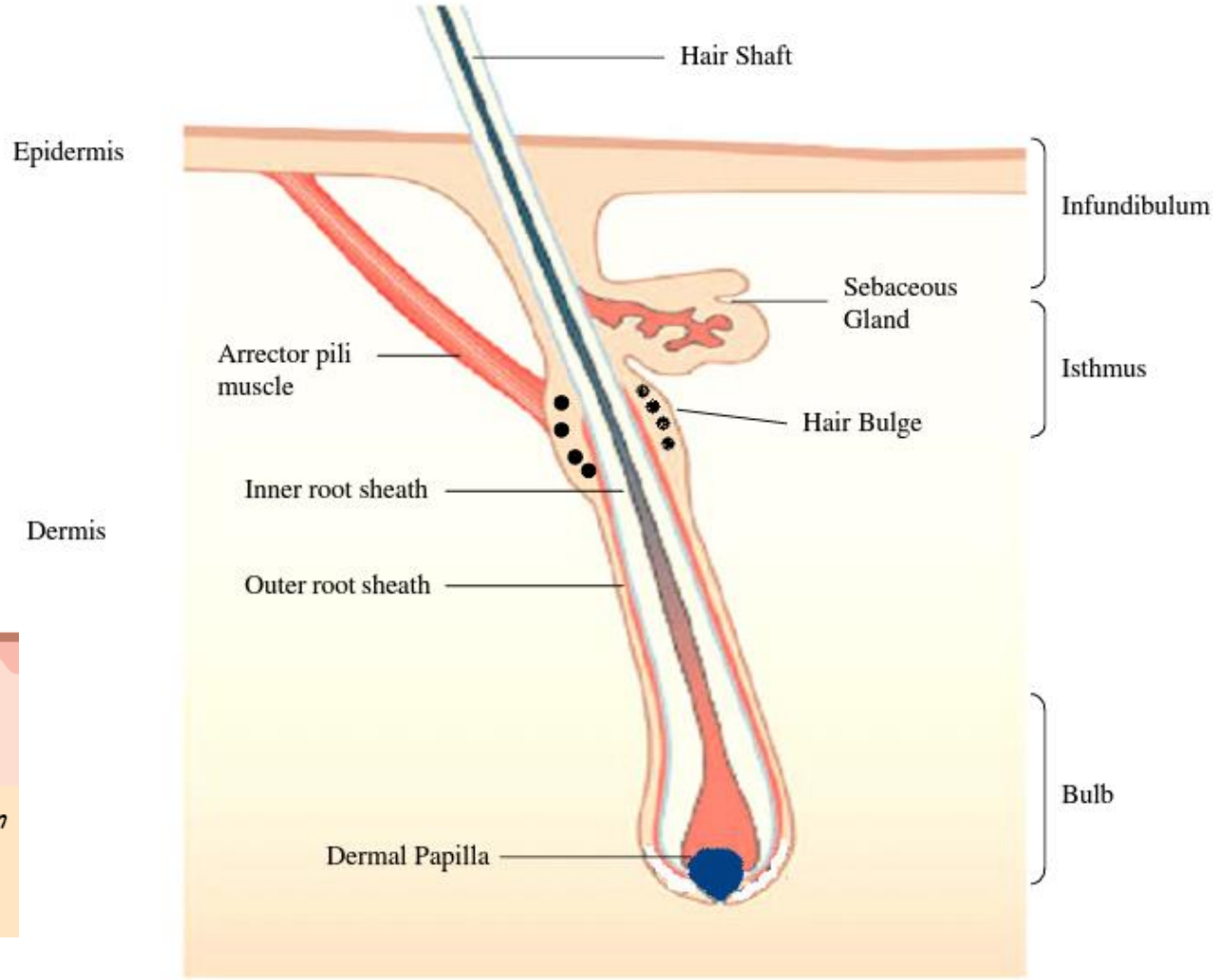
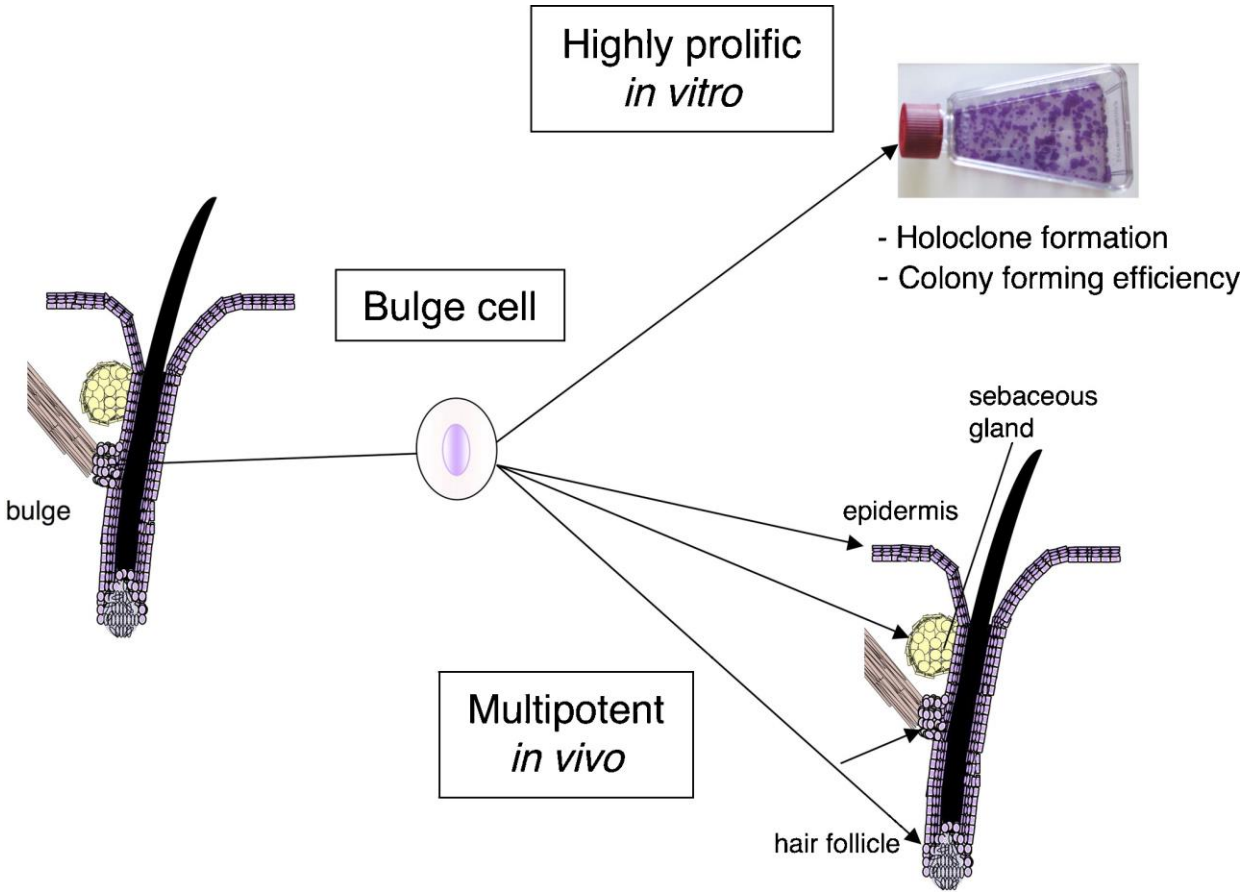


Figure 7.1.

Diagram of a hair follicle showing the position of the hair bulge.

Target: The Hair Bulge



Journal of Dermatological Science (2007) 46, 81–89

ELSEVIER

Journal of Dermatological SCIENCE

www.intl.elsevierhealth.com/journals/jods

INVITED REVIEW ARTICLE

Hair follicle bulge: A fascinating reservoir of epithelial stem cells

Manabu Ohyama *

Department of Dermatology, Keio University School of Medicine, 35 Shinanomachi, Shinjuku-ku, Tokyo 160-8582, Japan

- For effective longer lasting hair removal, it is the hair bulge that should be damaged.
- Follicular stem cells in the bulge are NOT PIGMENTED.
- Extended photothermolysis: pulses longer than TRT of the hair shaft (≈1 ms)
- Confinement of damage: pulses shorter that TRT of the hair follicle (10-100 ms)

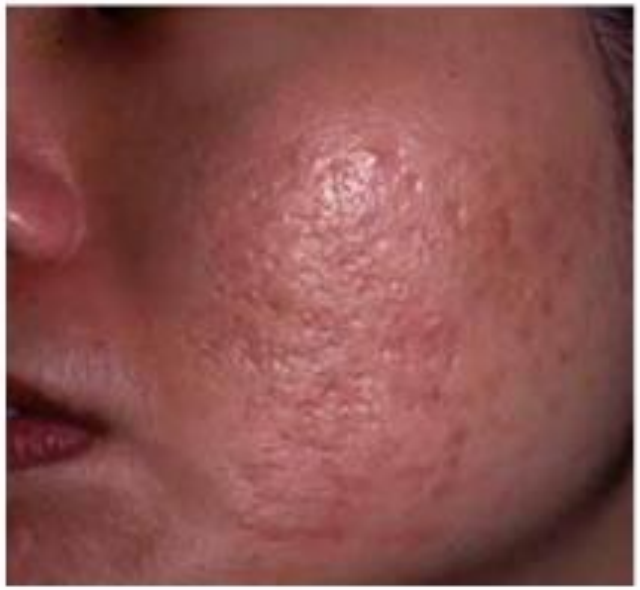
- Fluence (J/cm^2) limited by patient tolerance > skin color (epidermal melanins)
- Additional cooling helps

Laser Skin Resurfacing

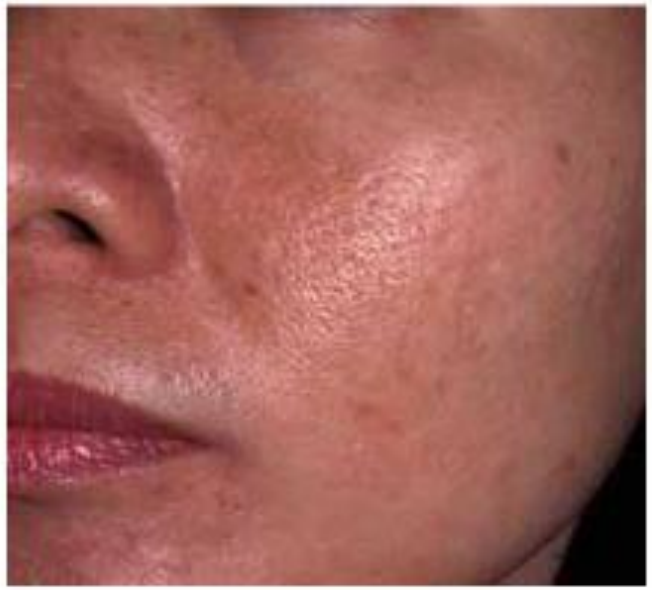
Wrinkles, dyschromia and telangiectasias are unwanted features of photoaging. Actinic keratoses and skin cancers may also result from photodamage. Scarring from severe acne, surgery, or trauma often becomes accentuated with aging. These skin changes cause disfigurement, often affecting the quality of life, and prompt patients to seek advice about treatment.

Skin rejuvenation treatments include topical retinoids, bleaching agents, chemical peeling, fractional photothermolysis, ablative laser resurfacing, and dermabrasion. In addition, some scars and wrinkles can be corrected by excision, subcision, and dermal fillers. These treatments are often used in combination to obtain optimal outcomes.

- Ablative laser resurfacing ablates the epidermis and portions of the superficial dermis and induces collagen remodeling in the deeper dermis
- It can reduce rhytides (wrinkles), dyschromia, vascular changes, and skin laxity.
- It is used to target the cutaneous signs of photodamage, progressively increasing with age.



Atrophic acne scars on cheeks



1 year post-ablative CO_2 laser resurfacing

Ablative laser resurfacing – a short history

- Technology for ablative laser resurfacing has continuously evolved from first use (1980s, CW CO_2 laser) >>> High risk of adverse effects
- **Pulsed** CO_2 lasers and **rapidly scanning** CW CO_2 lasers improved the safety of treatment
- In the 1990s the erbium:yttrium aluminum garnet (**Er:YAG**) laser was introduced: more precise control over the depth of cutaneous ablation, lower incidence of adverse effects.
- In the early 2000s, development of **fractional lasers**, which emit numerous narrow, microscopic columns of laser light. Fractional lasers treat only a defined fraction of the skin within a targeted area, leaving intervening areas of skin unaffected. The reservoir of undamaged skin adjacent to sites of laser injury allows for rapid reepithelialization after treatment through the migration of viable cells into wounded areas.
- Aside from the repair of photodamaged skin, ablative laser resurfacing is used for a variety of other indications, such as the treatment of scars, actinic keratoses, epidermal nevi, and other cutaneous lesions and disorders. Nonablative traditional and fractional lasers also have been studied for facial rejuvenation; however, these lasers generally are less efficacious than their ablative counterparts for this indication

TRADITIONAL ABLATIVE LASERS

The traditional ablative lasers used for skin rejuvenation include the 10,600 nm pulsed and rapidly scanning CO_2 lasers and the 2940 nm pulsed Er:YAG laser.

Mechanism of action for efficacy ablative lasers in skin rejuvenation > selective photothermolysis; target: water;

- The wavelength of light utilized should be absorbed preferentially by light absorbing molecules (chromophores) in the target and must penetrate the skin sufficiently to reach its depth.
- The light must be delivered in a period of time that is short enough to prevent the transfer of excessive heat to adjacent structures.
- The energy delivered per unit area (fluence) must be sufficient to exert the desired therapeutic effect, but should also be at a level that minimizes undesired collateral tissue damage.

Photoablation: absorption of light > rapid accumulation of heat > vaporization of the epidermis.

TRADITIONAL ABLATIVE LASERS in skin resurfacing

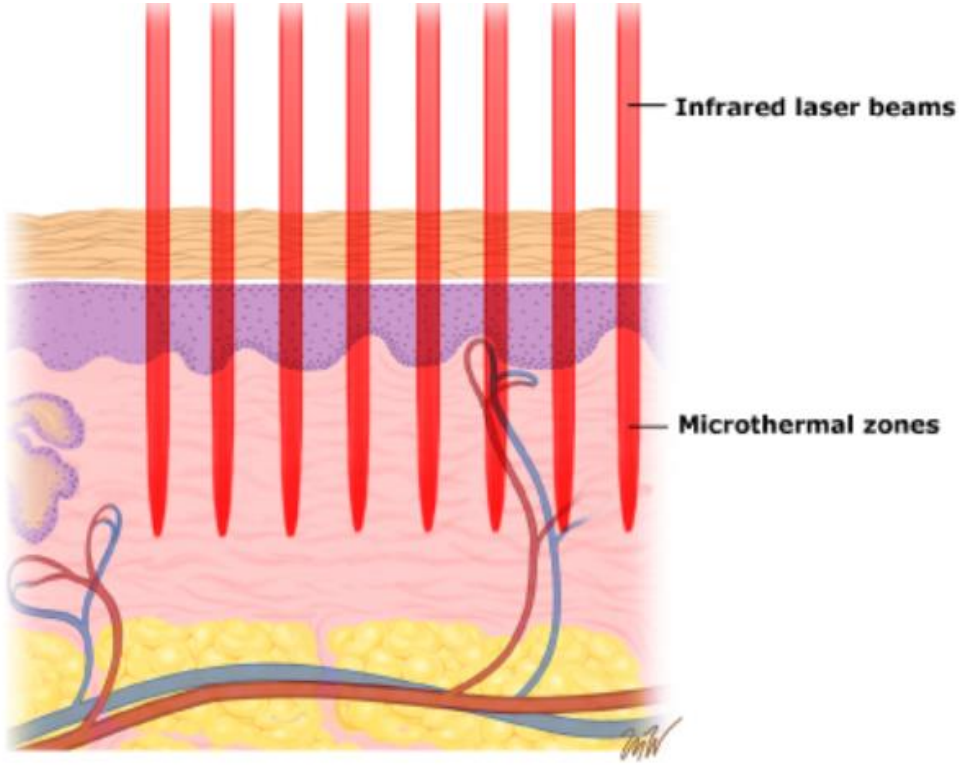
- The depth of light absorption into the skin generally rises with increasing light wavelengths. However, because light emitted by CO_2 and Er:YAG lasers is highly absorbed by water in the epidermis, little light reaches deeper levels of the skin. At a setting of 5 J/cm^2 and a pulse duration of less than 1 ms, light from the CO_2 laser penetrates to a depth of approximately 20 to 30 micrometers. Water molecules have an even greater extinction coefficient at wavelengths emitted by Er:YAG lasers, which reaches depths of only 1 to 3 micrometers.
- Residual thermal damage reaches depths of 100 to 150 micrometers with CO_2 lasers and 10 to 40 micrometers with ER:YAG lasers.
- The heat transferred to underlying dermal collagen is believed to contribute to collagen contraction and remodeling as well as clinically evident skin tightening.
- Excessive transfer of heat to the dermis can lead to adverse effects such as scarring and permanent hypopigmentation.
- CO_2 lasers appear to have a greater effect on skin tightening, possibly related to greater transfer of heat to underlying dermal collagen during irradiation with the CO_2 laser.
- However, CO_2 laser resurfacing is associated with a relatively longer recovery period, higher risk for scarring and dyspigmentation, and a longer period of persistent erythema after treatment.
- Due to an elevated risk for dyspigmentation in patients with dark skin, CO_2 laser is typically limited to resurfacing patients with skin phototypes I to III.

ABLATIVE FRACTIONAL LASERS

The relatively long recovery period required for CO_2 laser resurfacing and its associated adverse effects stimulated the search for alternative methods for laser skin rejuvenation. Ablative fractional photothermolysis is a newer form of laser therapy with relevant advantages over traditional ablative laser resurfacing.

Mechanism — Similar to traditional ablative lasers, the target chromophore for fractional lasers is water. The ablative fractional lasers include the 2940 nm fractional erbium:yttrium aluminum garnet (Er:YAG) laser, the 2790 nm fractional yttrium scandium gallium garnet (YSGG) laser, and the 10,600 nm fractional CO_2 laser.

Fractional lasers deliver a multitude of narrow columns of laser light to the skin, resulting in the creation of numerous microscopic vertical zones of thermal damage called **microscopic thermal zones (MTZs).** MTZs are usually less than 400 micrometers in diameter and up to 1300 micrometers deep; the type of fractional laser and specific laser settings determine the size of the MTZ.



Fractional photothermolysis involves the delivery of narrow columns of infrared light to the target tissue. In skin, this leads to microscopic columns of thermally damaged tissue (microthermal zones).

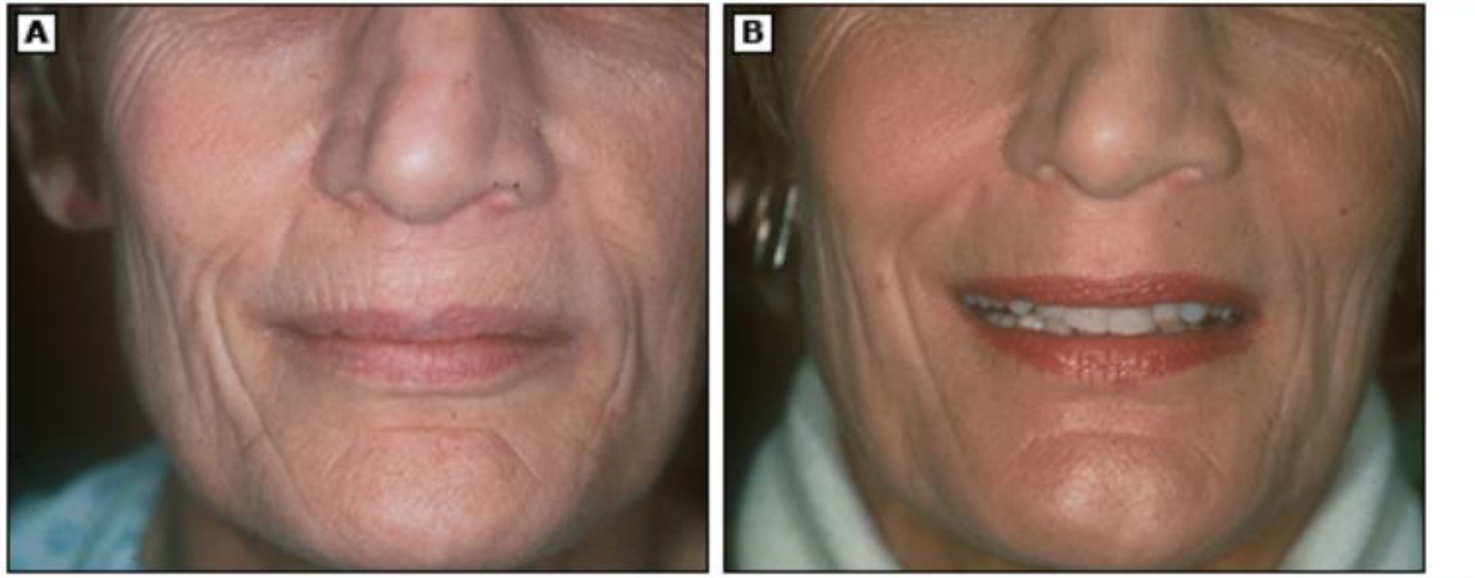
ABLATIVE FRACTIONAL LASERS

The **undamaged surrounding skin** immediately adjacent to an MTZ serves as a **reservoir of viable tissue**, permitting the **rapid repopulation of the epidermis** observed after fractional laser therapy. Reepithelialization typically occurs within a few days. In contrast, reepithelialization after traditional laser ablation is dependent on migration of epidermal cells from adnexal structures.

Skin tightening effect also occurs after treatment with ablative fractional lasers; both immediate and delayed collagen contraction and collagen remodeling may contribute to improvements in skin laxity

Nonablative fractional lasers have also been used for skin rejuvenation, but are less effective for this indication.

Improvement in facial wrinkles following ablative fractional laser resurfacing



This patient was treated with a fractional carbon dioxide laser for facial wrinkles. She is shown before (A) and after treatment (B).

ABLATIVE FRACTIONAL LASERS

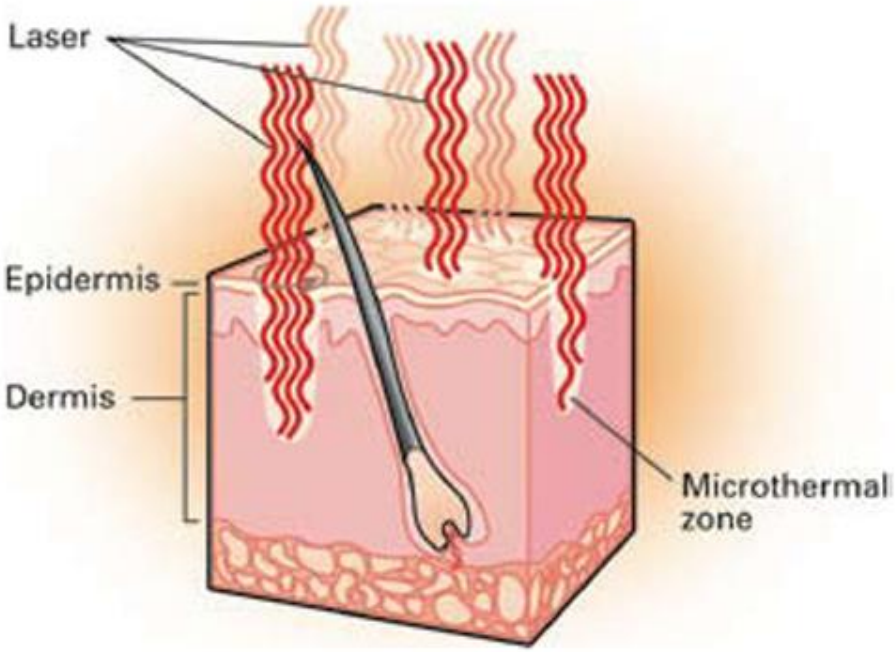


Figure 10.1.

Fractional photothermolysis is a novel concept of delivering laser energy to the skin via microbeams to induce thermal injury to the epidermis and underlying dermis in strictly confined microscopic zones rather than in broad macroscopic and confluent zones.

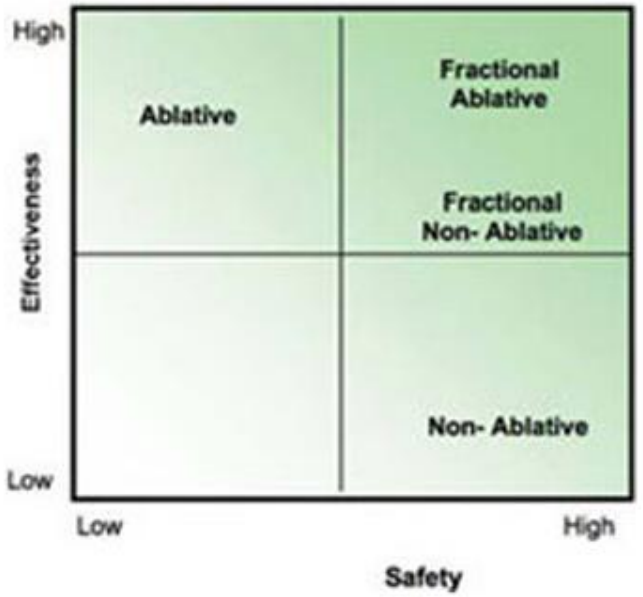


Figure 10.2.

Comparative safety and efficacy of skin rejuvenation technologies.

Lumenis
Energy to Healthcare

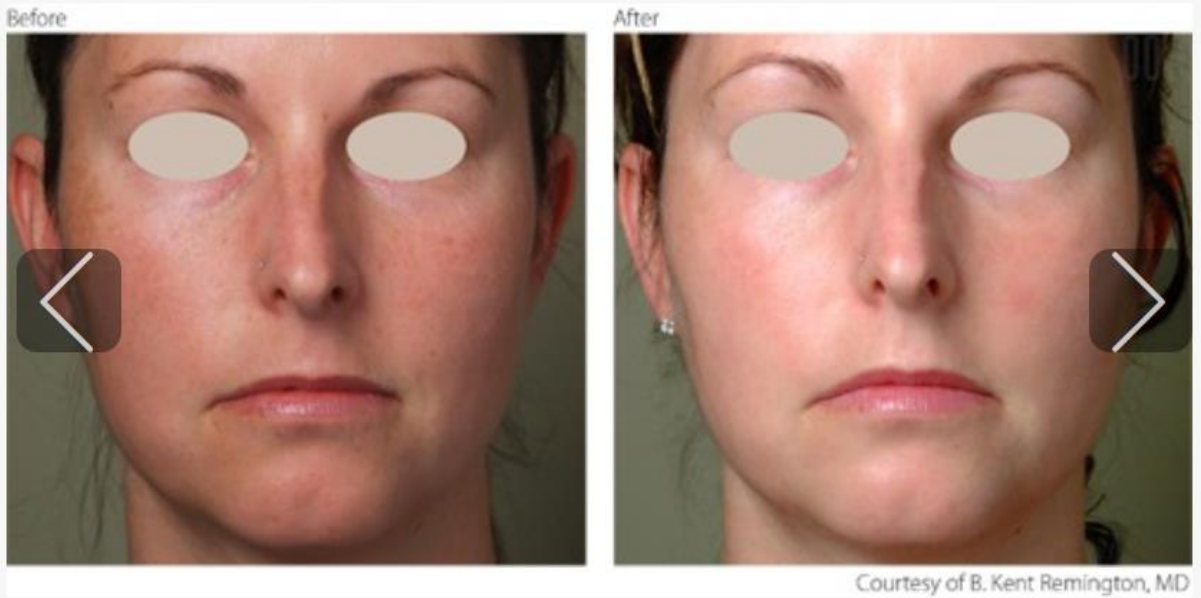
Medical | Aesthetics | Service | Patients | About | Contact

Photorejuvenation | Non-ablative skin resurfacing | Photoacoustic skin rejuvenation | Ablative skin resurfacing | RF skin rejuvenation | Blepharoplasty

Photorejuvenation

Photorejuvenation refers to the use of Intense Pulsed Light (IPL) to treat conditions related to sun-induced skin damage and vascularity issues. IPL uses a broad spectrum of light which is primarily absorbed by melanin and oxyhemoglobin and effectively reduces the appearance of sun spots, capillaries, and elastosis, and builds collagen.

IPL was invented by Lumenis and is still considered the gold standard for photorejuvenation treatments. Available through our technologically advanced and highly versatile M22™ platform, Lumenis IPL with Optimal Pulse Technology (OPT™) enables delivery of high peak power with shorter pulses, ensuring homogeneous fluence delivery along the pulse duration. The efficacy of IPL with OPT™ has been proven in over 80 peer reviewed papers.



More about Photorejuvenation treatment

GET MORE INFO

//lumenis.com/

IPL (Intense Pulsed Light)

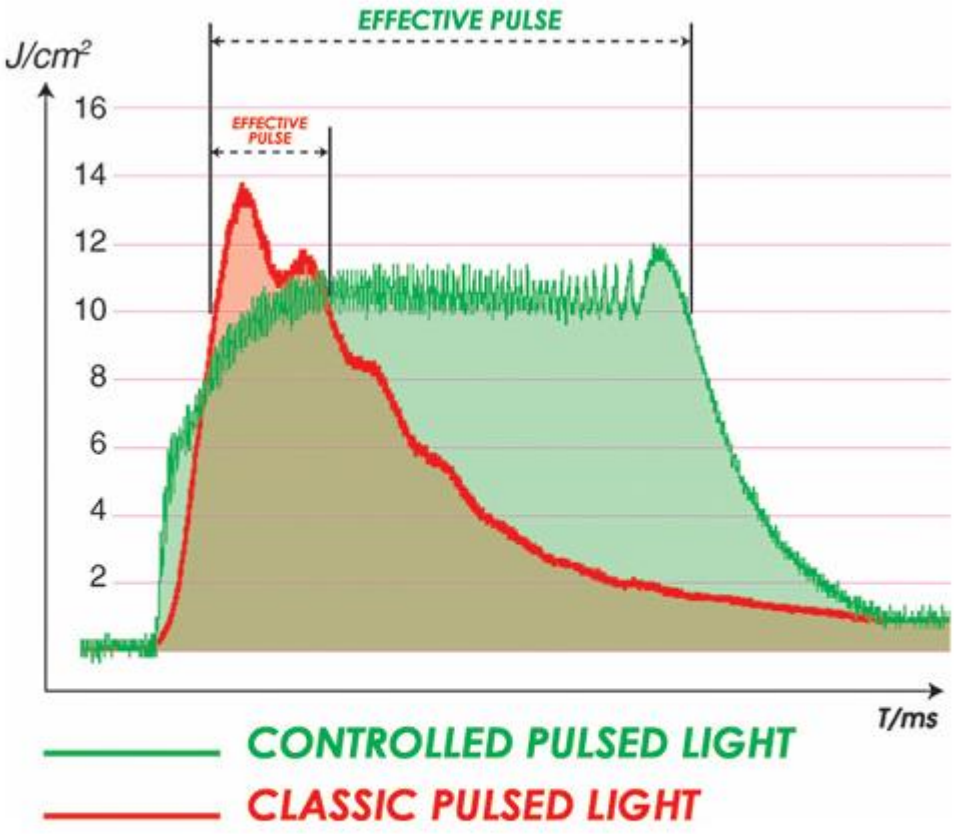


Figure 11.1.

The classic sigmoidal shaped beam profile and the square-shaped beam profile.

What Is IPL?

Intense Pulsed Light (abbreviated IPL) describes the use of intense pulses of non-coherent light distributed over a range of wavelengths; from 400nm to 1200nm. The technology utilizes specific wavelength ranges to target various chromophores in the skin. This enables effective treatment of a broad spectrum of conditions, including vascular and pigmented lesions, skin photoaging treatments and hair removal.

How Does IPL Works?

Broad spectrum pulsed light is transmitted through a continuously cooled applicator, gently placed over the skin. Cut-off filters in the handpiece change the range of wavelengths, optimizing it for different applications and skin types. The light penetrates the tissue and is absorbed by either the relevant chromophores and damages them (blood chromophores when treating vascular lesions and melanin chromophores when treating pigmented lesions). The body's natural processes then clear the lesion debris, giving the skin a more even and youthful appearance.

Common Skin Flaws

Good skin care practices can help to maintain firm, smooth, and healthy skin. Eventually, though, **time and sun exposure** take a toll on the skin's appearance. Some common skin flaws are the result of genetics, viruses, and other causes.

- One of the most common facial skin problems for adolescents is **acne**, a troubling skin condition that can affect confidence and self-esteem. As sebaceous glands become overactive and produce excess oil, follicles become plugged, resulting in blackheads and whiteheads. These plugged follicles can then become inflamed, causing pimples, nodules and cysts. Although acne is not harmful to health and will usually go away after time, moderate to severe acne can leave scars.

- **Hyperpigmentation** refers to brownish patches that appear on the skin as a person ages or as a result of acne. The condition can be worsened either sun damage or genetics. Although they are not harmful, many people wish to have them removed for cosmetic reasons.

- **Large Pores:** Pores are the tiny openings in the surface of the skin through which moisturizing oils are released. When pores on the face are large enough to be visible, they can cause frustration as well as facial skin problems. To some degree, pore size is hereditary, but pores also appear larger when they contain trapped oil and skin cells.

Common Skin Flaws

- Characterized by facial redness and swelling, **rosacea** is a facial skin problem that usually afflicts adults with fair skin. It can appear at any age. Rosacea usually develops slowly at first, appearing periodically as a facial flush. The condition worsens over time and rarely resolves on its own.

- A **scar** is an area of skin that is a different color or texture from surrounding skin that results after an injury heals. Although most scars fade over time, certain types and those that occur in noticeable areas may remain apparent for a lifetime.

- **Undereye Circles:** Darkened skin beneath the eyes is a common skin problem caused by factors such as heredity, lack of sleep, allergies, diet, and sun exposure. In many cases, the darkened circles can be reversed by resolving the underlying cause, or they can be concealed with cosmetics.

- **Wrinkles** and lines on the skin are among the most common facial skin problems for women and men as they age. Lines and wrinkles appear where skin naturally folds and creases, becoming more and more permanent as time goes on. Sun exposure, smoking, and extreme dieting can hasten this effect, making skin look older than it is.