



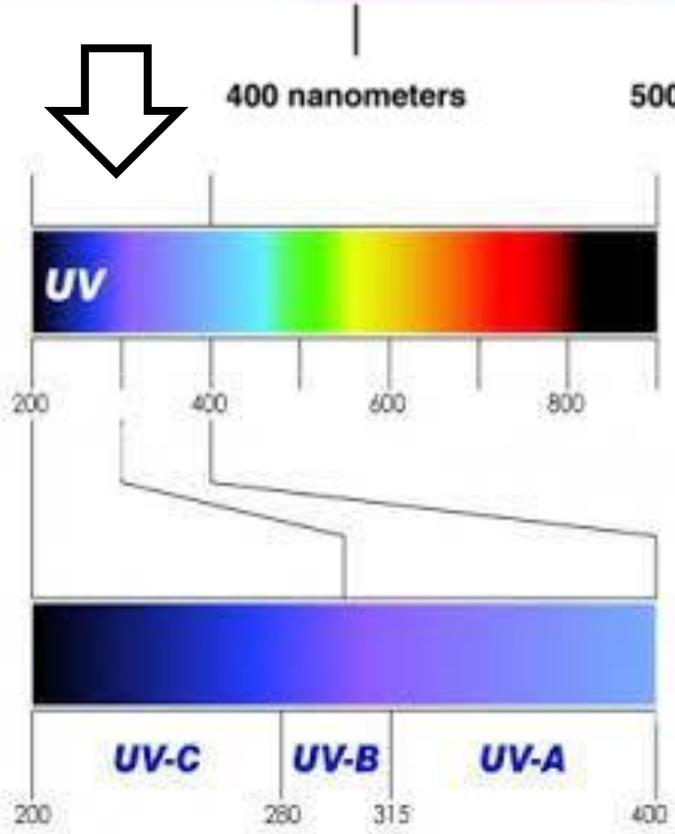
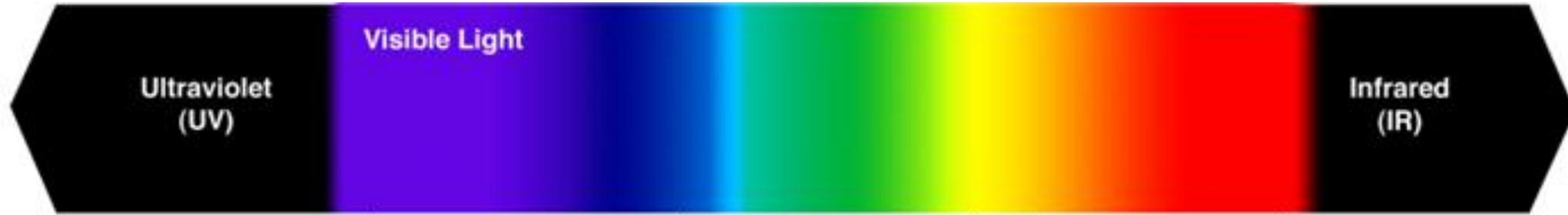
Biological effects of light

Haluszka Dóra

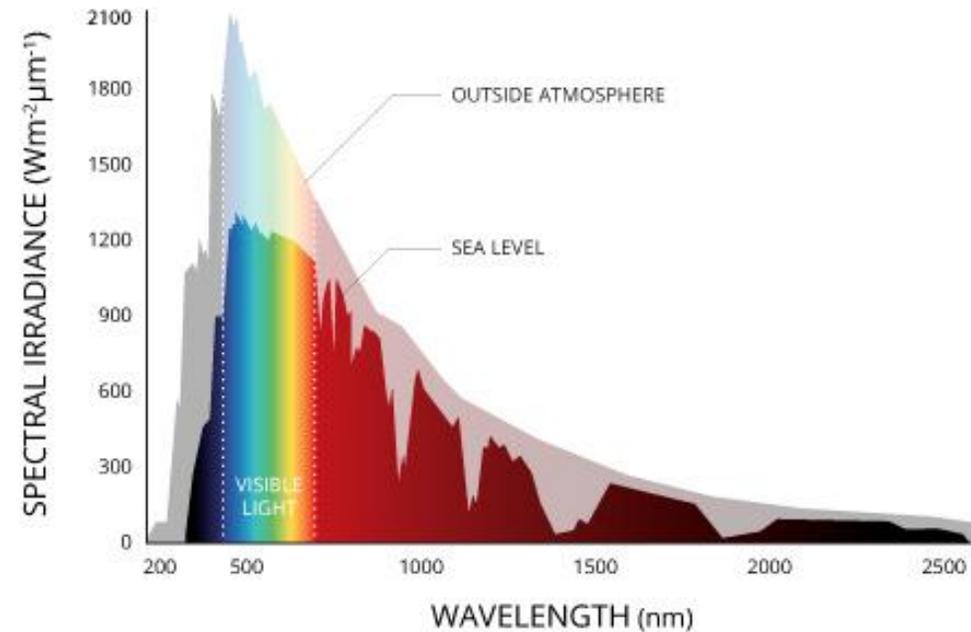
11/11/2022



Optical regions of electromagnetic spectrum



Emission spectrum of the Sun



Steps leading to photobiological alterations

Photophysical processes
(absorption of light)



Photochemical reaction



Photobiological
processes/consequences

Absorption of light is a precondition of photobiological processes!

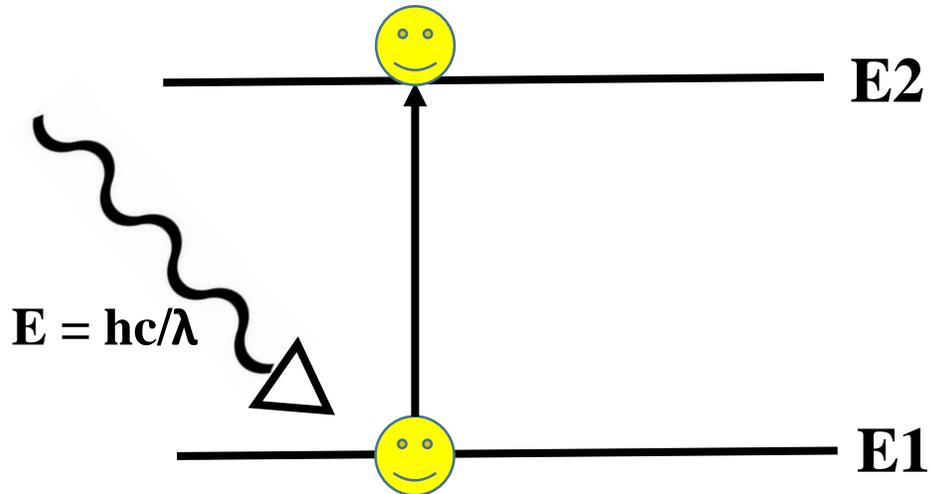
Precondition of light absorption

Absorbing atom/molecule

Proper wavelength



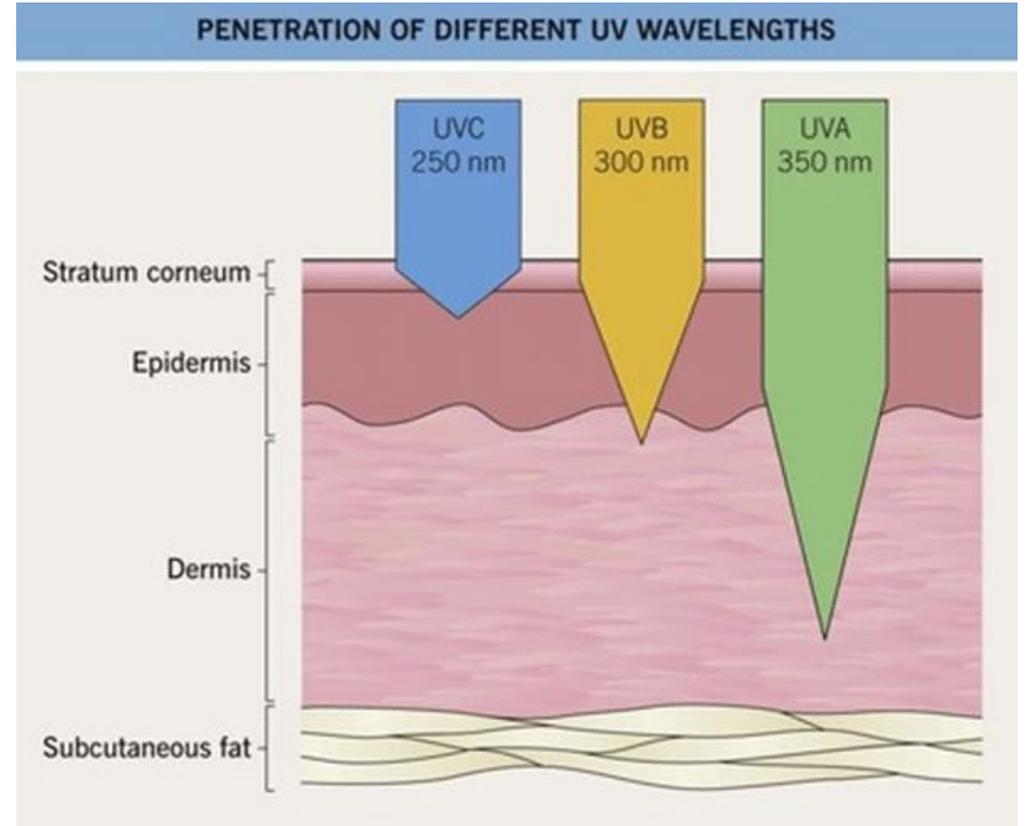
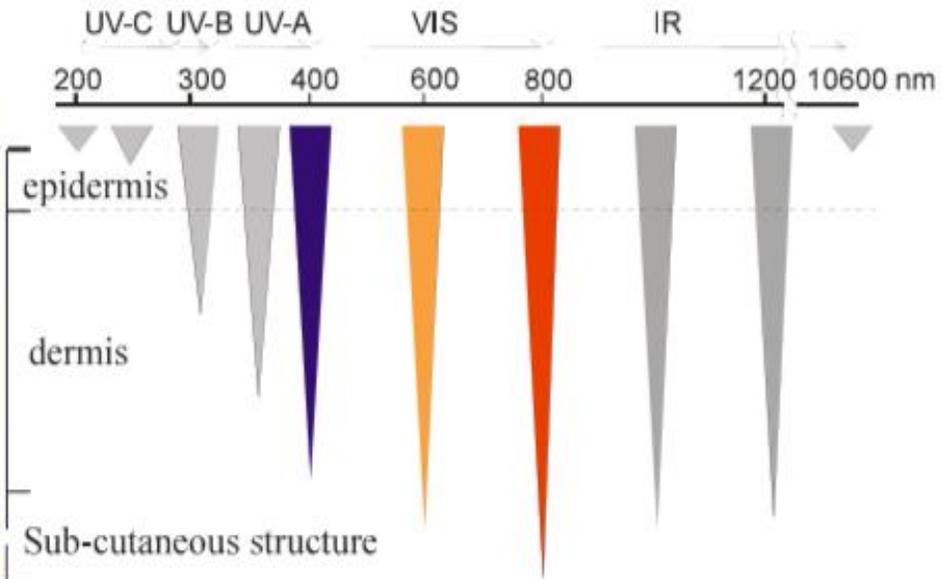
matching



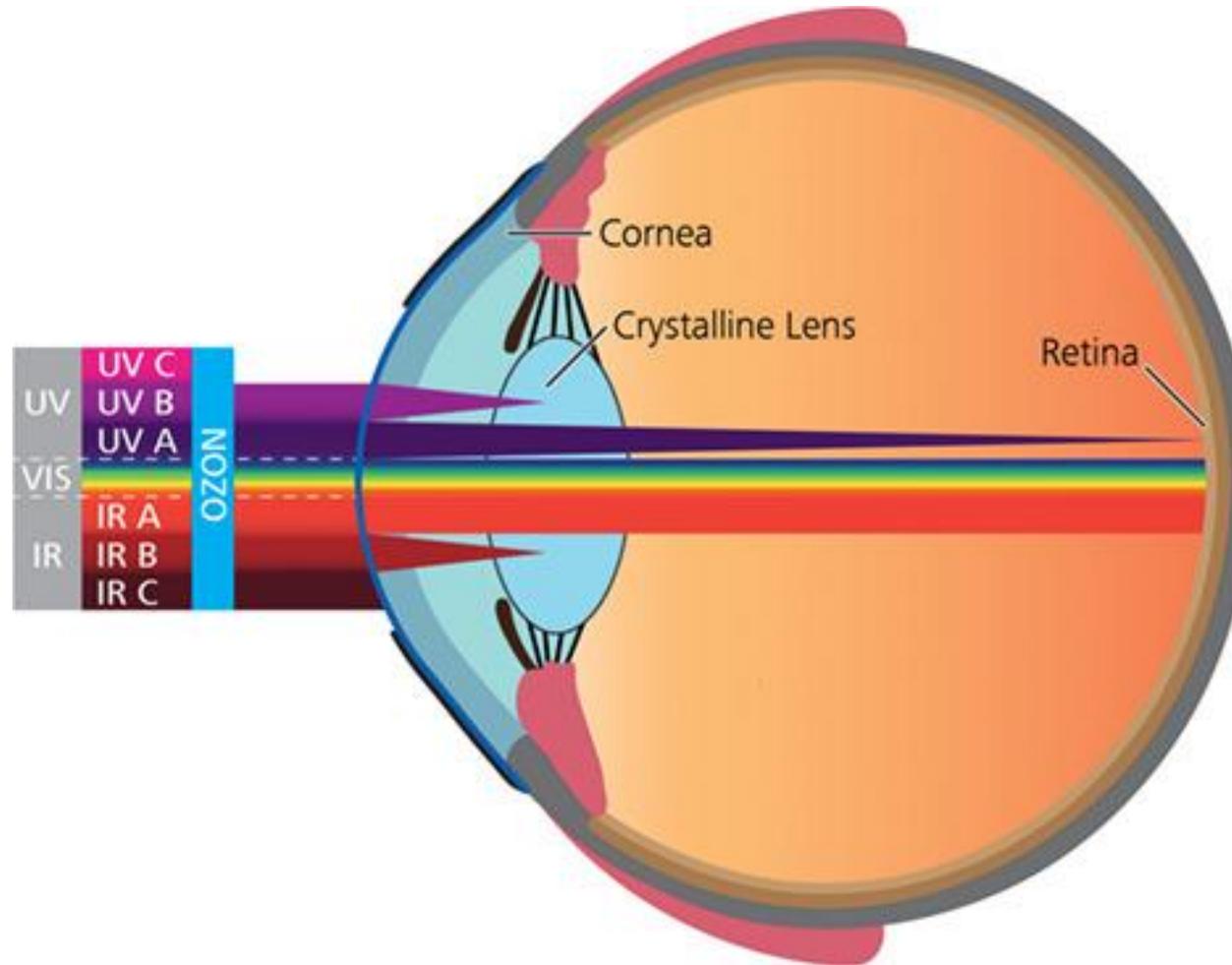
Important rule: the energy of incident photon must be equal to excitation energy!

$$E_2 - E_1 = \frac{hc}{\lambda}$$

Light penetration in the skin



Light penetration in the eye



The penetration ability of light highly depends on its wavelength
(absorption, reflection)

Light absorbers (chromophores) in human tissues

Endogenous chromophores

Nucleic acids

Proteins

Nucleotids (NADH, ATP)

Flavonoids

Melanin

Opsins

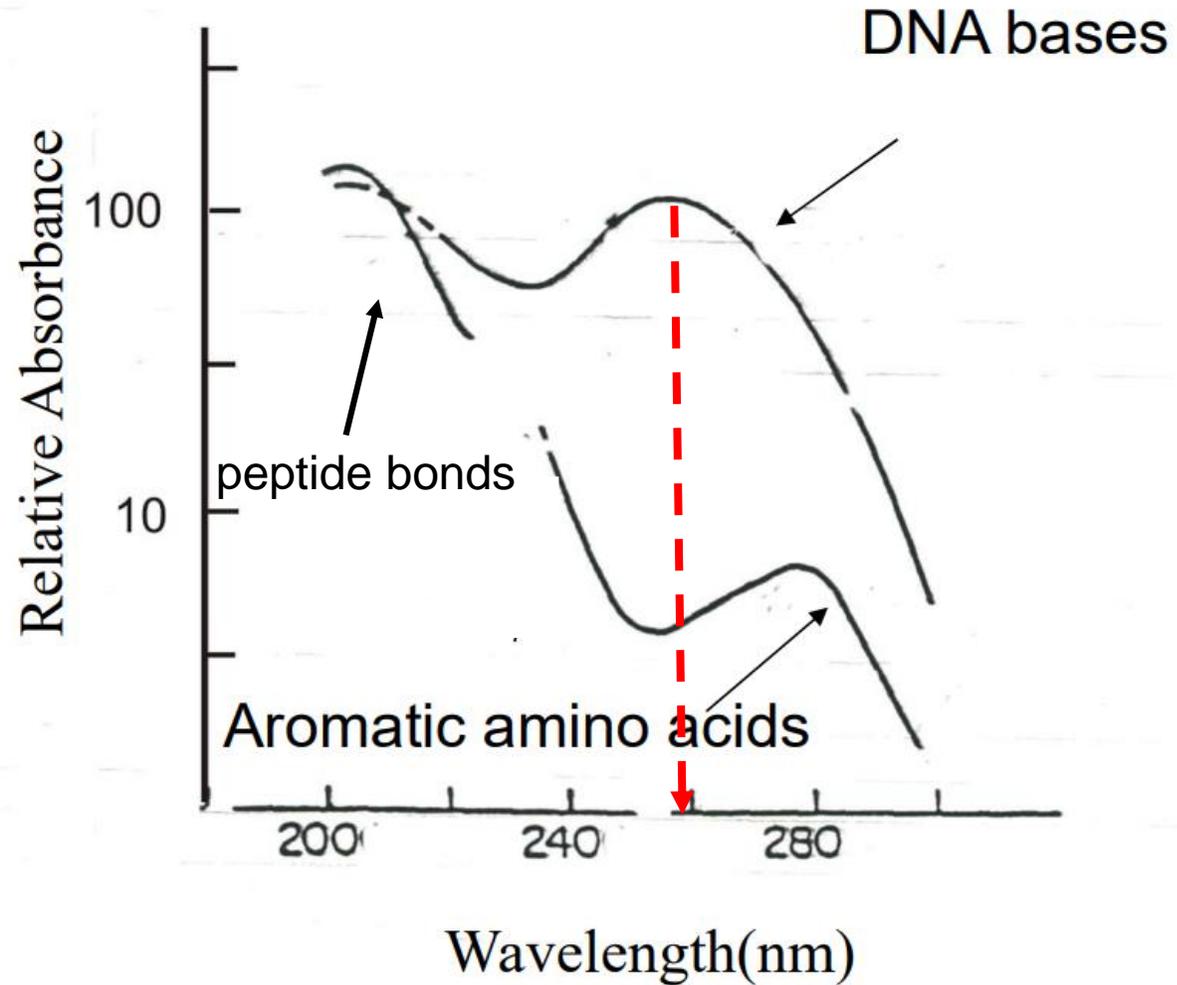
Exogenous chromophores

Food coloring dyes

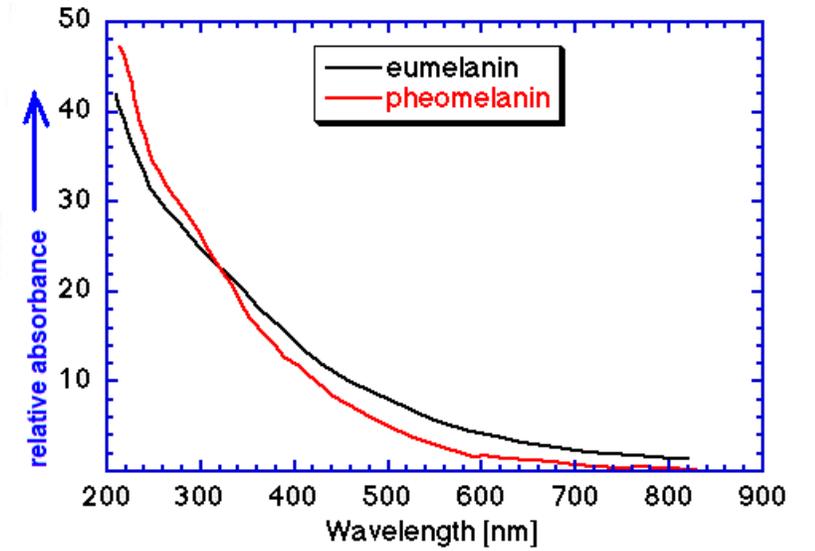
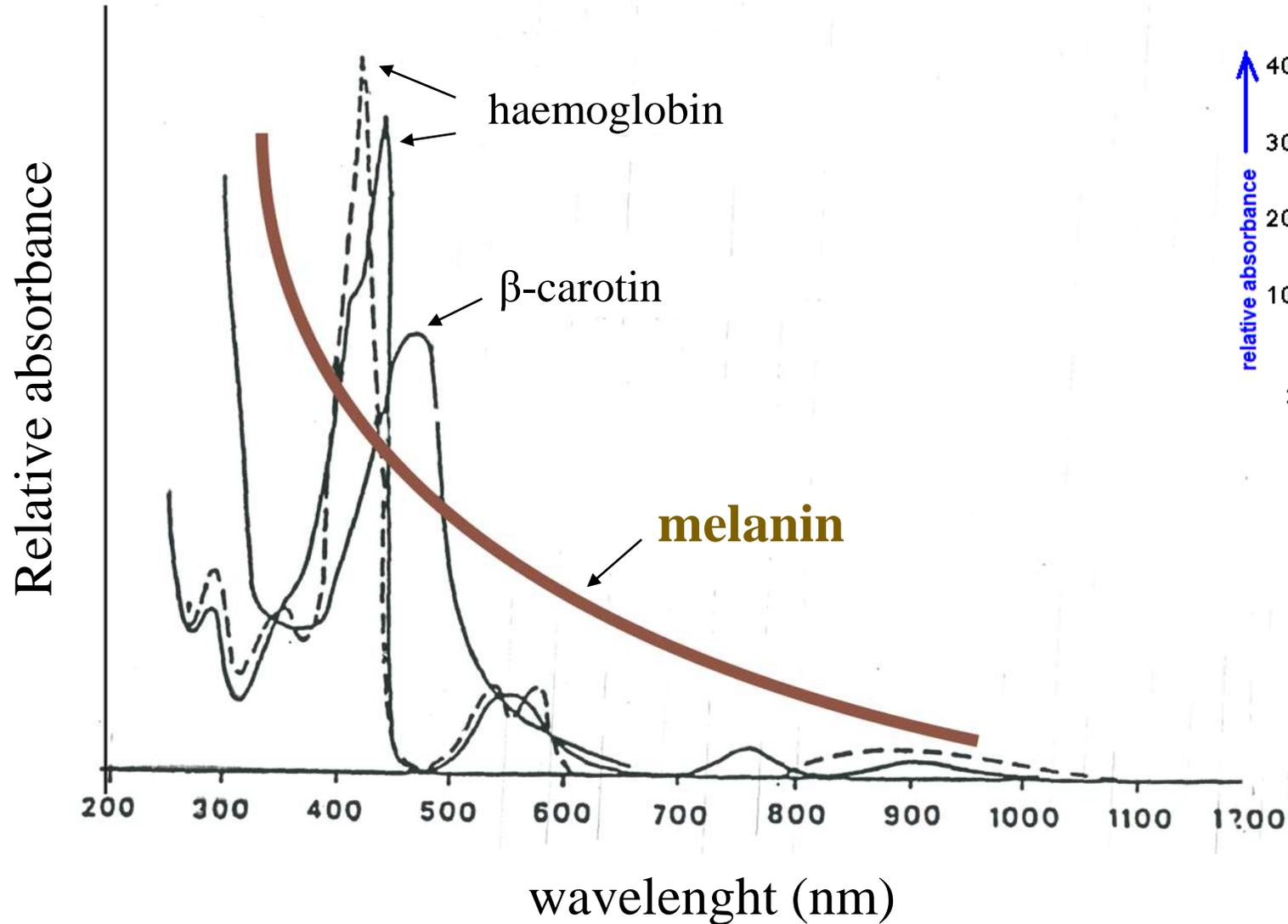
Cosmetics

Drugs

Absorption spectra of endogenous chromophores I.

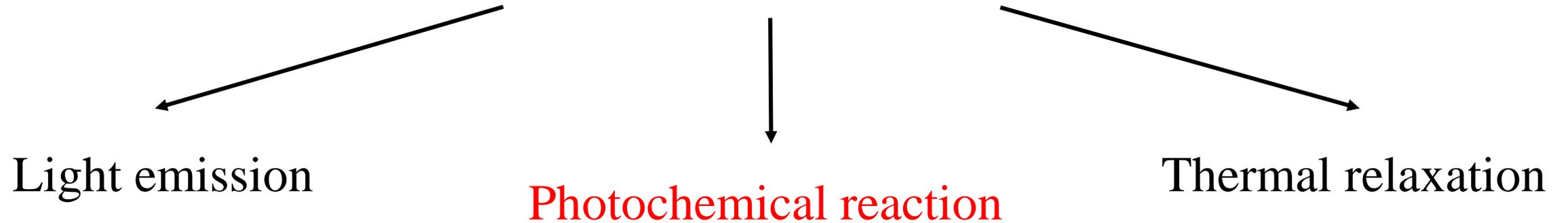


Absorption spectra of endogenous chromophores I.



Consequence of light absorption: excited state

relaxation of excited state

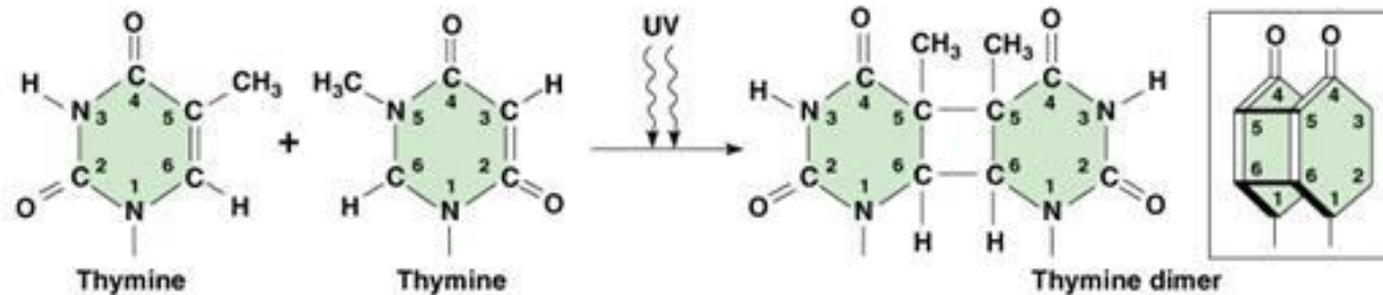
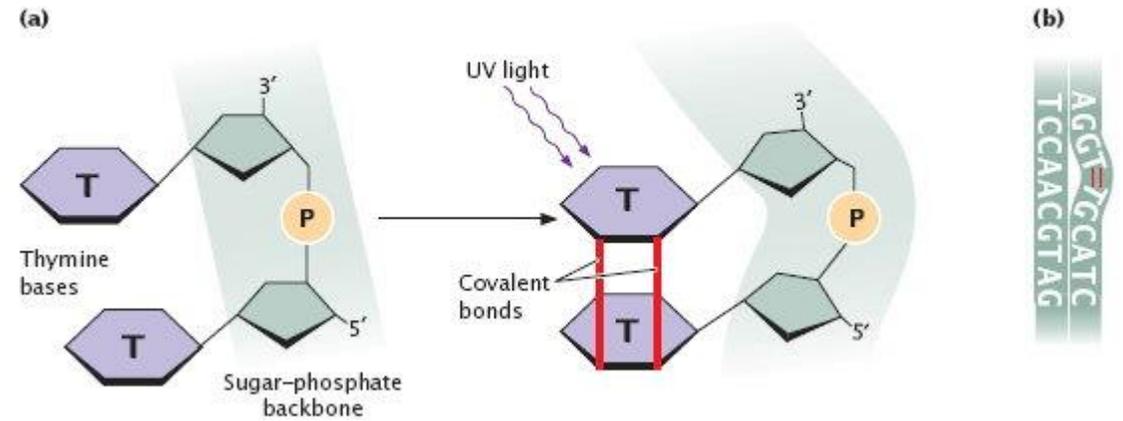
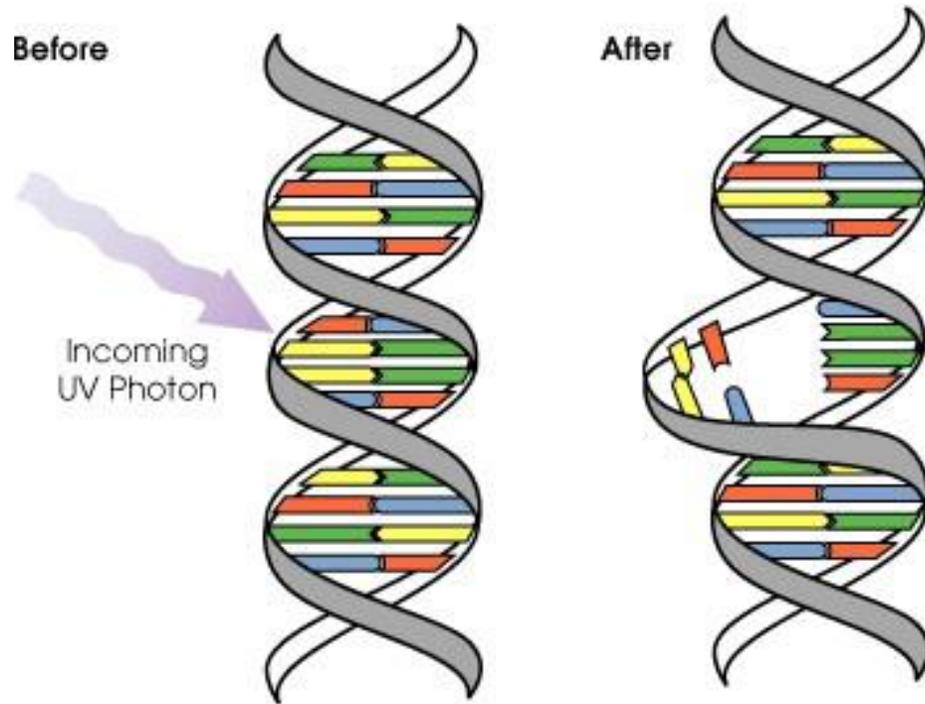


Quantum yield (Φ) : is the number of events (e.g., number of photochemical reactions) divided by the number of photons absorbed by the system.

$$\Sigma\Phi = 1$$

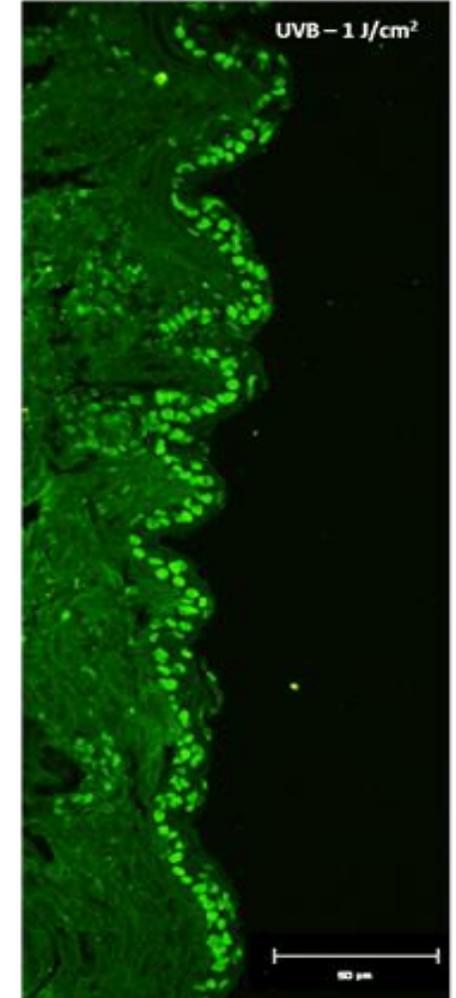
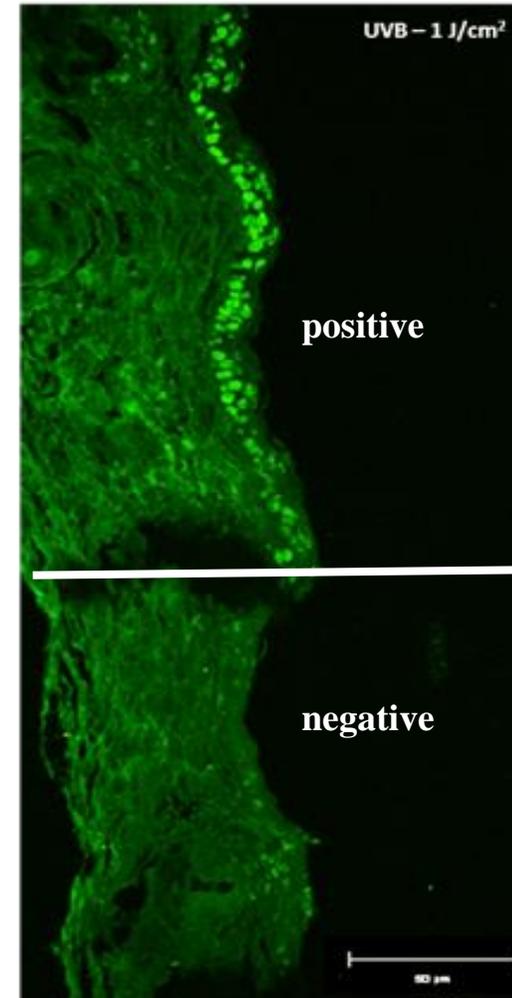
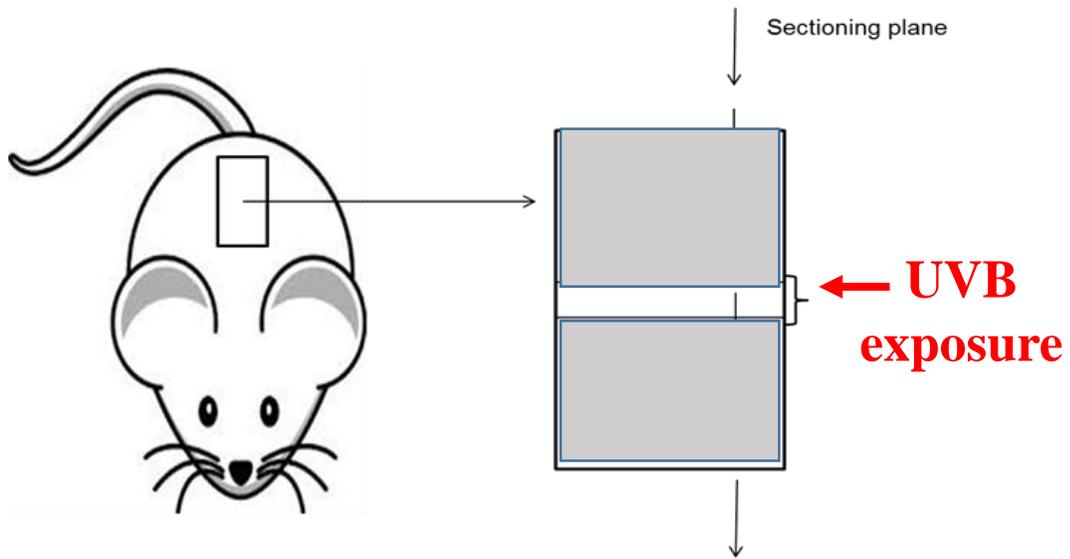
Direct photochemical reaction

Formation of DNA damage – pyrimidin dimers (thymine)



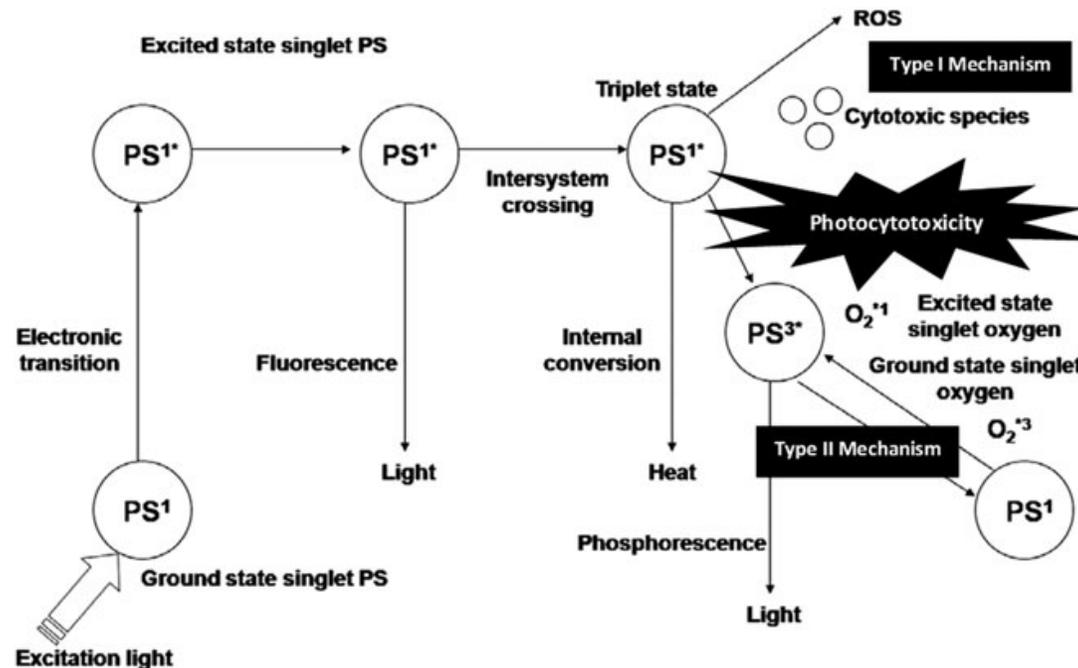
Direct photochemical reaction

Formation of DNA damage – fluorescence labeling of pyrimidin dimers (thymine)

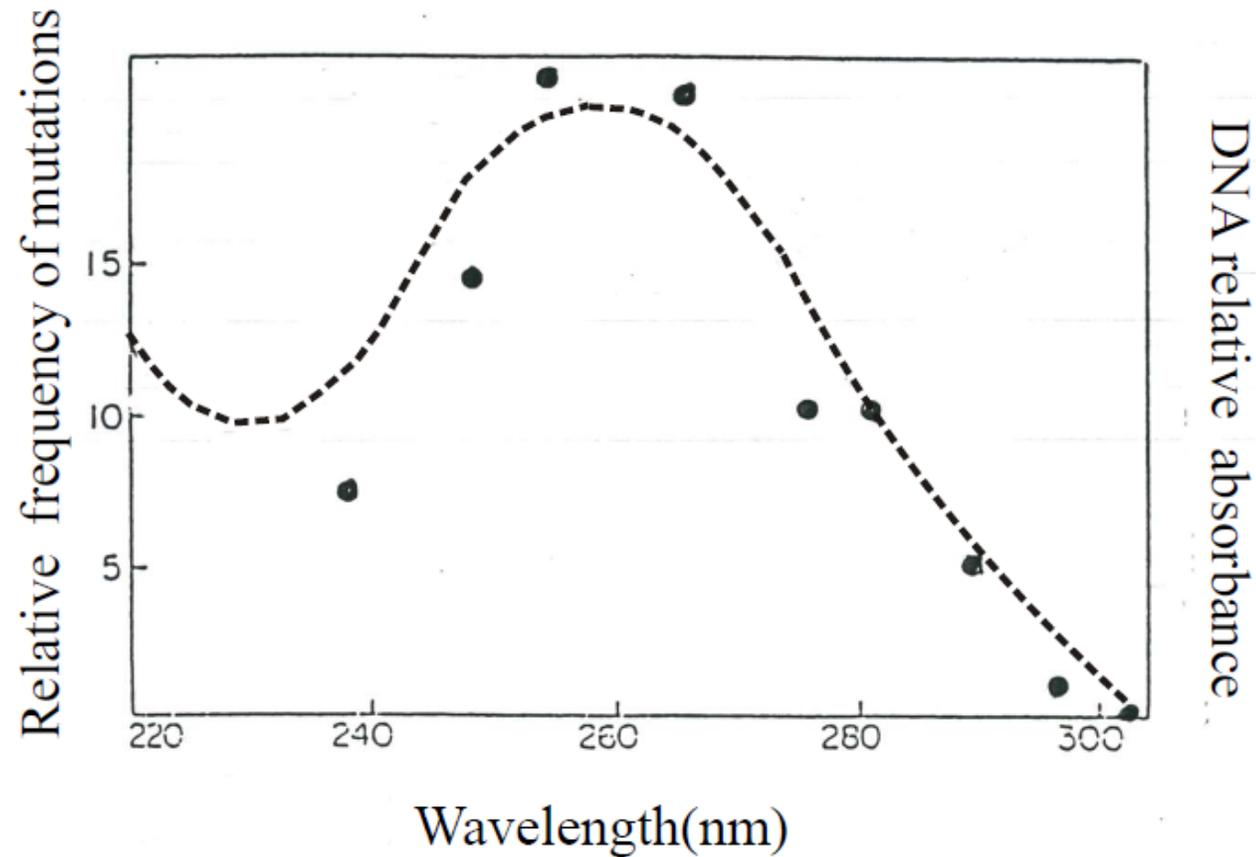


Indirect photochemical reactions

1. step: excitation of photosensitizing compound (PS) by light
2. step: generation of reactive free radicals by **electron transfer**
or
generation of reactive oxygen species by **energy transfer**
3. step: oxidative damage of cellular structures



Spectral distribution of photobiological efficiency



Efficiency varies with the wavelength

Mutations are induced by the photons absorbed in DNA

Reciprocity

$$J_{(\lambda)} \left[\frac{J}{s} m^2 \right] \cdot t [s] = D_{(\lambda)} \left[\frac{J}{m^2} \right]$$

The result depends only on the incident dose ($\mathbf{D}_{(\lambda)}$)

or

On intensity (\mathbf{J}) and on time (t) separately?

Reciprocity is valid for photochemical reactions but not for photobiological results.

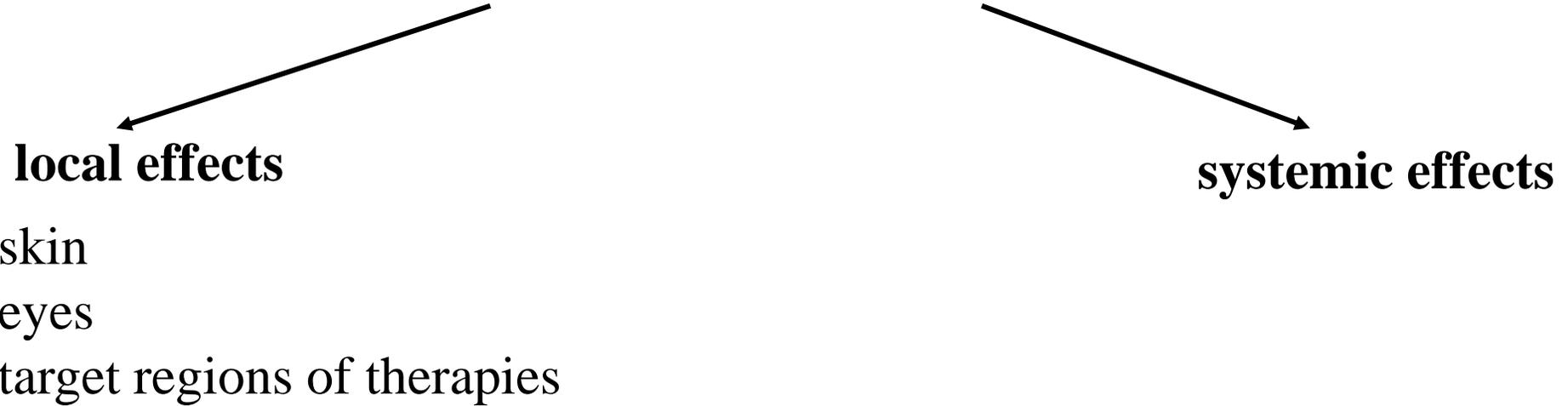
Beneficial vs. harmful effects of sunlight



sunburn
wrinkles
age-related pigmentation
skin cancer
immunosuppression

visions
vitamin-D production
pigmentation
daily and annual rhythms
therapeutic applications

Effects of sunlight – spatial distribution



local effects

skin

eyes

target regions of therapies

systemic effects

Effects of sunlight – temporal distribution



short-term

sunburn

immuno-suppression

long-term

photoageing

hiperpigmentation

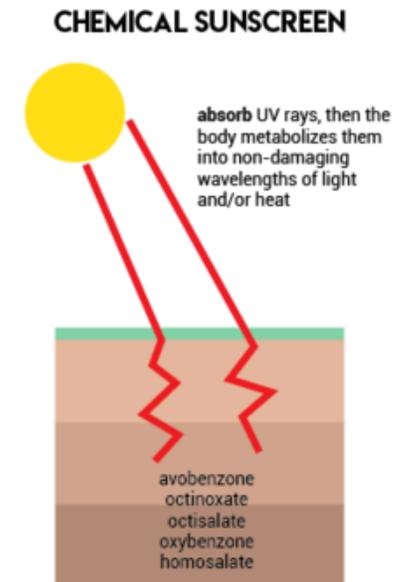
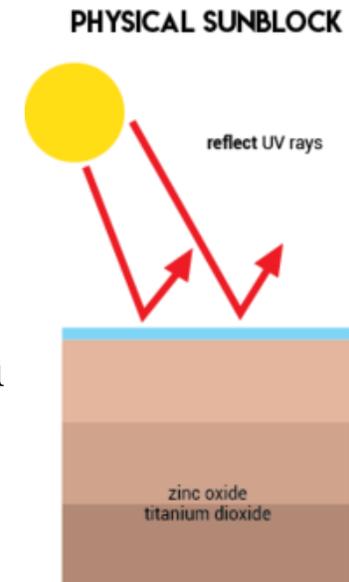
skin cancer

Sunburn

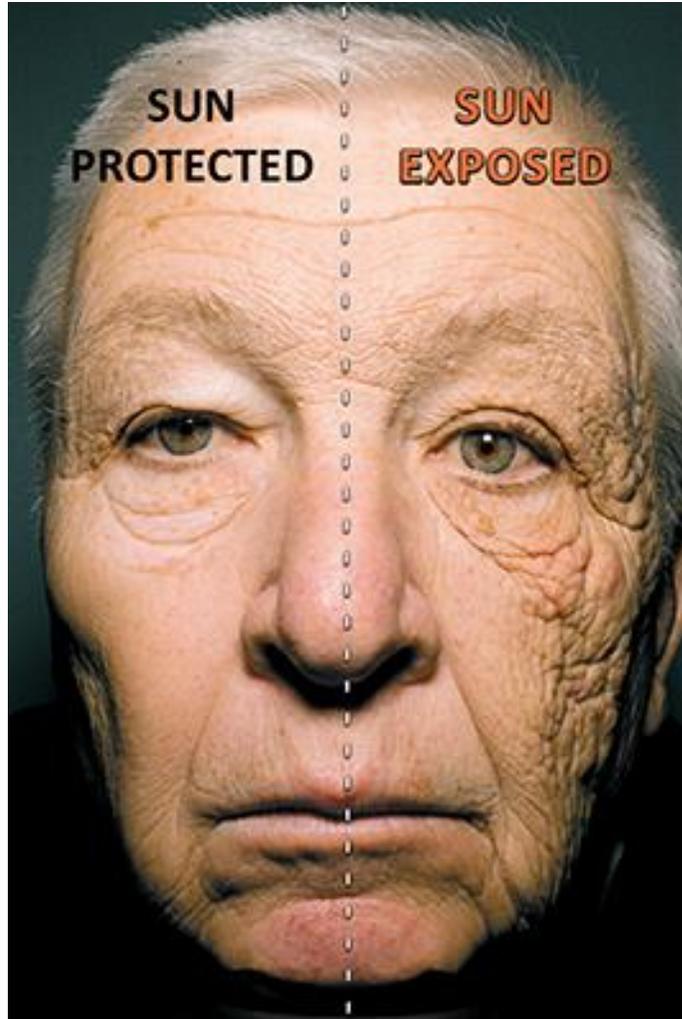


UV protection!

- Physical (sunblock): TiO_2 , ZnO – scattering, reflection
- Chemical (sunscreens): absorption of UV light



Photoaging



Skin cancer – non-melanoma skin cancers



Solaris keratosis – precancerous

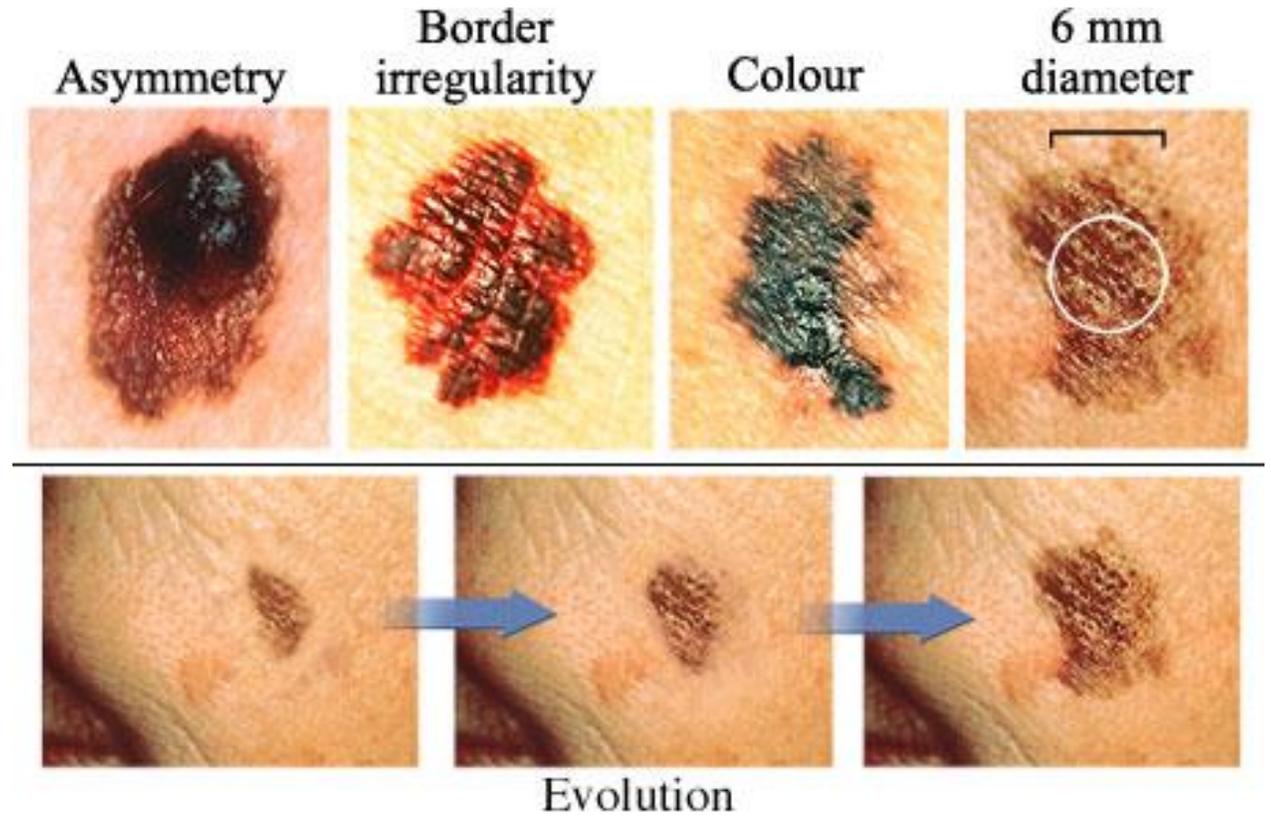
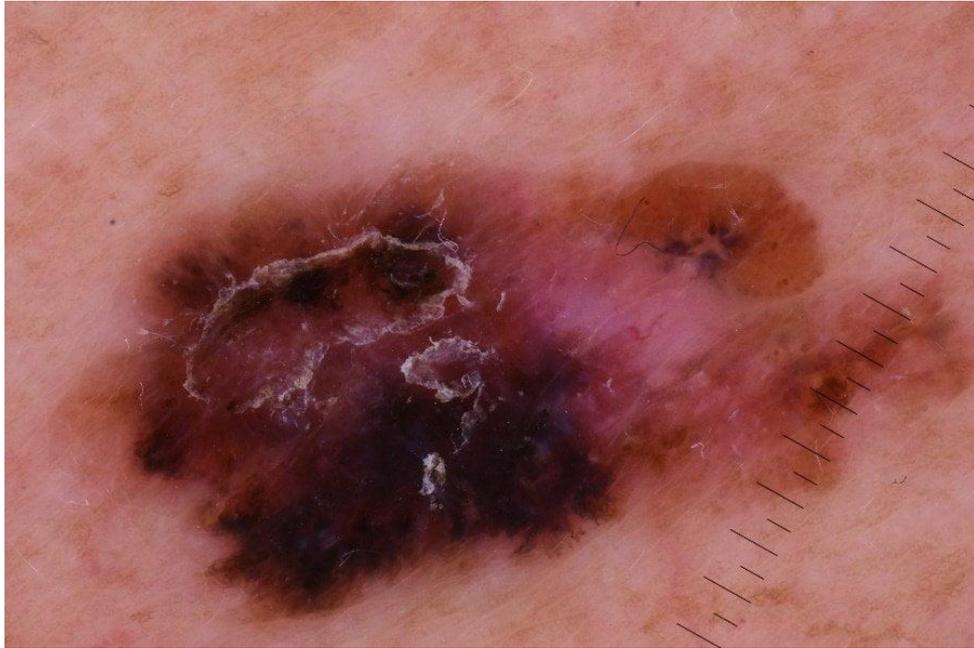


basal cell carcinoma

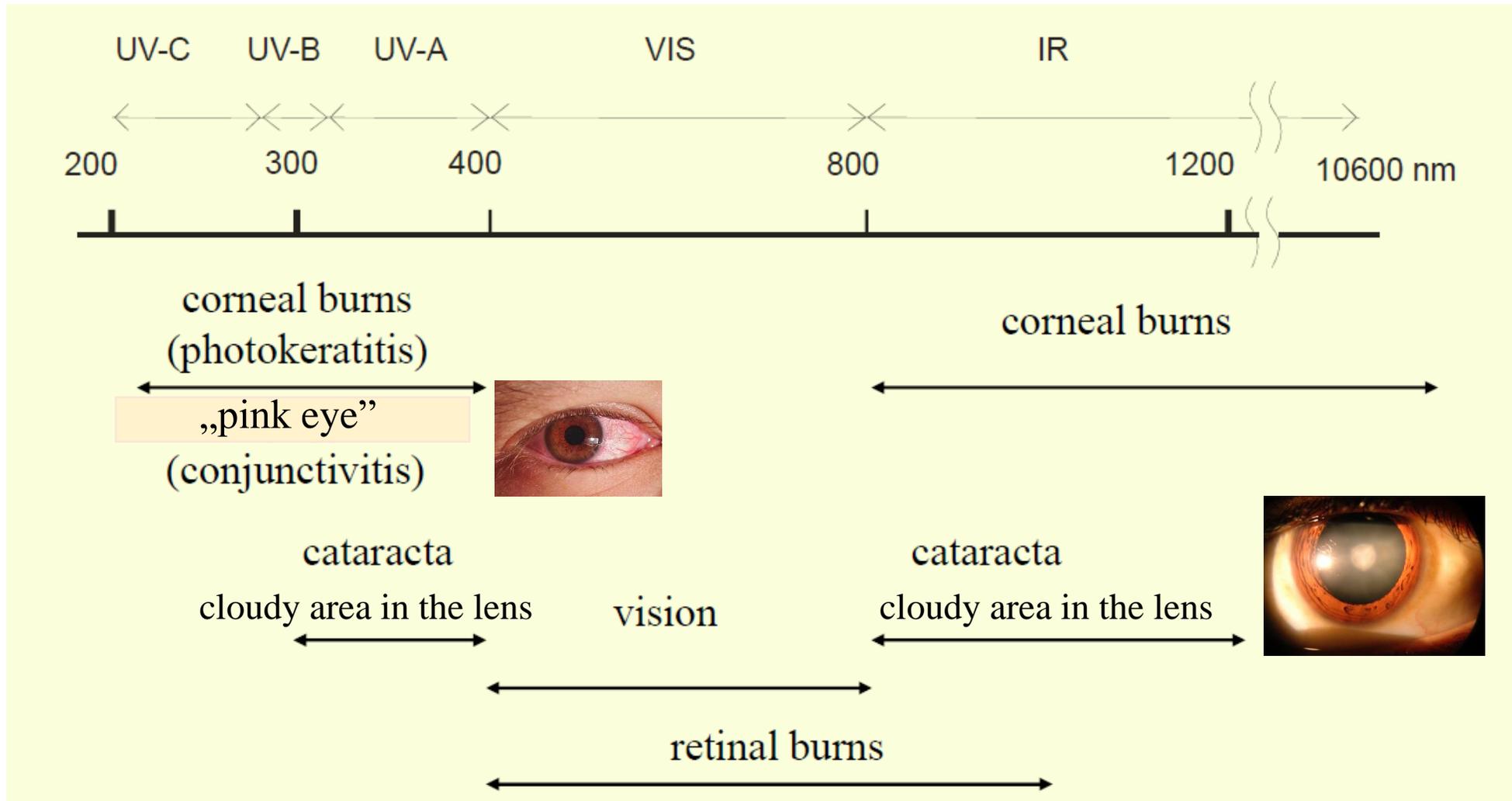


squamous cell carcinoma

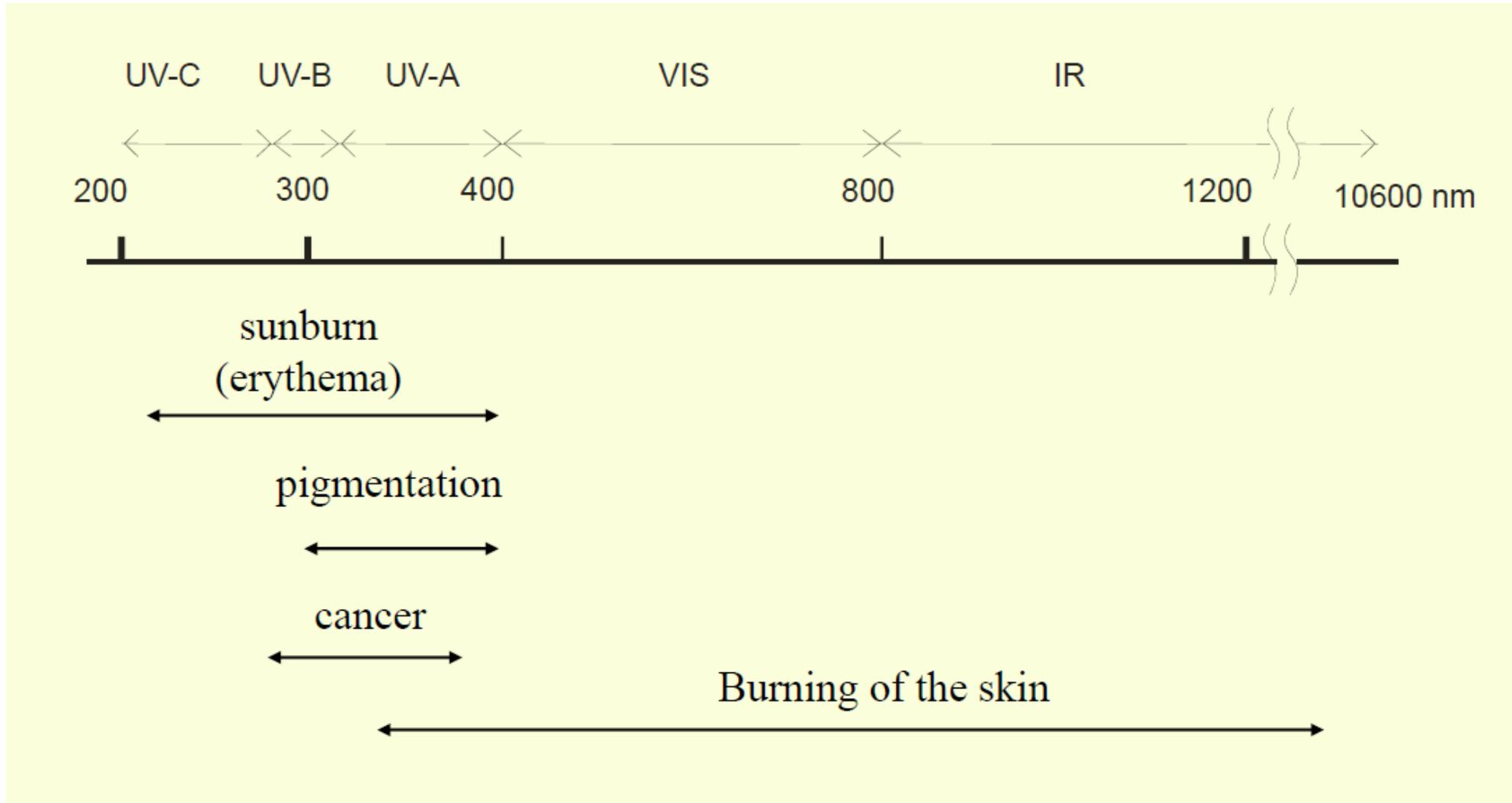
Skin cancer – melanoma malignum



Penetration distance and localization of damages - EYE



Penetration distance and localization of damages - SKIN



Daily and annual periodicity of biological functions

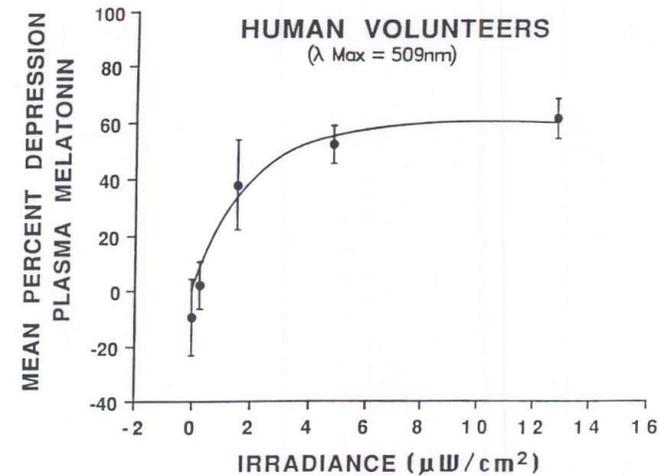
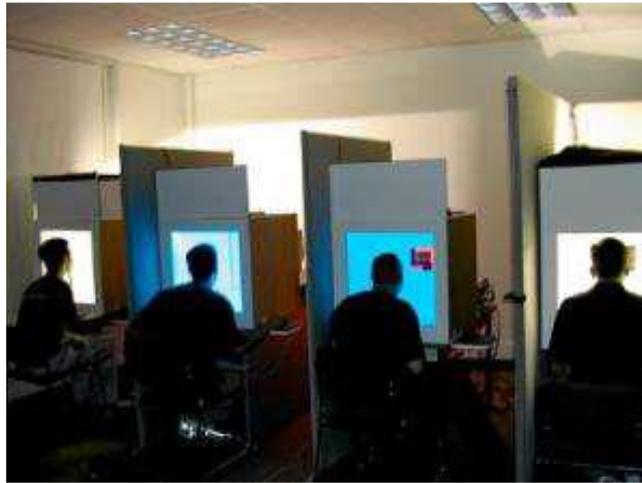
temperature
hormon production
digestion
sleep-wake cycle



Role of light on circadian rhythm

Seasonal Affective Disorder (S.A.D.)

Background of SAD: high serum level of melatonin hormone



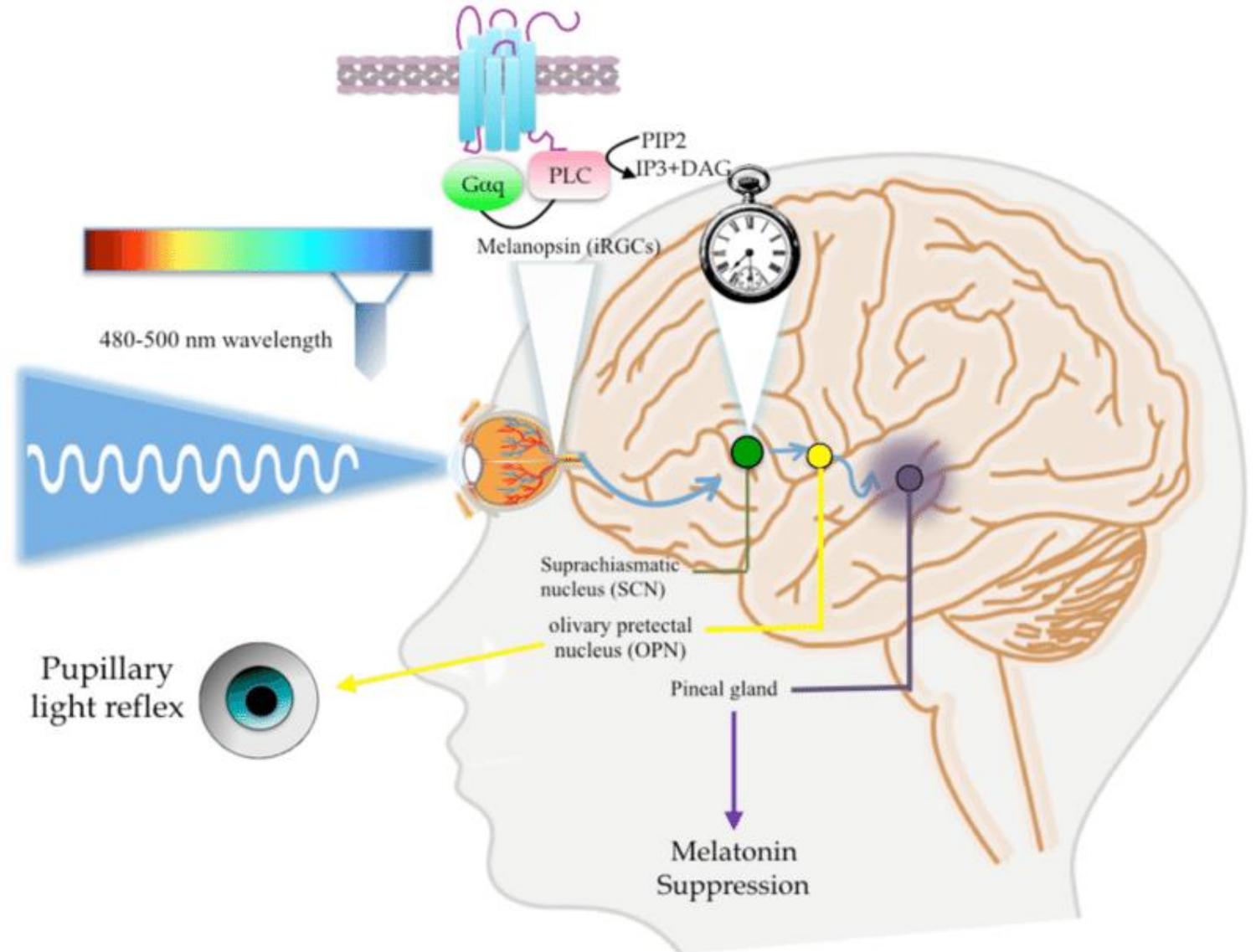
Melatonin level is regulated by the intensity, wavelength and time period of incident light into the eye

Melatonin level regulation is independent from vision – blindness do not inhibit this process

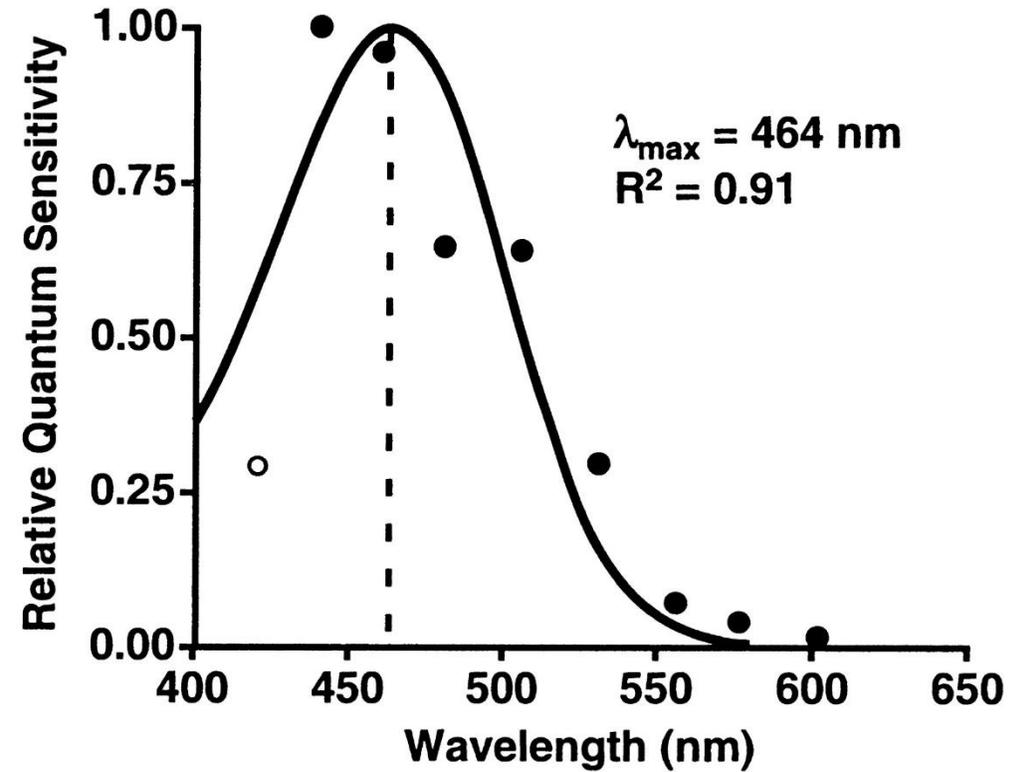
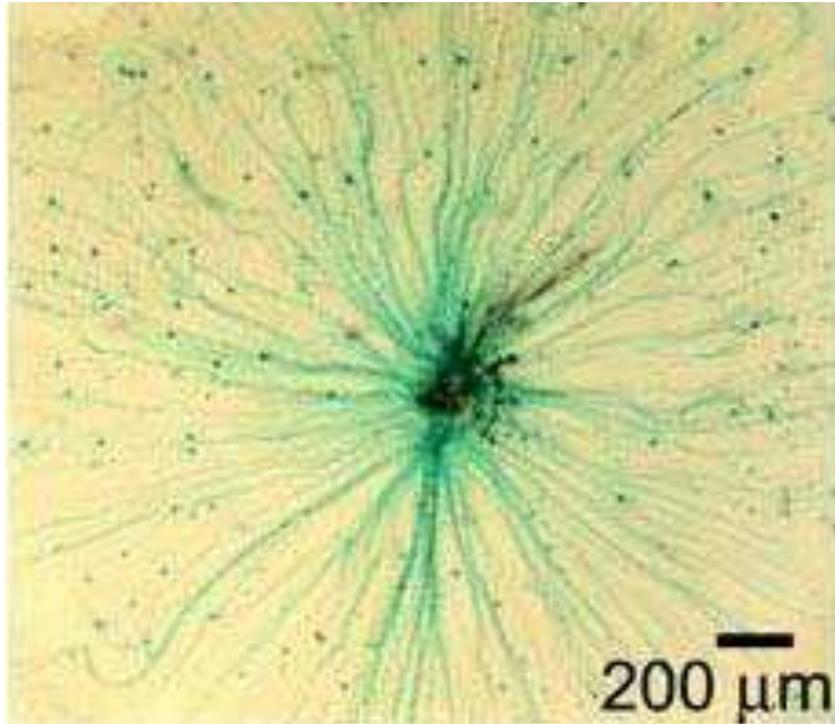
A new type of photosensitive cells (RGC) in retina

non-visual pigment:
„melanopsin”

Retinal ganglion cells are particularly sensitive to the absorption of short-wavelength (blue) visible light and communicate information directly to the area of the brain called the suprachiasmatic nucleus (SCN), also known as the central "body clock", in mammals



Melanopsin



Action spectrum of melatonin

Seasonal Affective Disorder (S.A.D.) treatment

Light sources

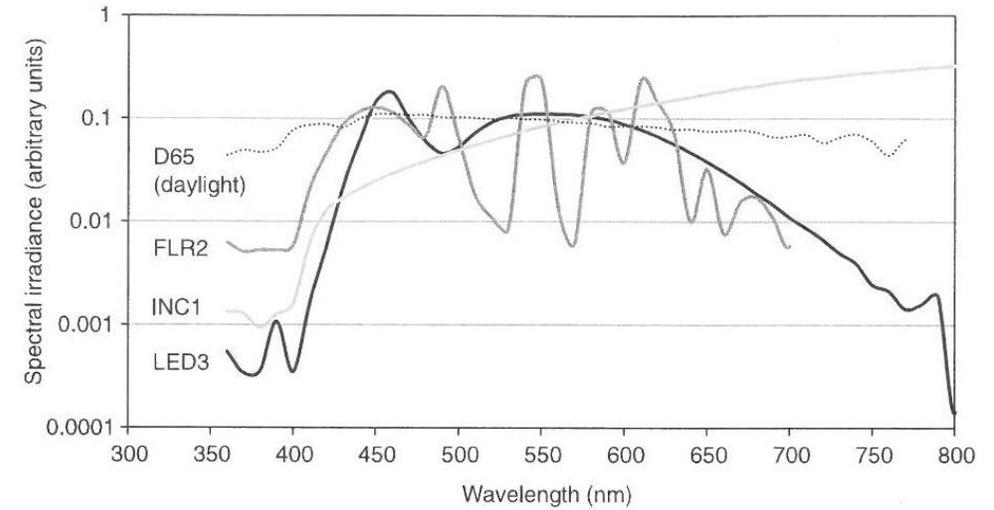
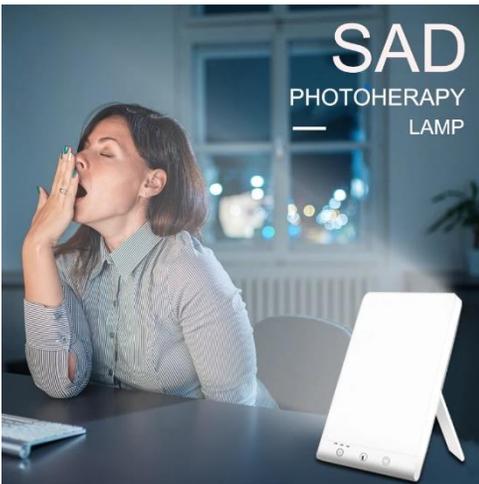


Figure 2 Typical spectra of seasonal affective disorder (SAD) lamps, sunrise simulators and daylight bulbs for light emitting diodes (LED3), fluorescent (FLR2), incandescent (INC1) lamps and the CIE standard illuminant D65,²⁴ representing natural daylight. The spectra are normalised for equal illuminance, and plotted in 10-nm steps

Examples for therapeutic application of light

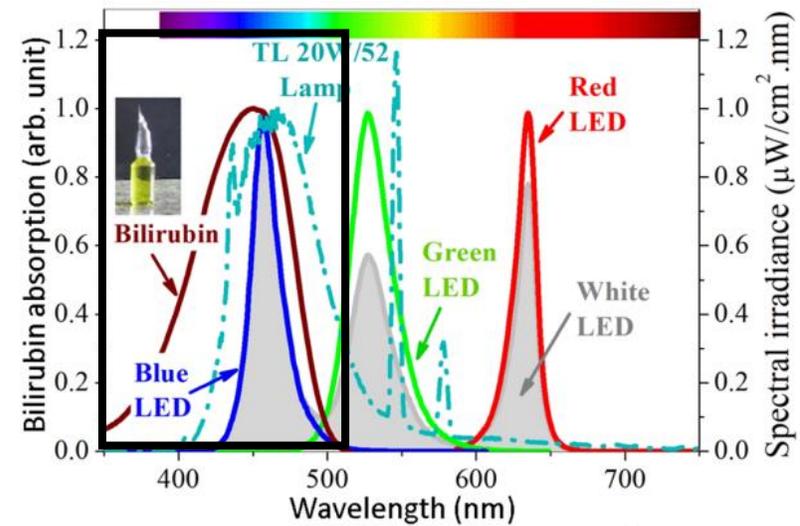
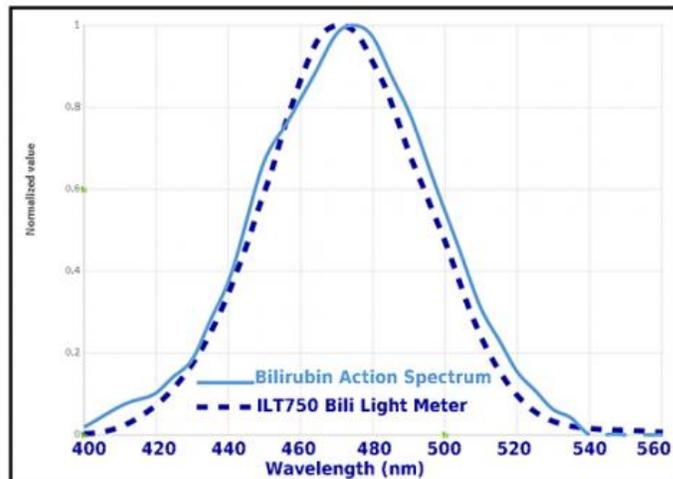
Phototherapy : light + endogenous chromophores
therapy by **light**

Photochemotherapy: light + exogenous chromophores
Therapy by **drug + light**

Newborn jaundice (hyperbilirubinemia)

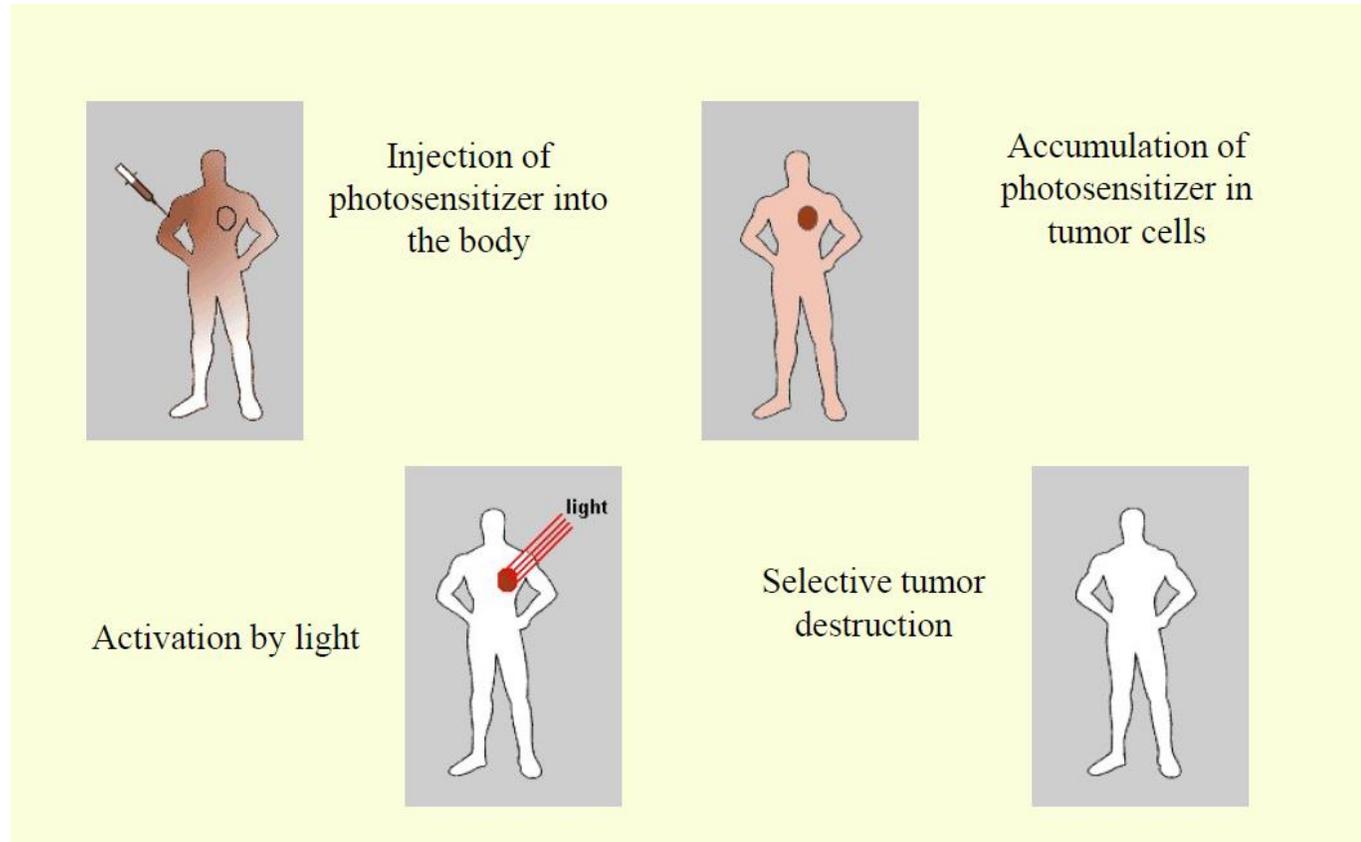


Spectral Response Curves



Photodynamic therapy (PDT)

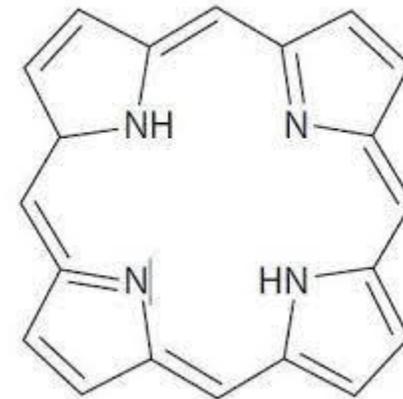
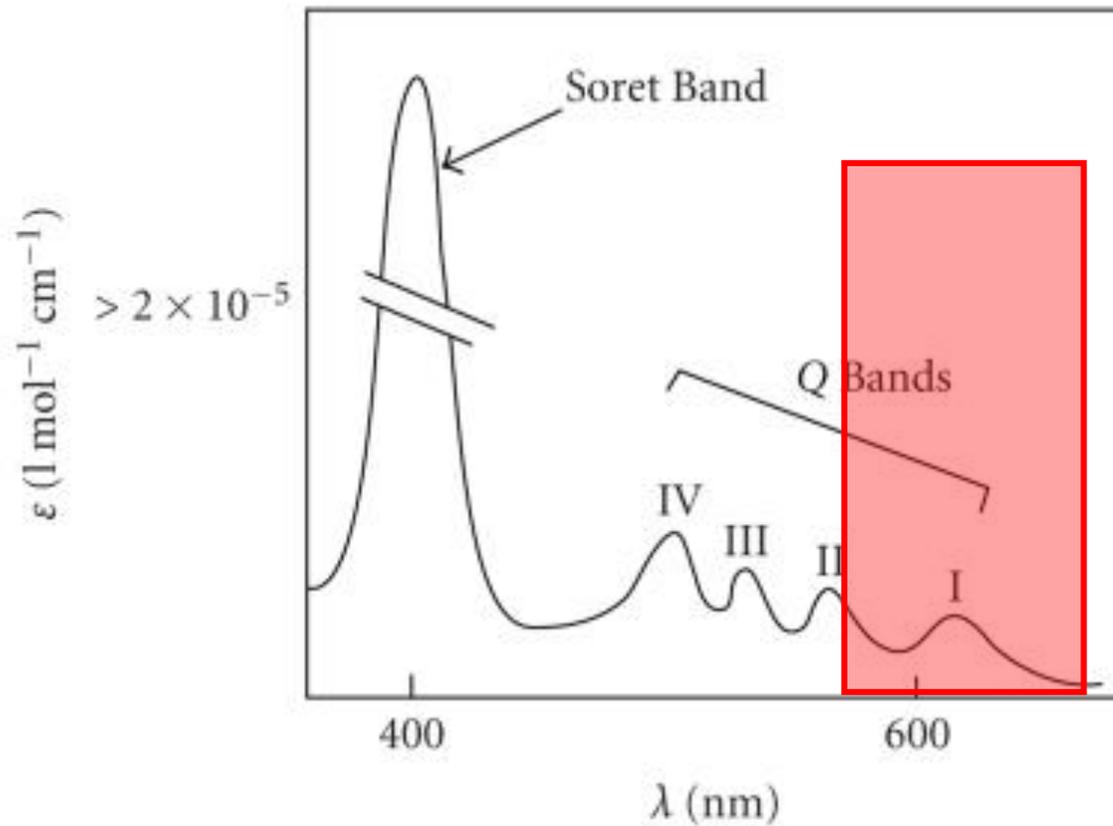
Light induced inactivation of photosensitized cells in the presence of molecular oxygen



Indirect photochemical reaction

electron transfer – free radicals
energy transfer – reactive oxygen

Absorption spectrum of porphyrins



Problem: at 400 nm high absorbance but poor penetration ability

Selection of another absorption maximum – application of longer wavelength

Application fields of PDT – malignant tumors

Dermatology

Urology: bladder cancer

Gastroenterology: oesophagus

Neurosurgery

Head and neck surgery (Otorhinolaryngology)

Pulmonology

Application fields of PDT – non-malignant diseases

Macula degeneration

Psoriasis

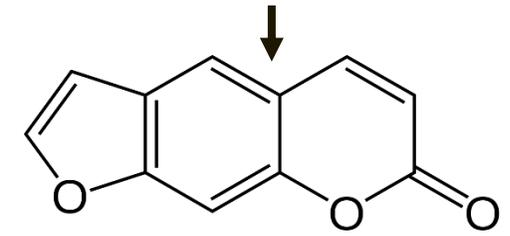
Arteriosclerosis – plaque removal

Photoinactivation of microorganisms

PUVA therapy - psoriasis



PUVA = psoralen + UVA



Treatment of oral squamous cell carcinoma (OSCC) with PDT



Fig. 1 Pre-PDT picture of a woman with a superficial T2N0 oral SCC.



Fig. 2 Post-treatment (Fig. 1 patient), 6 months after PDT.

Antimicrobial PDT of periodontitis

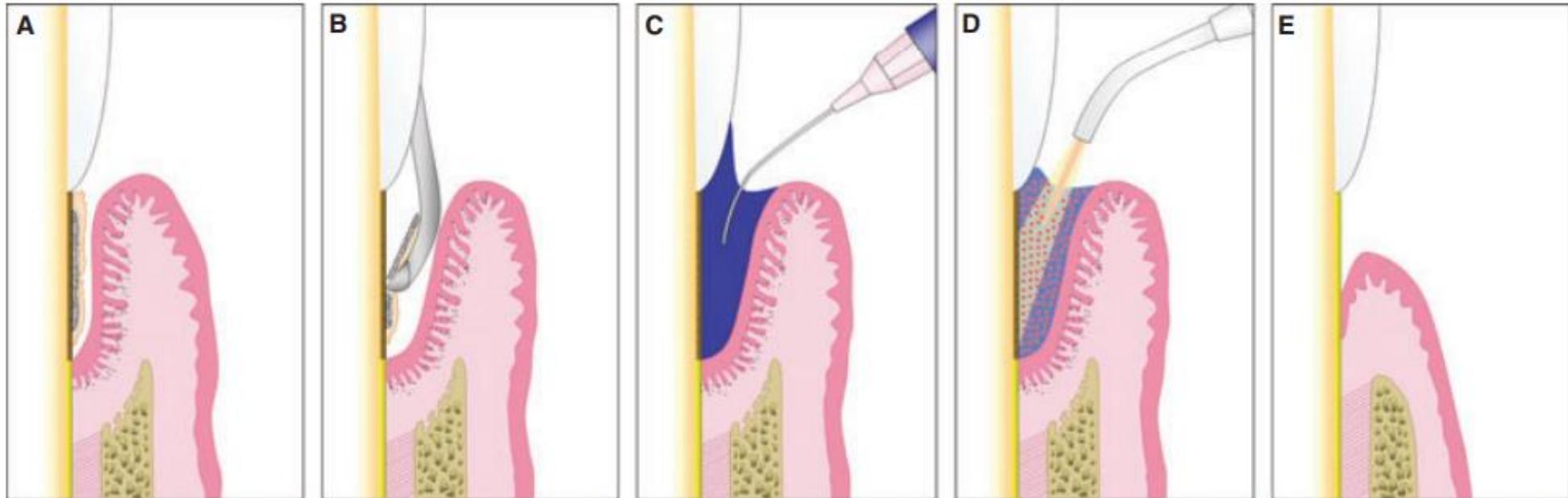


Fig. 2. Diagram showing the steps of application of antimicrobial photodynamic therapy in the treatment of periodontitis. (A) Periodontally diseased site before treatment. (B) Mechanical debridement using hand cures. (C) Application of the photosensitizer via syringe at the diseased site that contains residual bacteria. Occasionally,

excess dye solution is removed using water spray. (D) Photosensitization is performed using an intensive light by a special tip applied in the pocket. Singlet oxygen and other very reactive agents that are toxic to bacteria are produced, resulting in photochemical disinfection of the periodontal pocket. (E) Improved wound healing in the treated site.