Physical agents non-ionizing radiation

- ElectroMagnetic Fields (EMF)
- UV radiation

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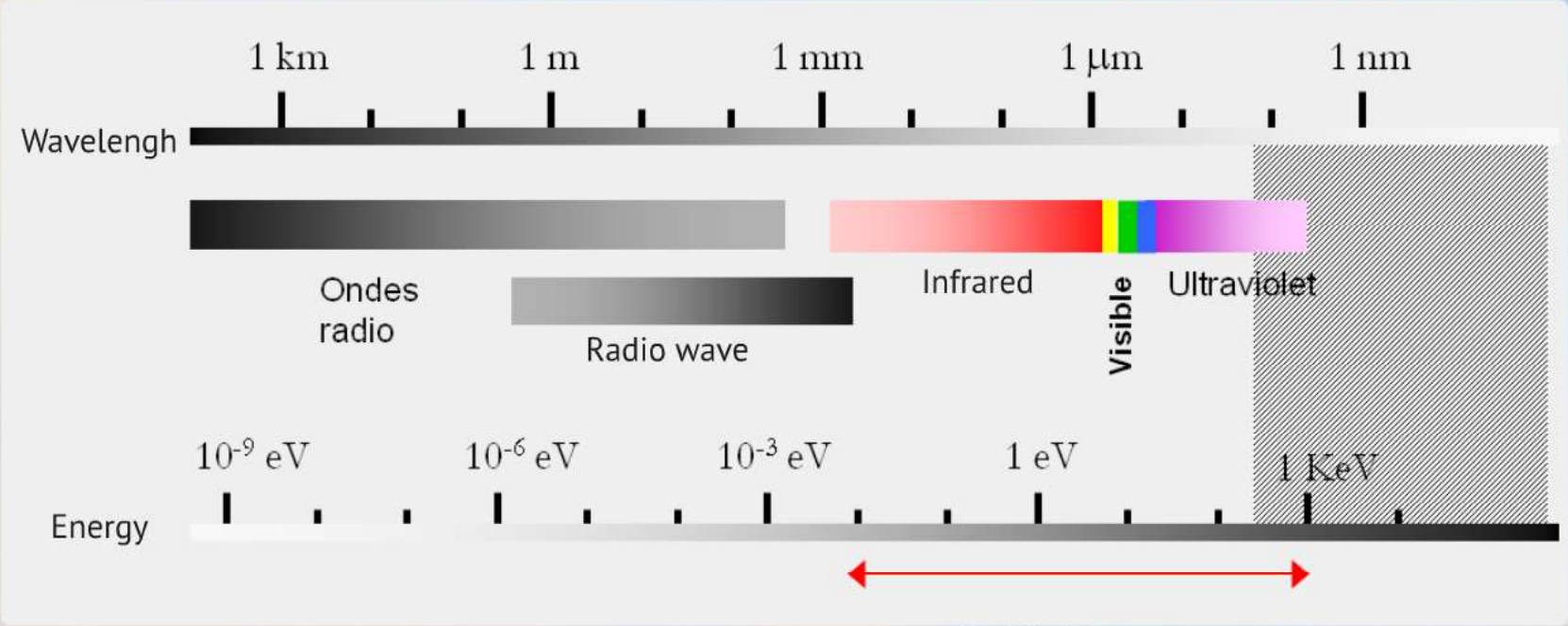
Non-ionizing radiation



Non-ionizing radiation range: > 1 nm
Beyond 12.4 eV, ionizing radiation.
Two main categories: radiofrequencies (radio waves, microwaves) and optical radiation

Relation frequency (f) - wavelength :

$$\lambda = \frac{c}{f}$$

with c: speed of light

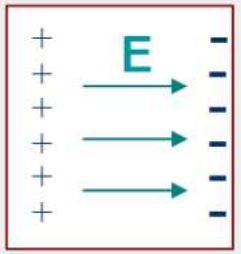
EMF - field properties

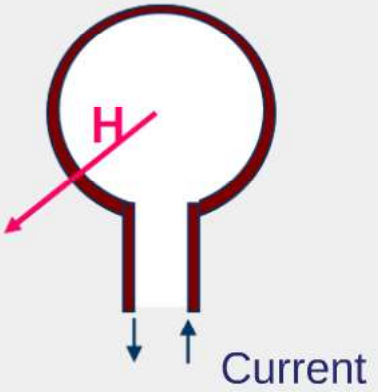
Electric field E
Field associated with the presence of electric charges

Magnetic field H
Resulting from the movement of charges and therefore of the electric current

Magnetic flux density B [Tesla]
Magnetic field H [A/m]

Units: 1 Gauss = 10-4 Tesla
1 A/m = 1.26 10-6 Tesla



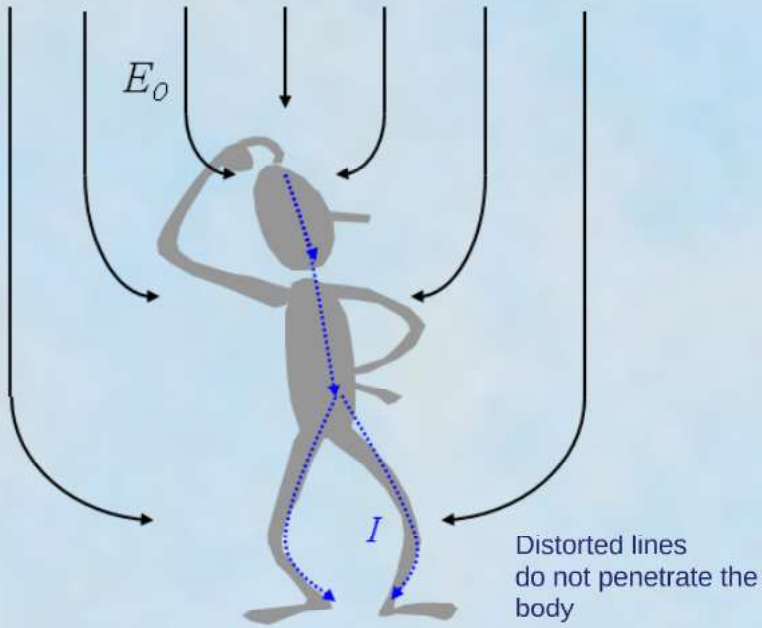


$B=\mu_0 H$ μ_0 magnetic permeability

In the air in a non-magnetic environment

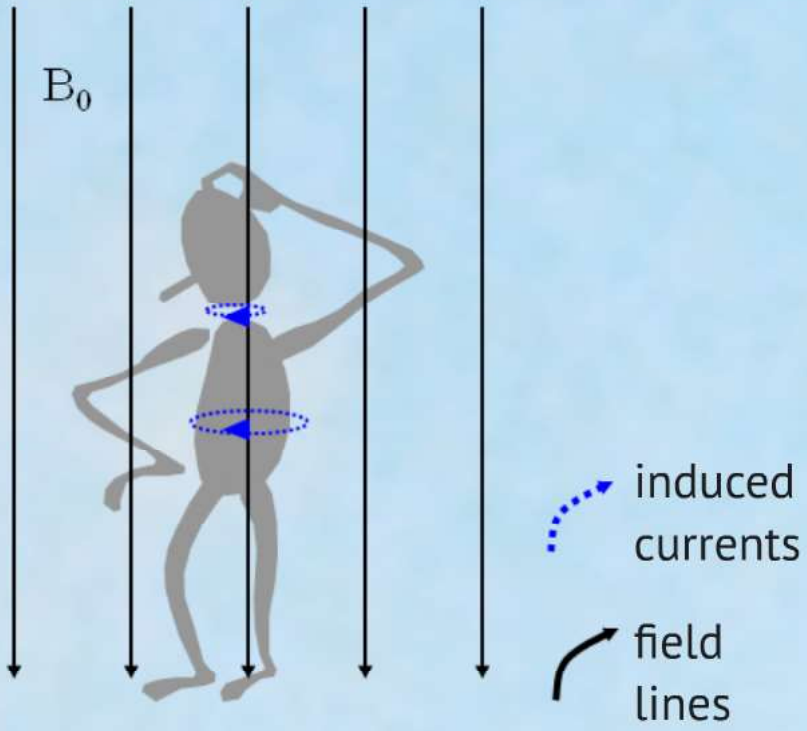
EMF - interactions with humans

E fields



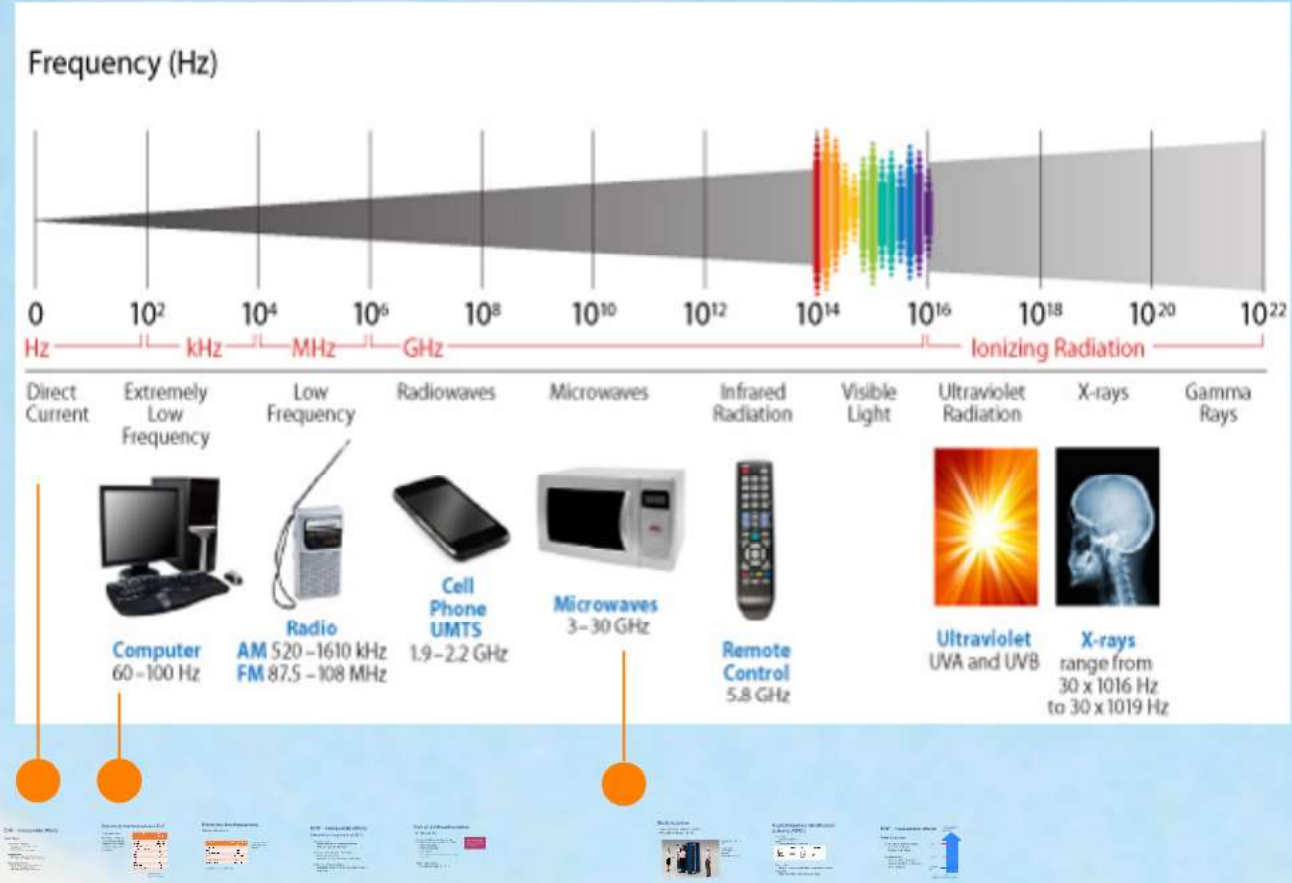
Dipole formation
Reorientation of dipoles
Current induction

H fields



Action on magnetosomes
Forces on the moving charges
Induction of E and current

Electromagnetic spectrum



EMF - measurable effects

Static fields

Deflection of moving charges

- Ionic current in the semicircular canals
  dizziness, nausea
- MRI > 2 Tesla, interaction with ECG

Mechanical effects

- Orientation or displacement of polar molecules
  water partition, blood fluidity, magnetite in bacteria

Electromagnetic interactions

- Influence on the kinetics of chemical reactions
- Magneto-navigation birds-insects
- Can activate the production of free radicals

Extremely low frequencies ELF

Daily exposures

Electricity distribution
Trains, subways, buses
Household appliances, industrial equipment, computers

Equipment (uT)	Magnetic induction (uT)
Hotplate	0.1 - 0.35
Refrigerator	0.01 - 0.25
Stereo system	0.19
Television (cathode ray)	0.04 - 0.2
Iron	0.12 – 0.3
Drill	2 -3.5
Washing machine	0.15 - 3
Saw	1 à 25
Dryer	0.08 – 0.3
Razor (3 cm)	15 – 1500
Hair dryer (3 cm)	6 - 2000

Magnetic fields measured at 30 cm

Extremely low frequencies

Occupational exposures

Equipment	Magnetic induction (uT)
Photocopier	1 – 1.2
Fax machine	0.4
Computer monitor	0.7
Electrolytic processes	1’000 – 7’000
Welding machines	130’000
Induction furnace	1’000 – 6’000

Magnetic fields at a typical operating distance

- Railroads: 12,5 uT (TGV cabin)

EMF - measurable effects

Extremely low frequency fields (ELF)

Induced currents

- low level, no confirmed biological effects
- high level, electrical discharge

Internal currents (extra-cellular liquids)

- heating by Joule effect
- depolarization of nerves, muscle contraction

Insulating membranes (cellular)

- strong attenuation of the external field (8 orders of magnitude)

Risk of childhood leukemia

ELF fields (50 Hz)

"Clusters of childhood leukemia in the vicinity of high voltage power lines (1979)

- Conflicting studies
- Confounding factors
- Rare disease

  statistical observation without explanatory mechanism

Recent meta-analyses :

- 40% increased risk if B > 0.4 µT

IARC classification (2001): 2B, possibly carcinogenic

Body scanner

Frequency range: 24 GHz (1.24 cm)
Penetration of about 1/10 mm

Average scan time: 10 sec.

Surface power:
0.76 mW/m2 passenger
0.05 mW/m2 operator

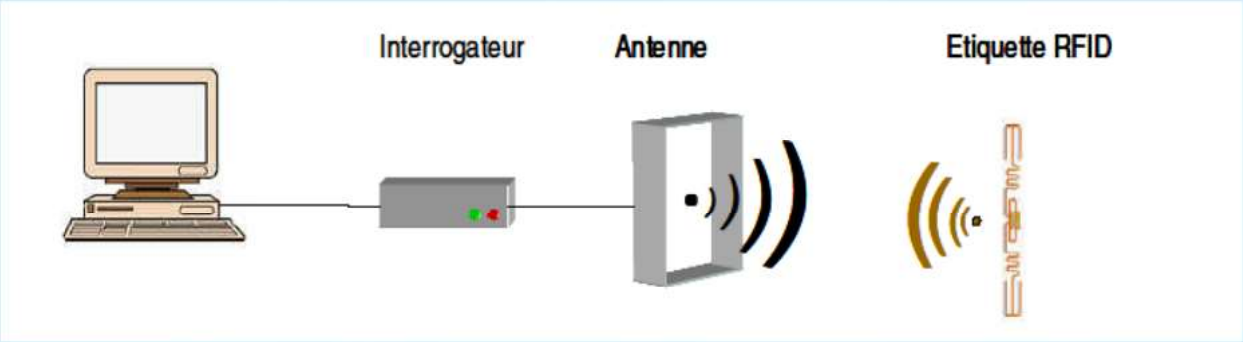
Radio frequency identification systems (RFID)

Short range:

- 125-148 kHz, 13 MHz

Far field:

- 434 MHz, 860 MHz, 2.45 GHz, 5.8Hz



Sectors of use:

- Smart cards, asset identification, automobiles, animals...

Production:

- Item identification: several tens of Mio/day

EMF - measurable effects

Radio frequencies

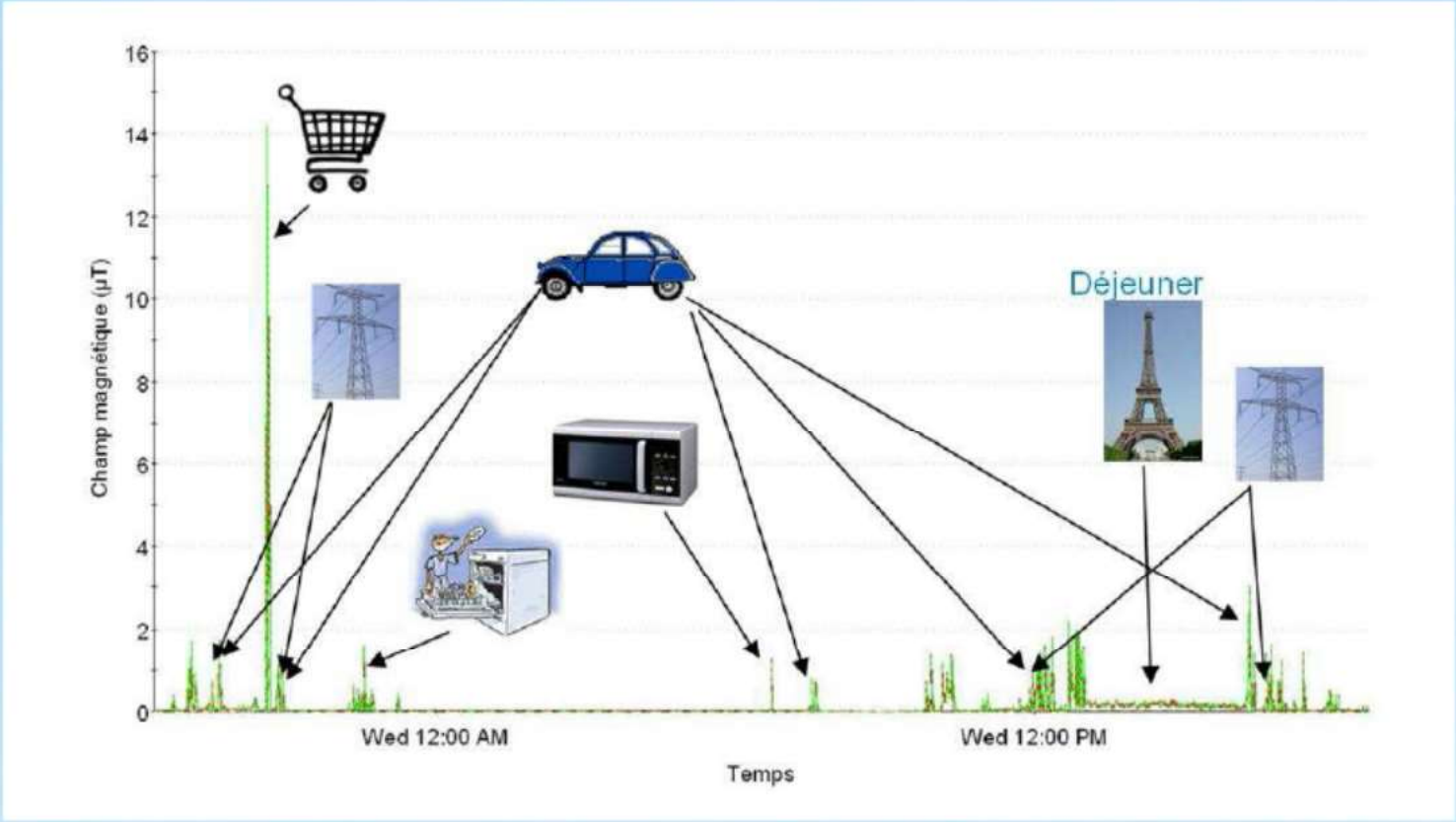
Orientation of polar molecules
- production of heat
- heating of the tissues

Possible effects
- brain activity (e.g. sleep)
- neurotransmitters disturbance
- brain tumors (?)

corresponds to E (50 V/m), order of magnitude wifi, antennas (1 V/m)

A typical day

Individual dosimetry



Recording during 24 hours of the low frequency magnetic field in the environment of a person and identification of the sources

EMF - health effects

MILIEU
BIOLOGIQUE
EXPOSE

External field

Internal
induced fields

molecular and
cellular effects

physiological
effects

?

pathology

- tissues heating
- Nerves and muscles stimulation
- Dysfunction of the cardiac rhythm
- Effect on melatonin levels
- Disturbance of vision
- Alteration of membrane properties/functions

- Increased risk of cancer (leukemia in children)?

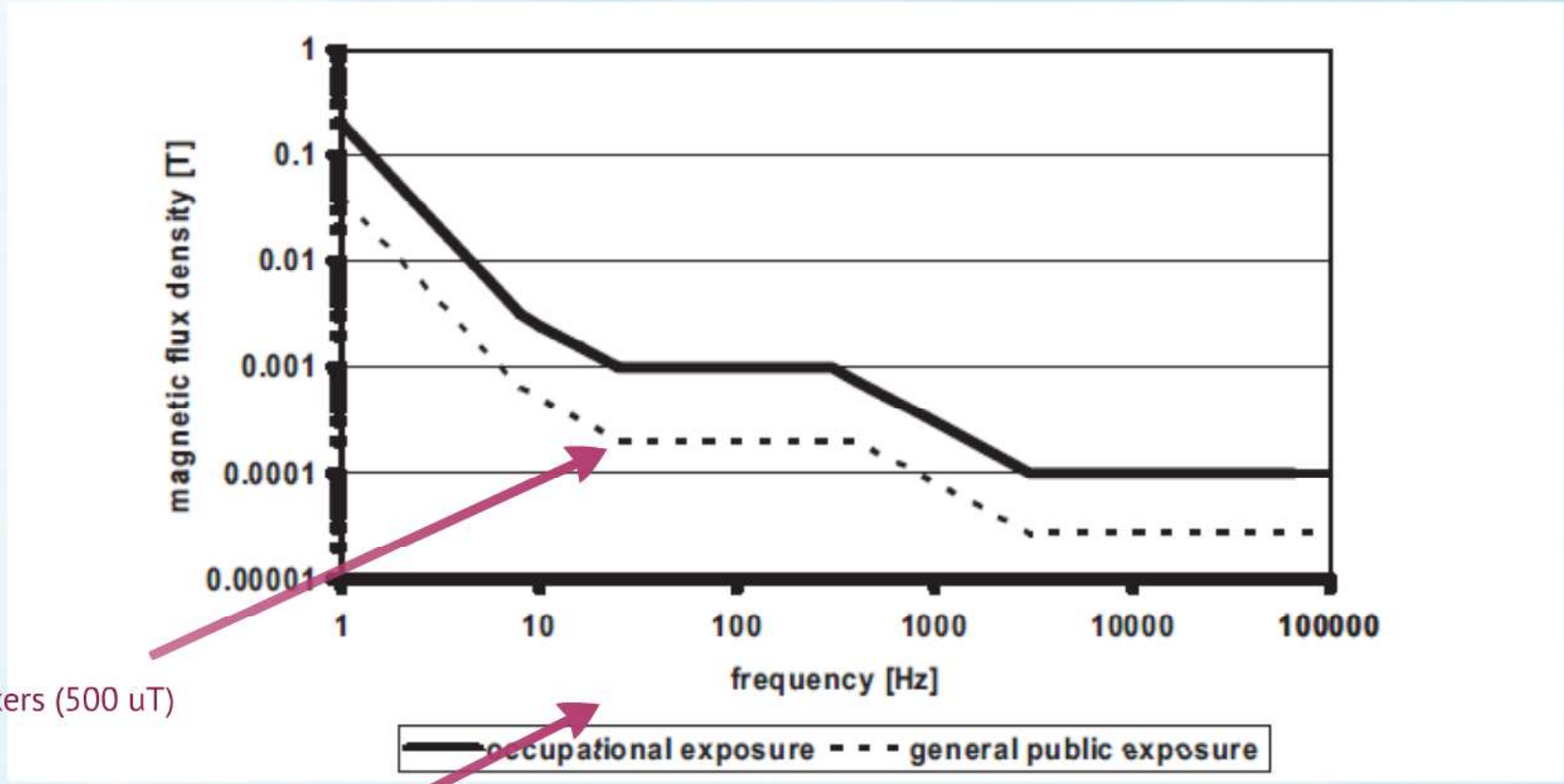
Is there a causal relation ?

Hills criteria for causality

Criteria	Comments	
Temporality	Cause precedes effect	✓
Strength	Large relative risk	✗
Dose-Response	Larger exposures to cause associated with higher disease rates	✗
Reversibility	Reduction/cessation of exposure followed by lower disease rates	
Consistency	Repeatedly observed by different persons, places, times etc.	✗
Biologic Plausibility	Makes sense according to scientific knowledge at the time	✗
Specificity	One cause leads to one effect	~
Analogy	Cause and effect relationship already established for similar disease or exposure	~

Exposure limits - ICNIRP

- Magnetic fields



workers (500 uT)

precautionary principle
ORNI (1 uT)

International Commission on Non Ionizing Radiation Protection (2010)

Difficulties and limitations of health assessment

Direct biological effects

- Known (e.g. tissue heating), but evident at very high levels

Health effects

- Poorly defined and not well known
- Conflicting data
- Epidemiological studies difficult (large cohorts needed, confounding factors…)

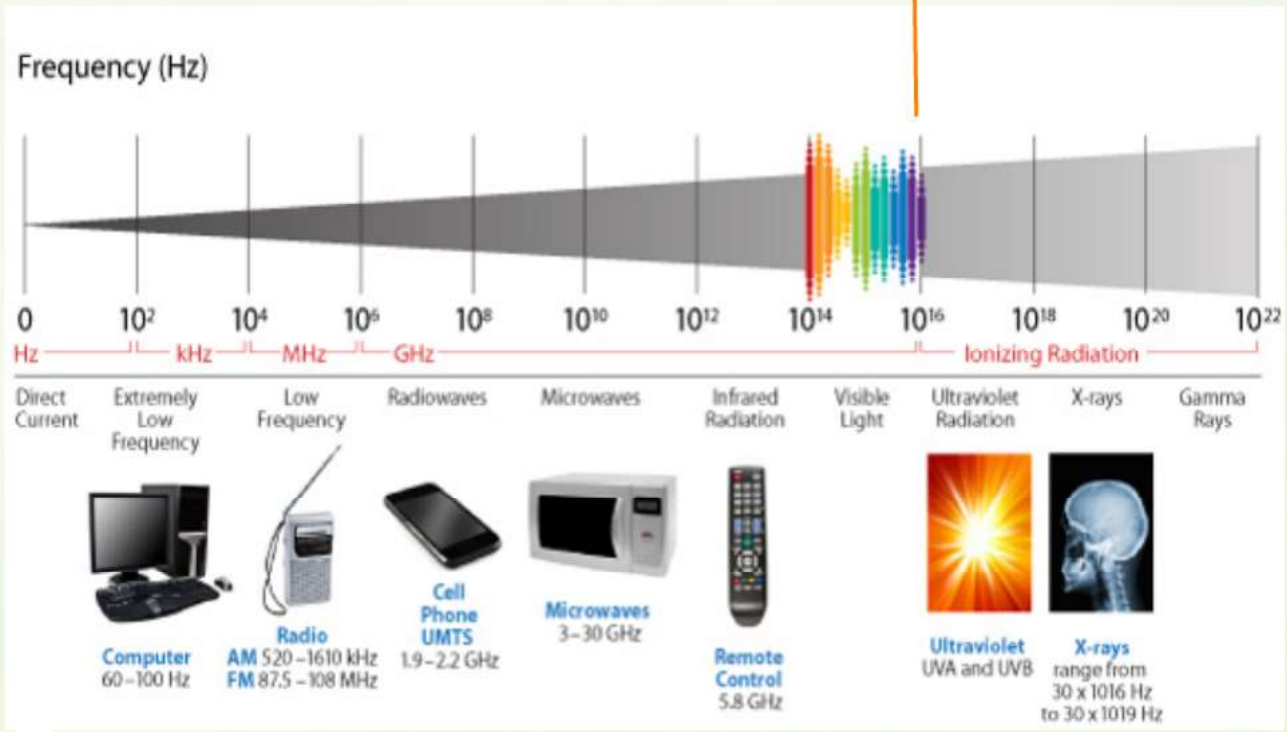
Exposure limits

- Based on proven effects (x safety factor)

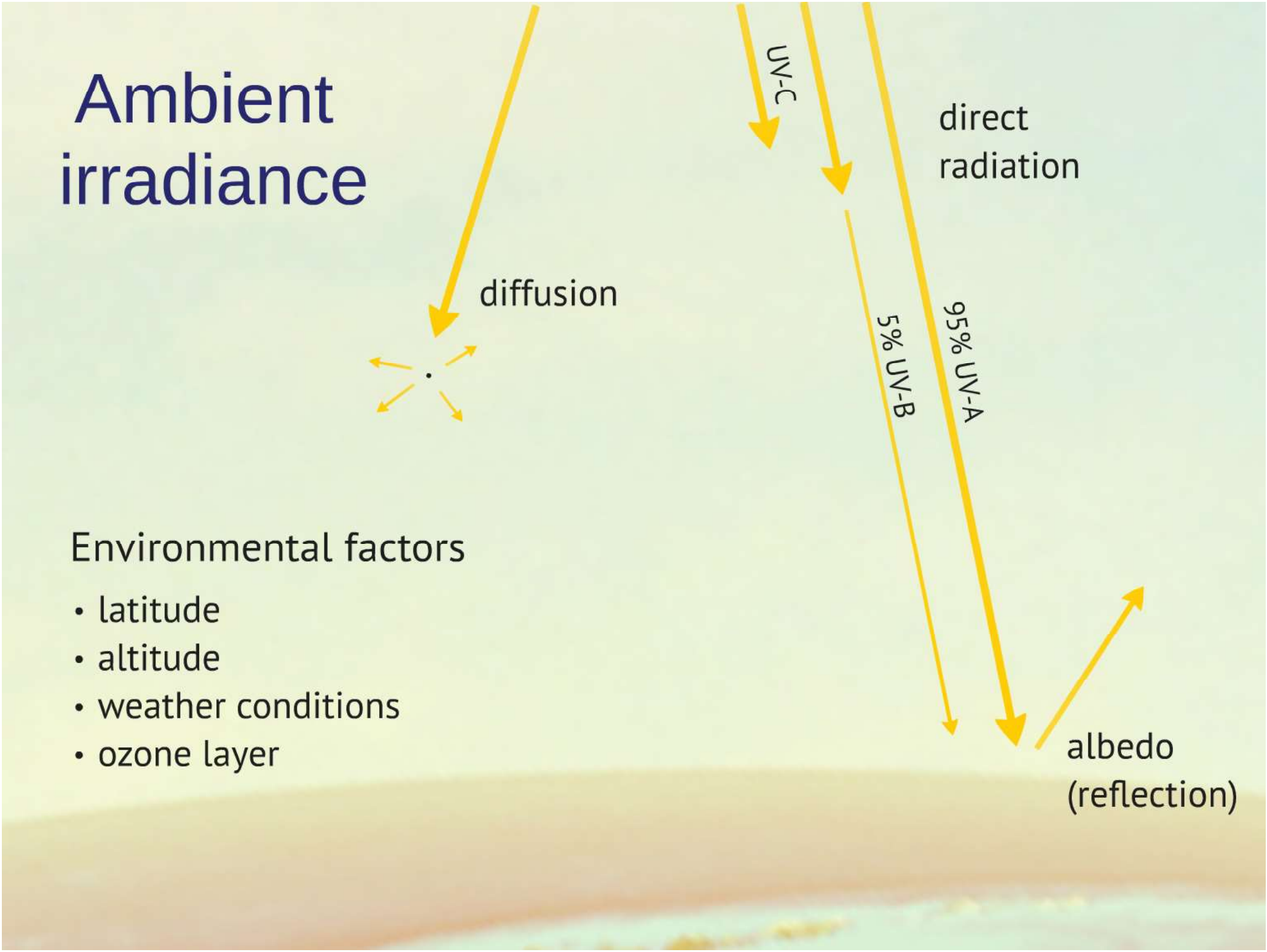
Public Fear
Cancer (brain tumors)
Headaches
Neurological disorders
Hormonal and immune system disorders
Sleep disorders
etc.

Electromagnetic spectrum

UV radiation



Ambient irradiance



Environmental factors

- latitude
- altitude
- weather conditions
- ozone layer

Exposure to solar UV

Individual factors

- clothing, sun protection
- duration and period of exposure
- posture

Exposed population

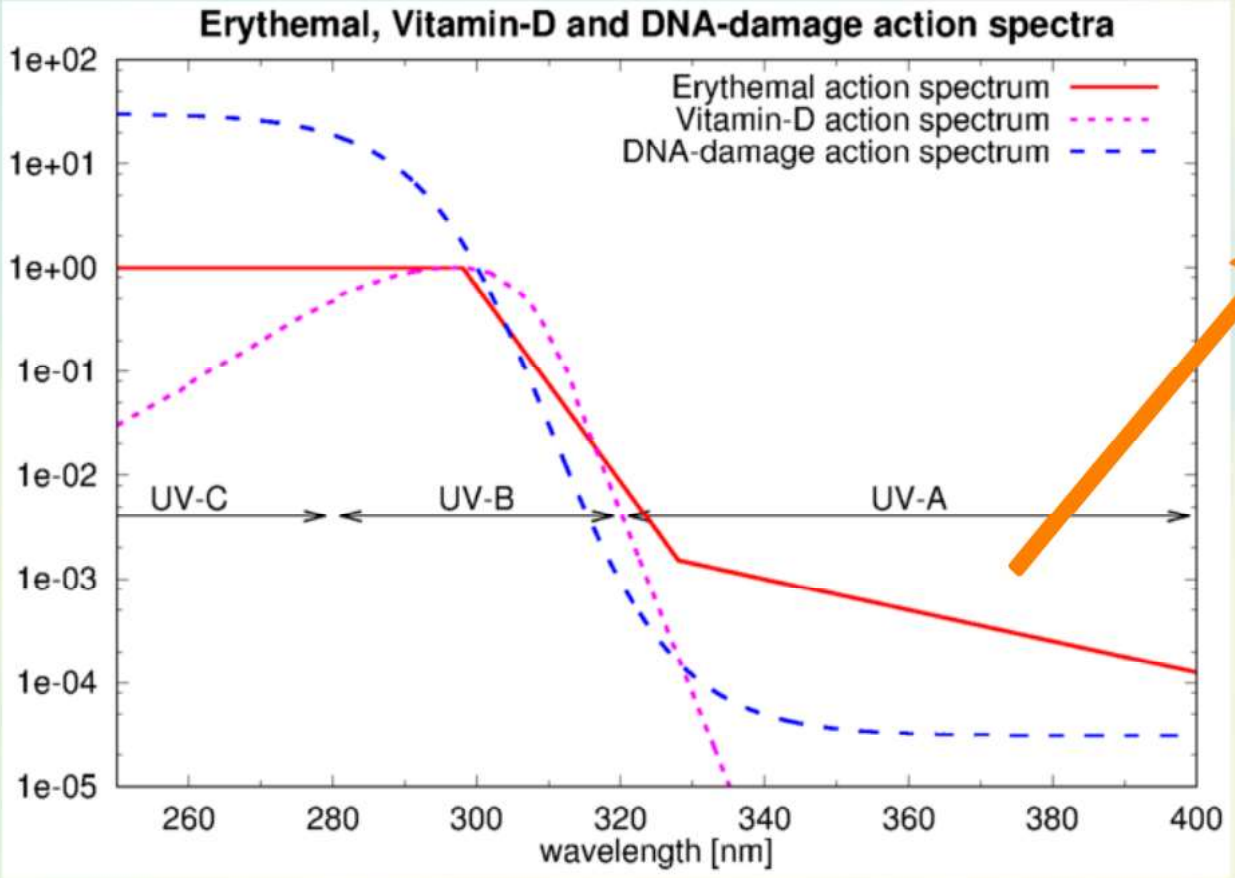
- general population
- outdoor workers

Little information about:

- doses and exposure conditions

Skin exposure

Curve action spectrum



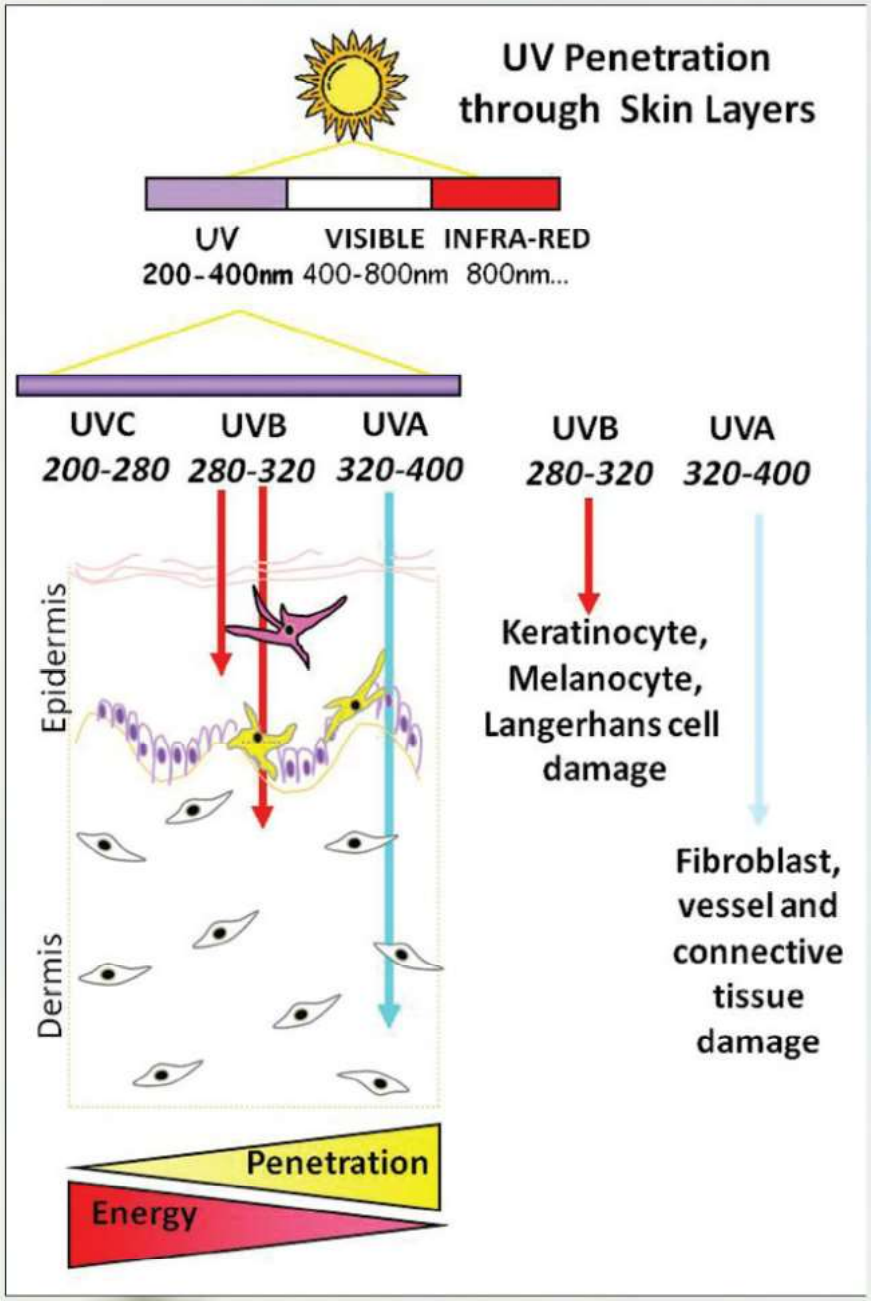
Skin ageing in truck driver

Skin exposure

Penetration of the radiation into the skin

vs. damage

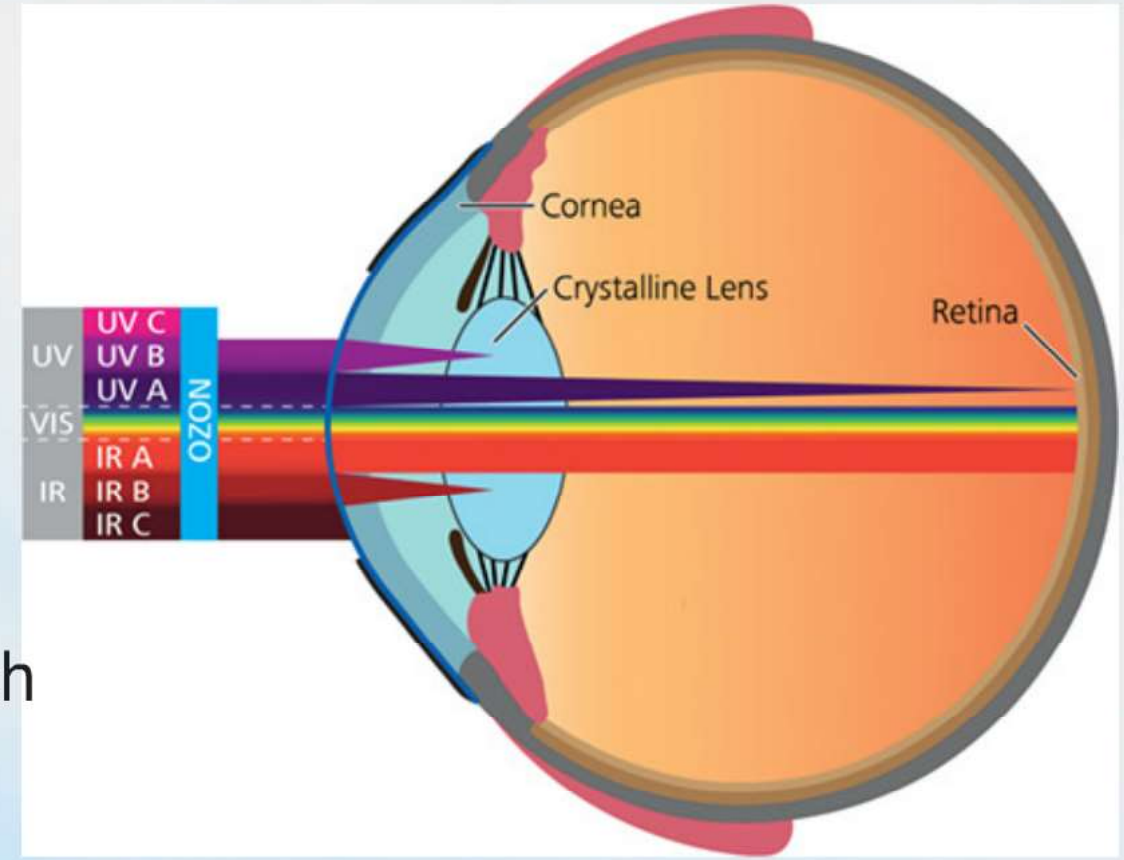
- ionising radiation
- oxidative stress mechanism



Eye exposure

Penetration of the radiation into the eye

- visible and blue light



Possible chronic health effects

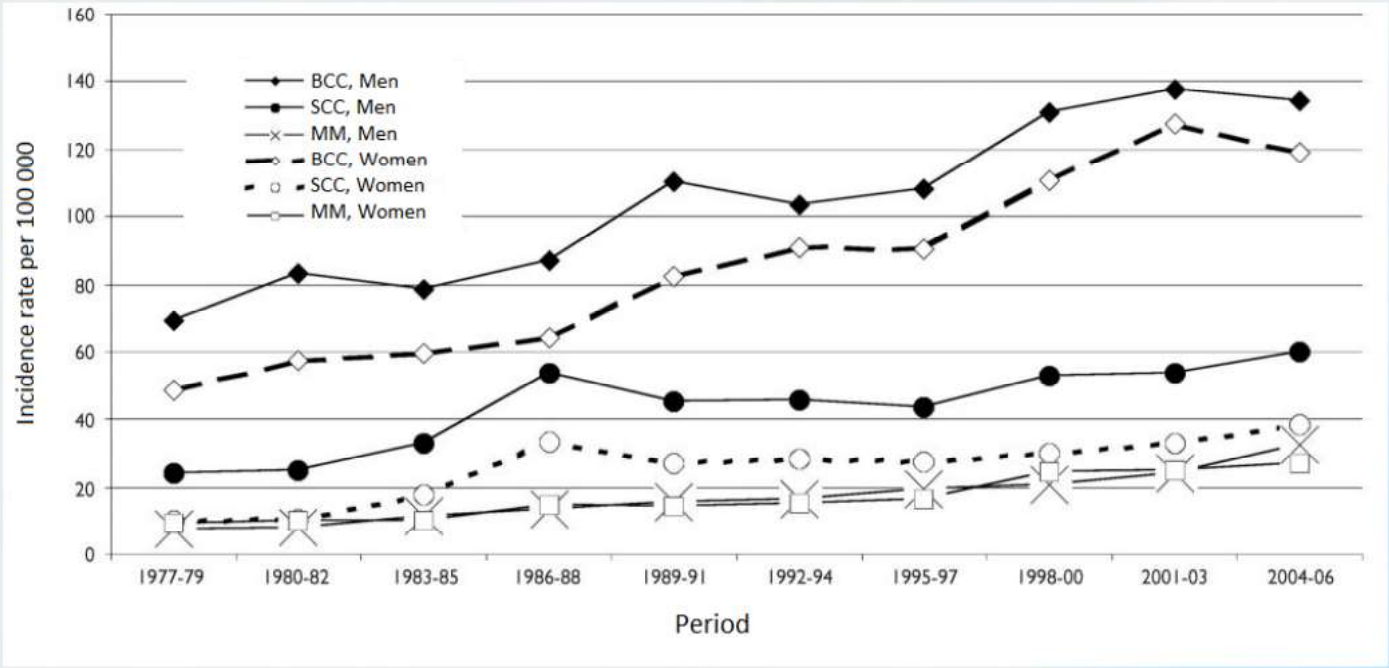
- cartaract, eye melanoma, age-related macular degeneration

Health effects

- erythema
- skin pigmentation
- vitamin D
- aging of the skin
- skin cancer...

about ~25'000 cases/ year in Switerland
90% carcinomes
10 % mélanomes

Incidence of skin cancer (Vaud)



Associated with outdoor work

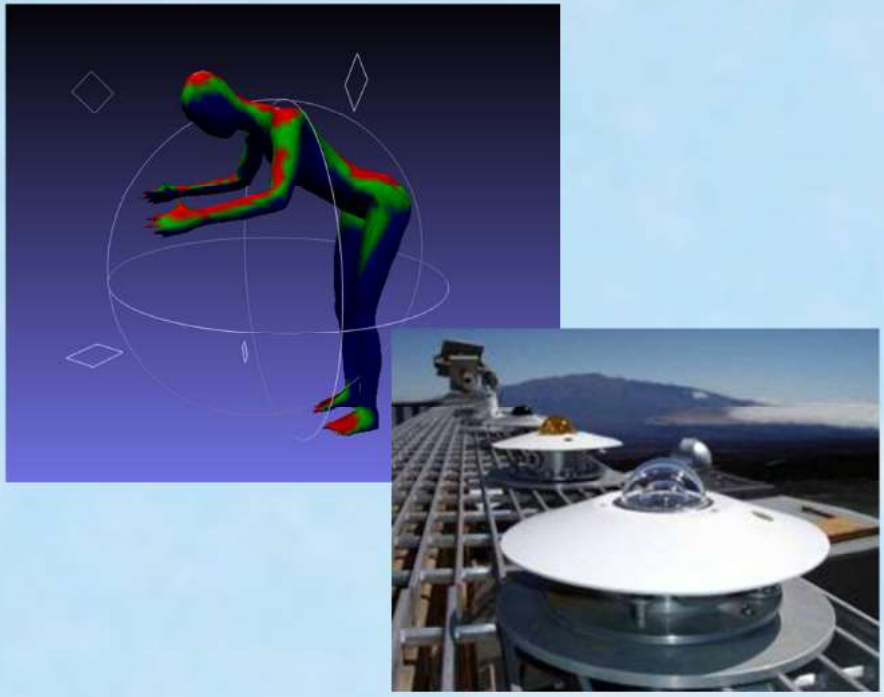
- Squamous and Basal Cell Carcinoma (SCC,BCC)
- Farmers SCC (OR>2)

Exposure assessment

Dosimetry

- individual, multiple anatomical sites
- requires time and resources

Individual dosimetry



irradiation measurement (broadband)

Modeling

- 3D model, using ground irradiance data
- does not take into account local conditions and individual factors

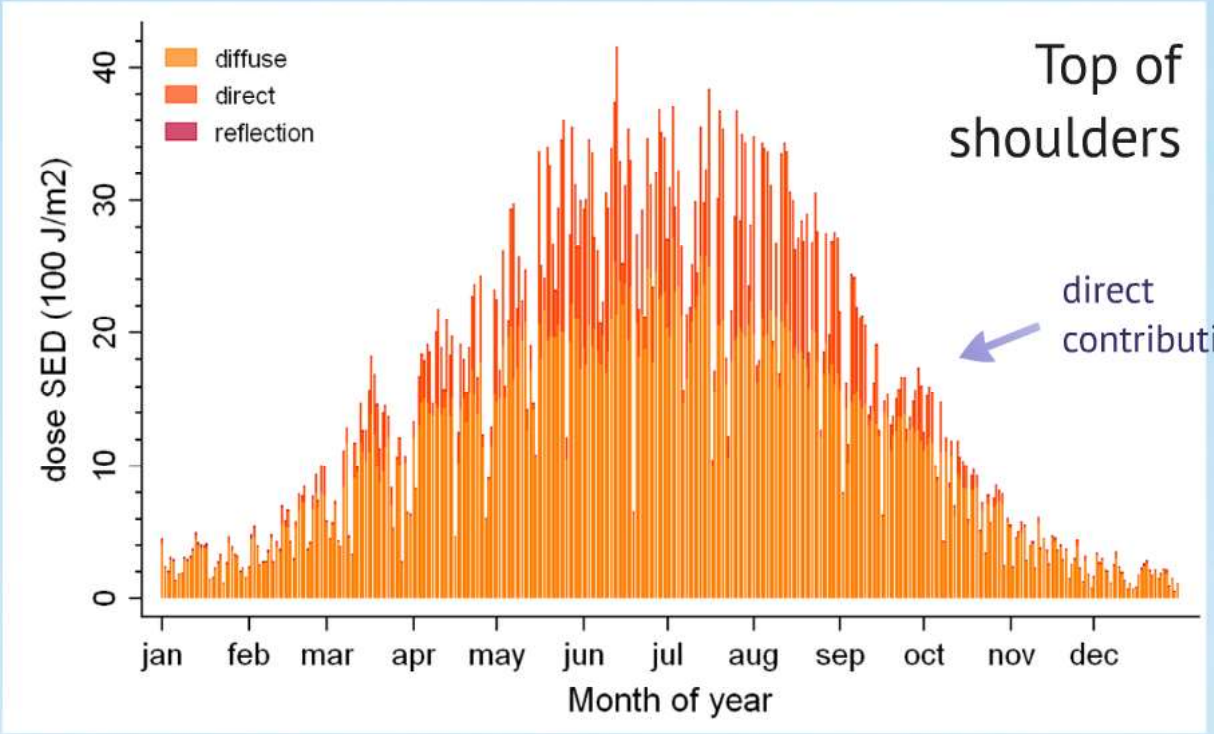
Estimated dose

Daily exposure of a standing man

- without protection, by radiation component
- contribution of direct radiation 24 %

Daily doses,
(8am-5pm)

Recommended value
0.3 SED



Vitamin D vs. sunburn

- comparison of exposure times
- monthly average, lowland situation (Switzerland)