

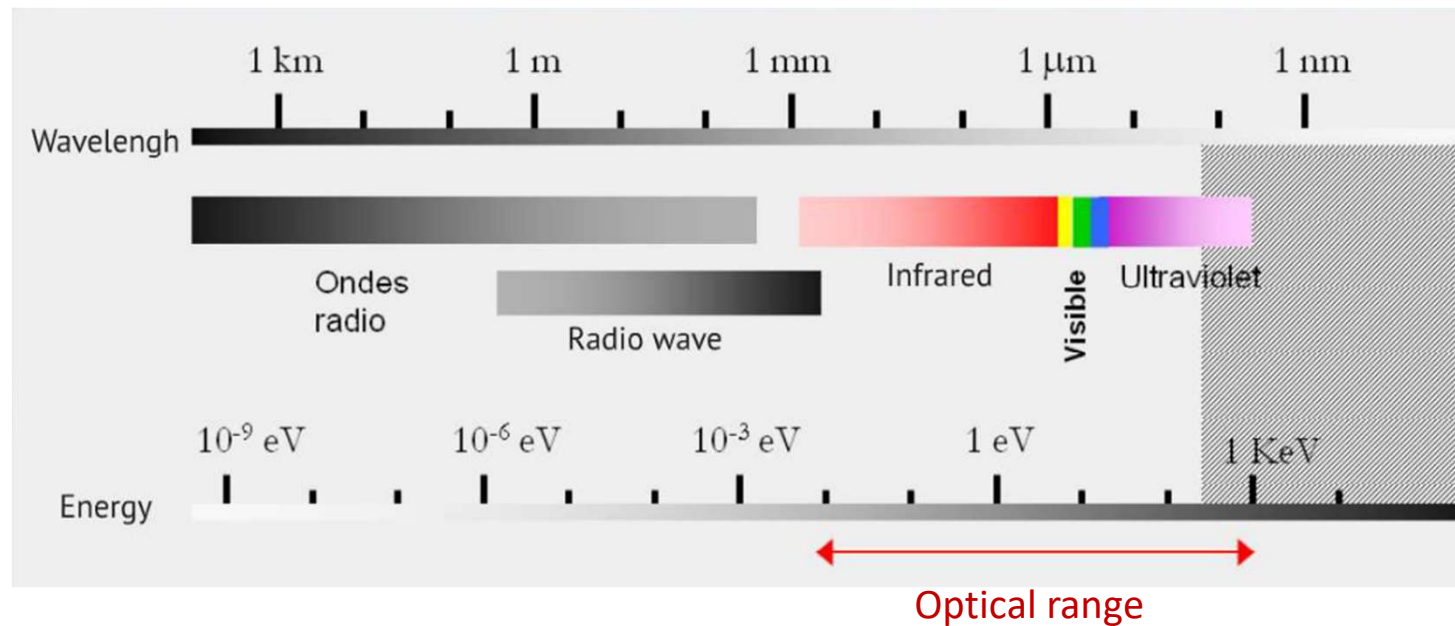
unisanté

4.3 Physical agents – Non ionizing radiations

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Electromagnetic field (EMF)



- Non ionizing radiation range: Wavelength > 1 nm
- Two main categories: radiofrequencies, optical radiation
- Relation frequency (f) – wavelength (λ) – speed of light (c)

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

Open question

EMF and risks

What are the risks related to electromagnetic fields?

Question (4.3 a)

Can you identify health risks related to electromagnetic fields and associate them with specific areas of application ?



EMF

Properties

Electric field E

- Associated with the presence of electric charges

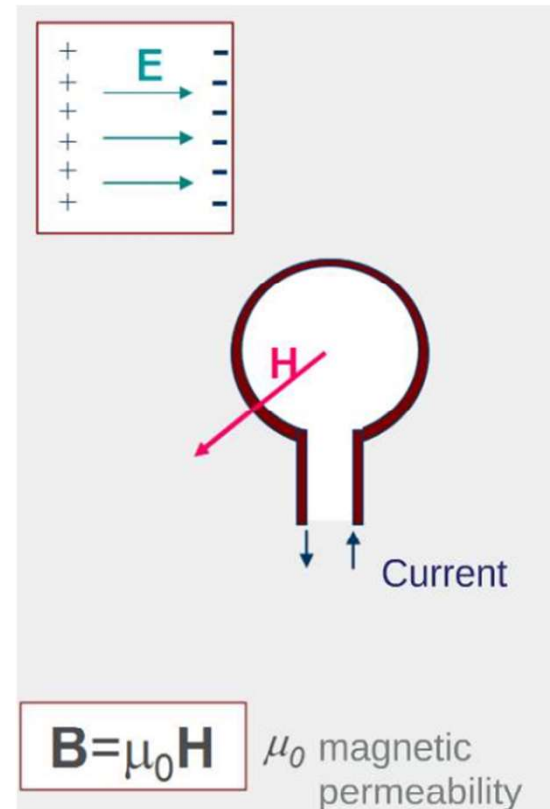
Magnetic field H

- Resulting from the movement of charges, and therefore of the electric current

Units

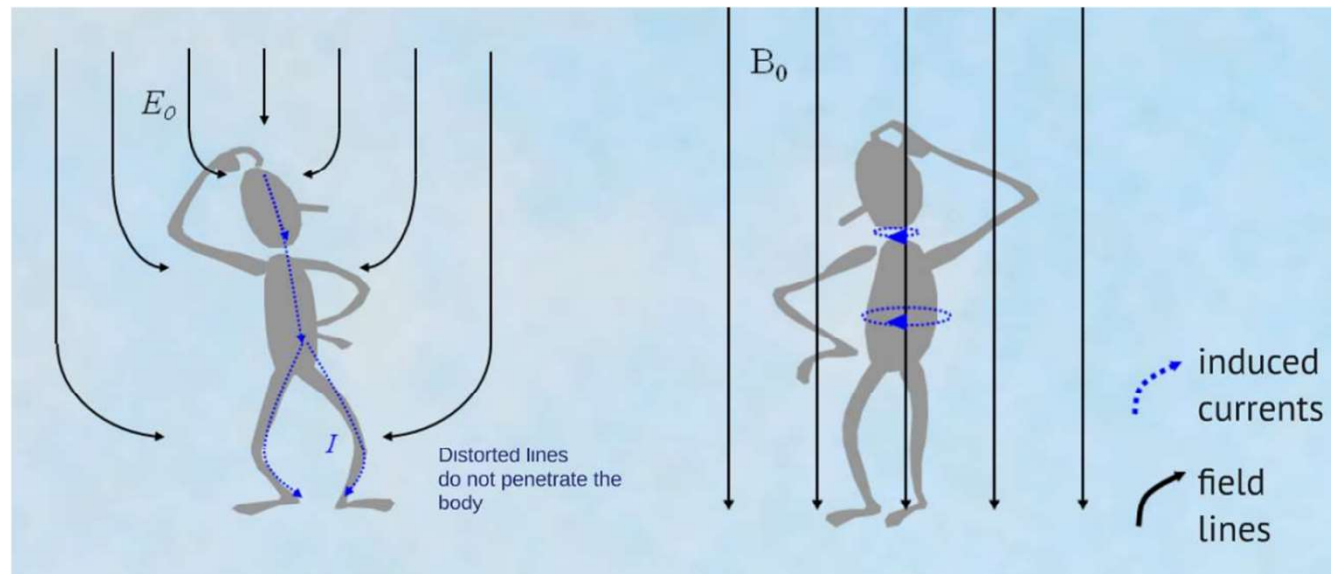
- Magnetic flux density B [Tesla]
- Magnetic field H [A/m]
- 1 Gauss = 10^{-4} Tesla

- In the air, a non magnetic environment
 $1 \text{ A/m} = 1.26 \cdot 10^{-6}$ Tesla



EMF

Interactions with the human body



E Field

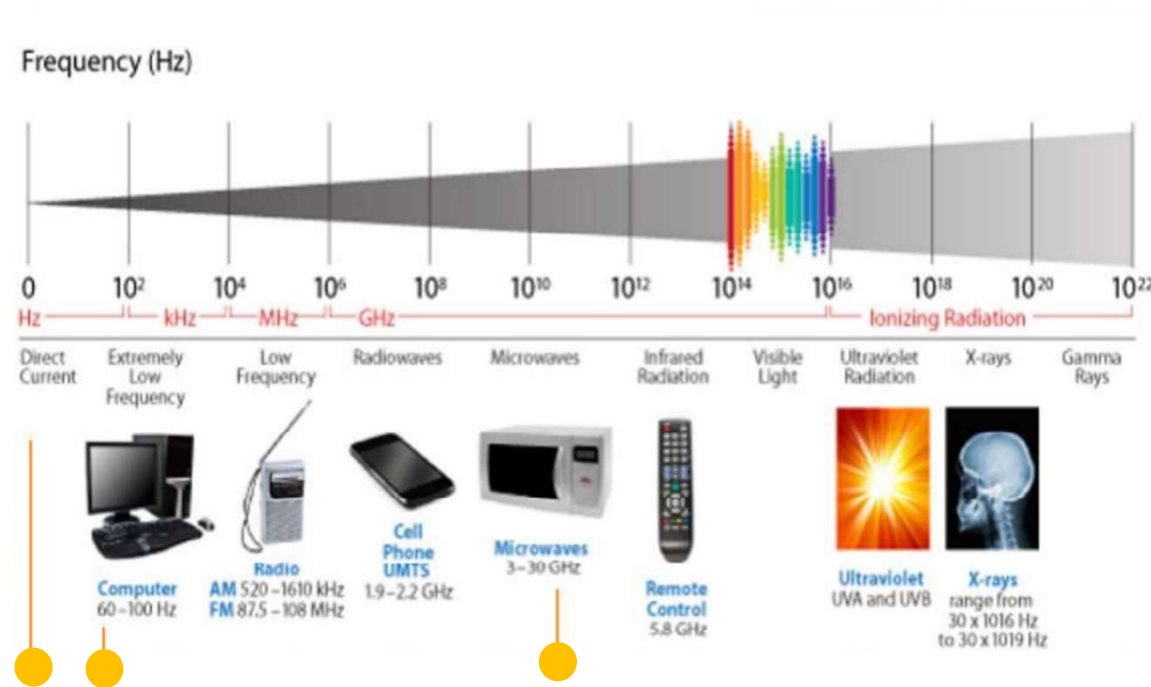
- Dipole formation
- Reorientation of dipoles
- Surface current formation

H Field

- Action on magnetosomes
- Force on the moving charges
- Current induction

EMF

Spectrum and applications



- Range of non-ionizing radiation over 16 orders of magnitude
- Domestic appliances, power lines (50 Hz)

EMF – static fields

Measurable effects

Deflection of moving charges

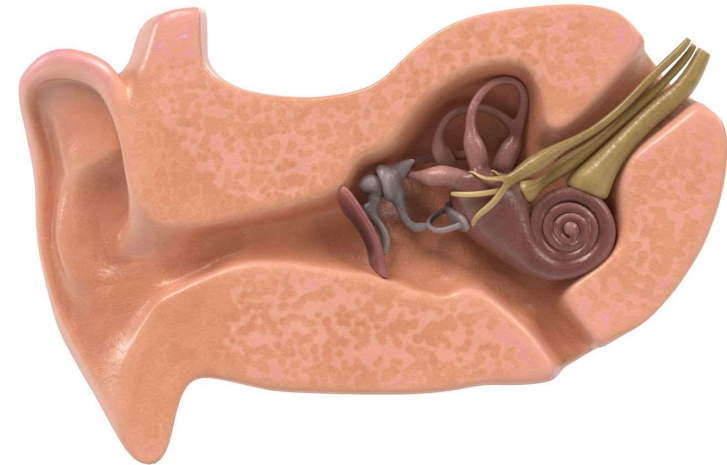
- Ionic currents in the semicircular canals
Dizziness, nausea
- > 2 Telsa, interactions with ECG
example: Magnetic Resonance (RMI)

Mechanical effects

- Orientation or displacement of polar molecules
Blood fluidity, magnetite in bacteria

Electromagnetic interactions

- Influence on the kinetic of chemical reactions
- Magneto-navigation in birds and insects
- Activate the production of free radical



High intensities

EMF – Extremely Low Frequencies (ELF)

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 field measured at 30 cm

Daily exposures (0-1000 Hz)

- Power lines, trains, subways, buses, electrical appliances, industrial equipment, computers

EMF – Extremely Low Frequencies (ELF)

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

Occupational exposures (0-1000 Hz)

- High intensities observed with industrial equipment

Magnetic field at a typical operating distance

EMF – Extremely Low Frequencies (ELF)

Measurable effects

Induced currents

- Low level, no confirmed biological effects
- High level, electrical discharge

Internal currents (extracellular fluids)

- Heating by Joule effect
- Depolarization of nerves, muscle contraction

Insulating membranes

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

EMF – Extremely Low Frequencies (ELF)

Risks of childhood leukemia

Power lines (50 Hz)

- Clusters of childhood leukemia in the vicinity of high voltage power lines (1979)
- Difficult interpretation
 - Rare disease
 - Conflicting studies
 - Confounding factor
- Statistical observation
 - No known explanatory mechanism
- Recent Meta-analysis
 - 40% of increased risk if $B > 0.4 \mu\text{T}$

IARC classification
(2001): 2B possibly
carcinogenic

EMF – Radiofrequencies

Body scanner (24 GHz)



- Low tissue penetration
1/10 mm
- Average scan time (10 s.)
- Surface power
 - 0.76 mW/m² passenger
 - 0.05 mW/m² passenger

EMF – Radiofrequencies

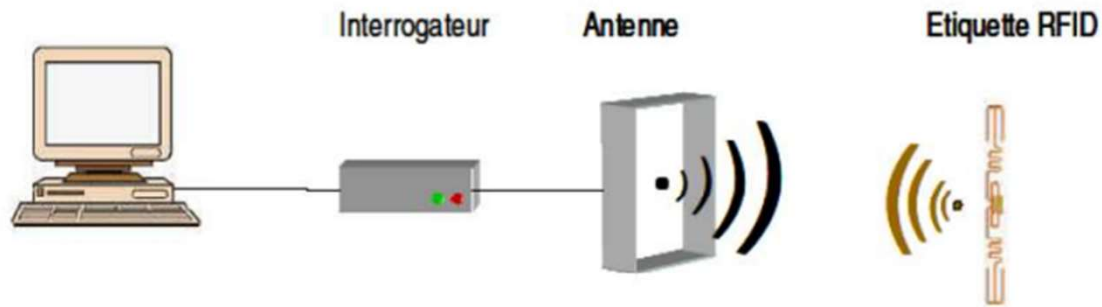
Radio frequency identification systems (RFID)

Short range

- 127-148 kHz, 13 MHz

Long range

- 434 MHz, 860 MHz, 2.45 GHz, 5,8 GHz



Sectors of use

- Smart cards, automobile, animals, Items identification
- > tens Mio/day produced for item identification

EMF – Radiofrequencies

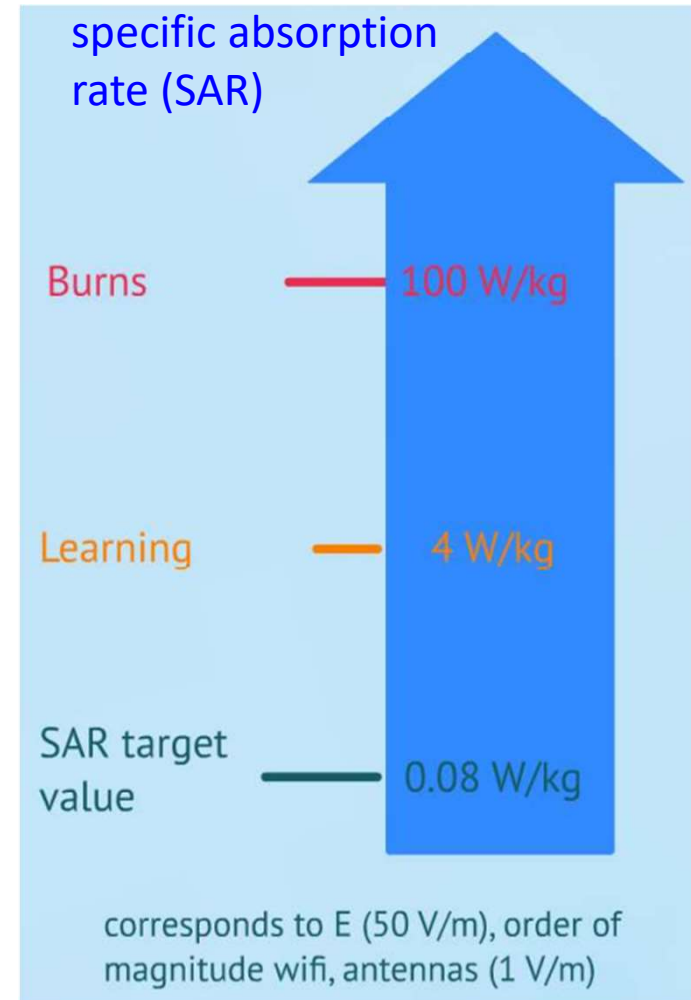
Measurable effects

Orientation of polar molecules

- Production of heat, heating of tissues

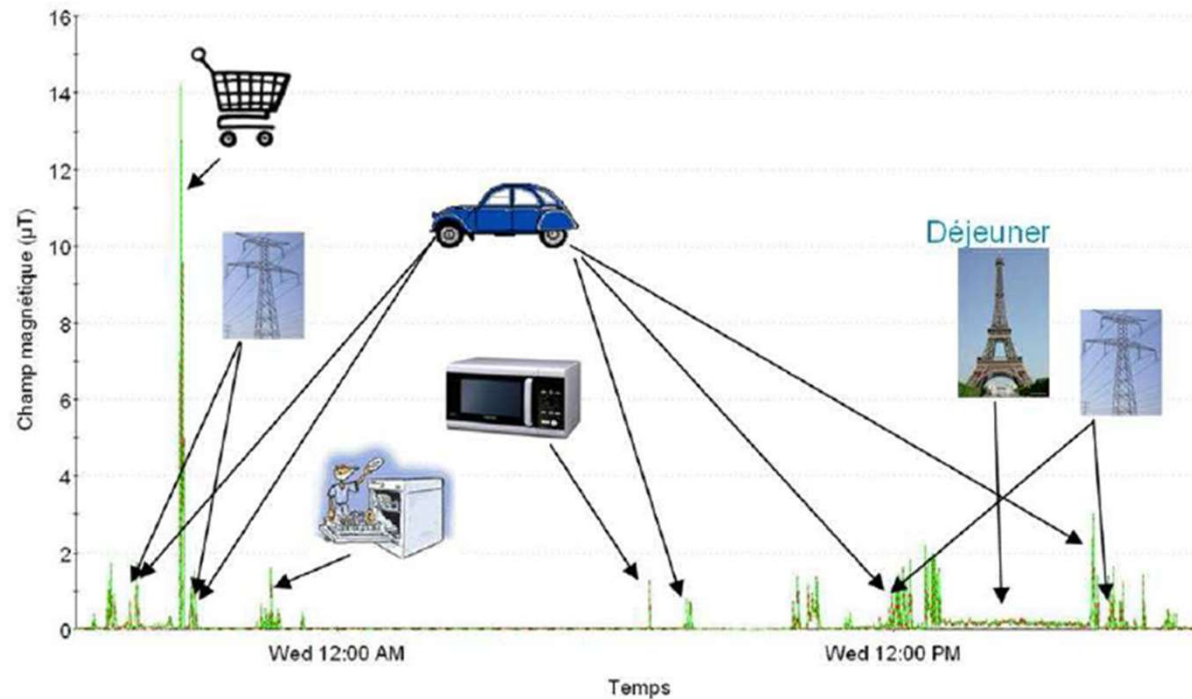
Possible effects

- Brain activity (e.g. sleep disturbance)
- Neurotransmitters disturbance
- Brain tumor (?)



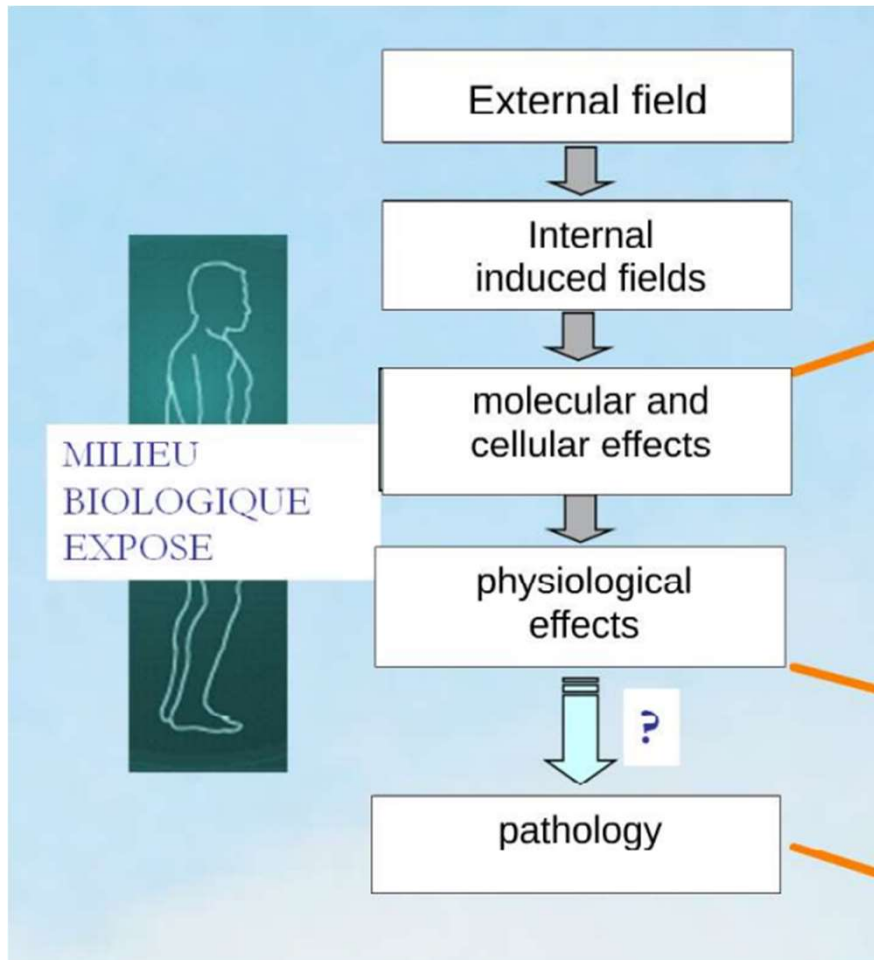
EMF – Cumulative exposure

A typical day in Paris



Individual dosimetry

- Recoding of a daily (24h) exposure pattern in low frequency range
- Identification of the sources



EMF – health effects

- Tissues heating
- Nerves and muscles simulations
- Dysfunction of the cardiac rhythm
- Effect on melatonin levels
- Disturbance of vision
- Alteration of cell membrane properties/functions
- Increased childhood leukemia

EMF – health effects

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



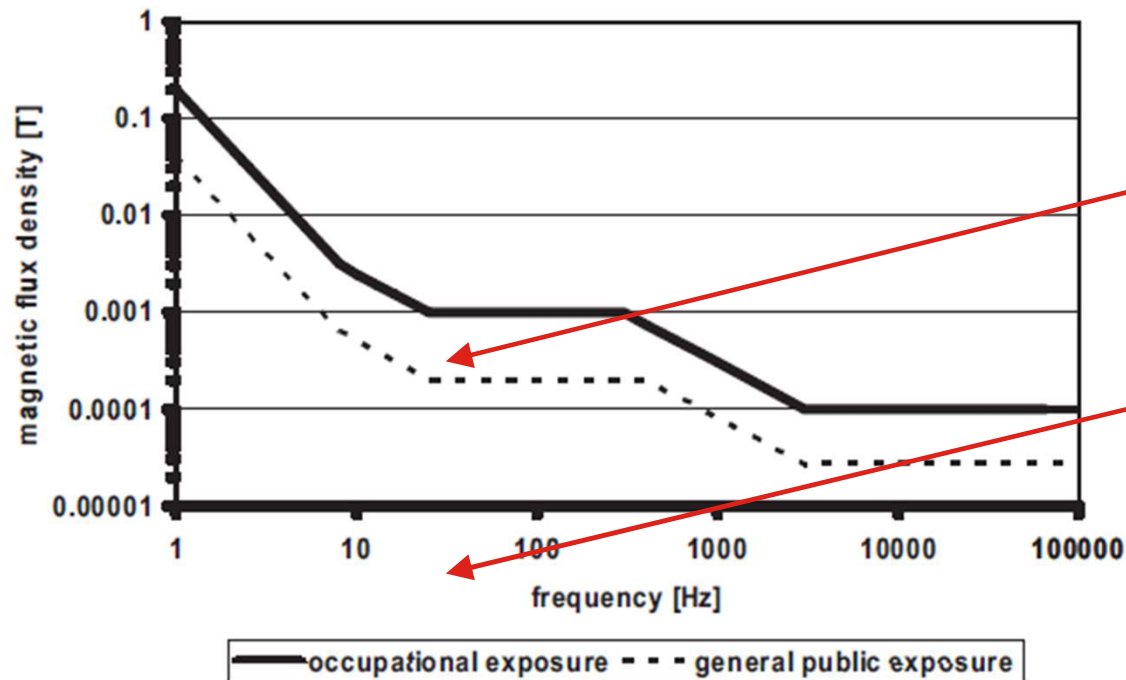
Is there a causal relation ?

Hills Criteria

EMF – exposure limits

ICNIRP guidelines

- International Commission on non ionizing radiation protection (2010)
- Magnetic field



Workers (Switzerland) – 500 μ T

General population (Switzerland) – 1 μ T (ORNI precautionary principle)

Case study

The MRI facility

Mrs Violet is manager in a medical research laboratory. She wishes to install an MRI (Magnetic Resonance Imaging). The device emits a permanent main magnetic field of 1.5 Teslas (300 mT at the tunnel exit and 5 mT at the control console located in the control room). It also emits a radiation of 6 V/m at 42 MHz during the examination.



Question (4.3 b)

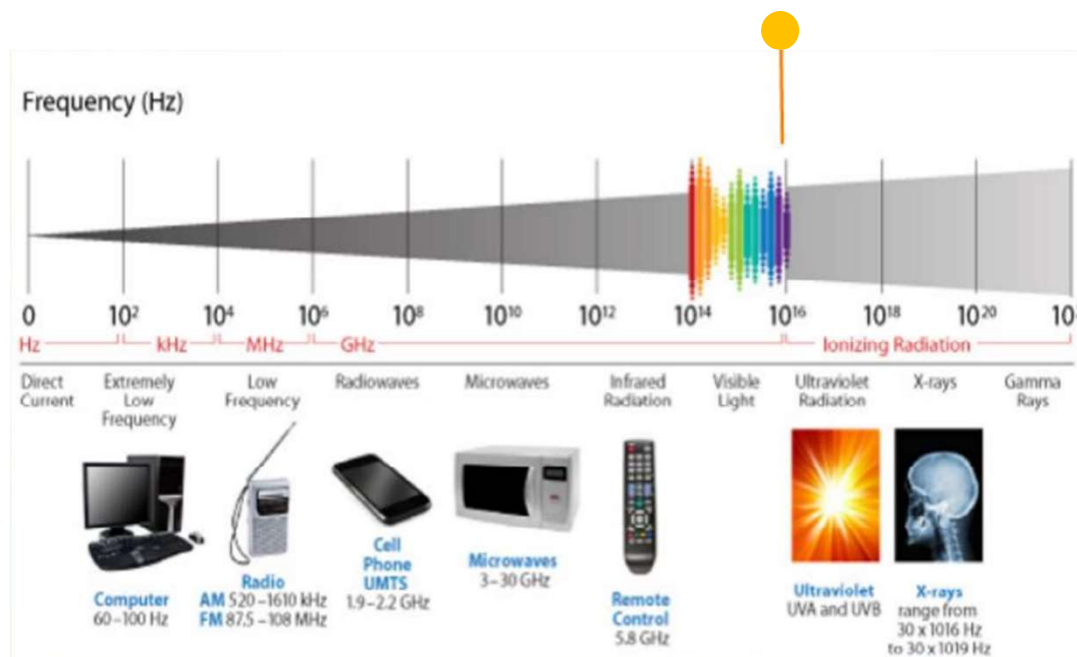
What risks (direct and indirect) should she consider when planning the layout of the room and the work organization ?

Consider the Suva reference values in your exercise: <https://www.suva.ch/fr-ch/prevention/themes-specialises/radioprotection-et-radioactive>

EMF

Spectrum and applications

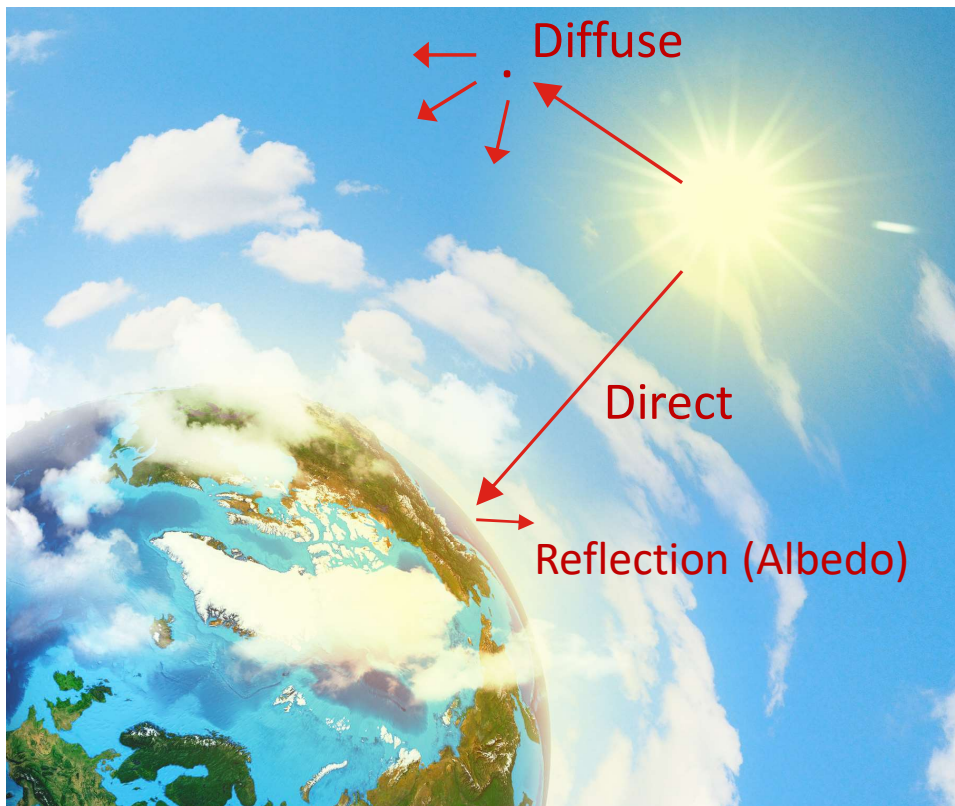
UV radiation



- Fringe of ionizing radiation
- Natural light, artificial sources

UV radiation

Ambient irradiance



- Radiation at ground level
 - 95% UV-A
 - 5 % UV-B
 - No UV-C
- Influencing factors
 - Altitude
 - Latitude
 - Weather conditions
 - Ozone layer

UV radiation

Exposure to solar UV

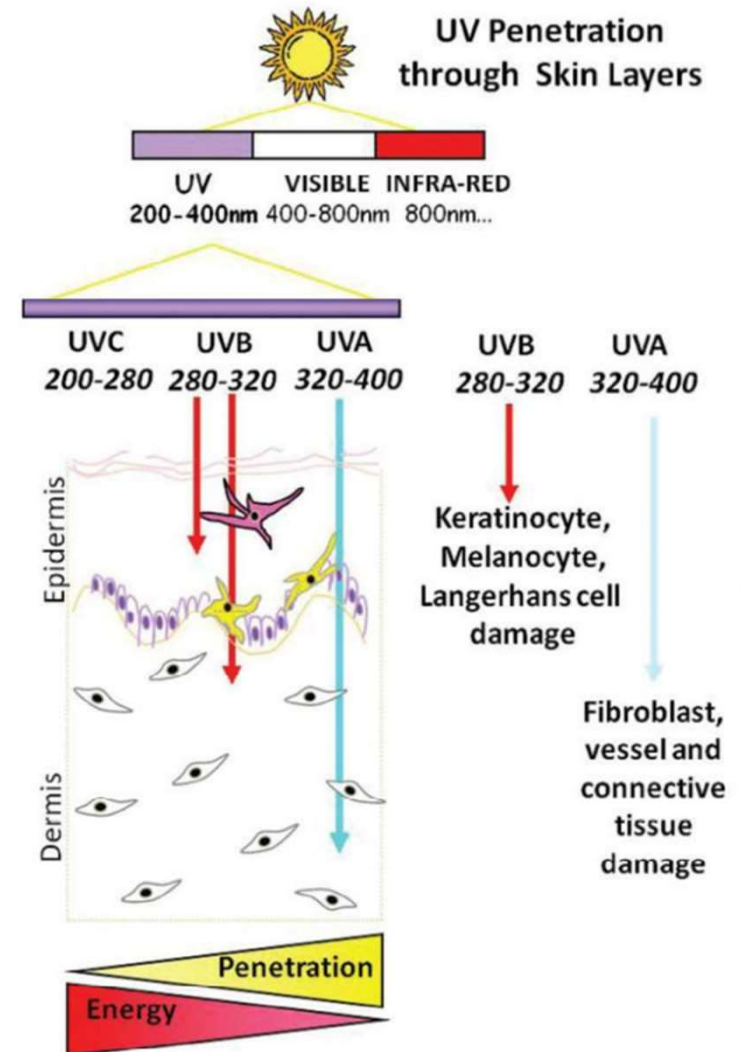
- Individual factors
 - Clothing sun protection
 - Exposure duration, period
 - Posture
- Exposed population
 - General population
 - Outdoor workers



UV radiation

Skin exposure

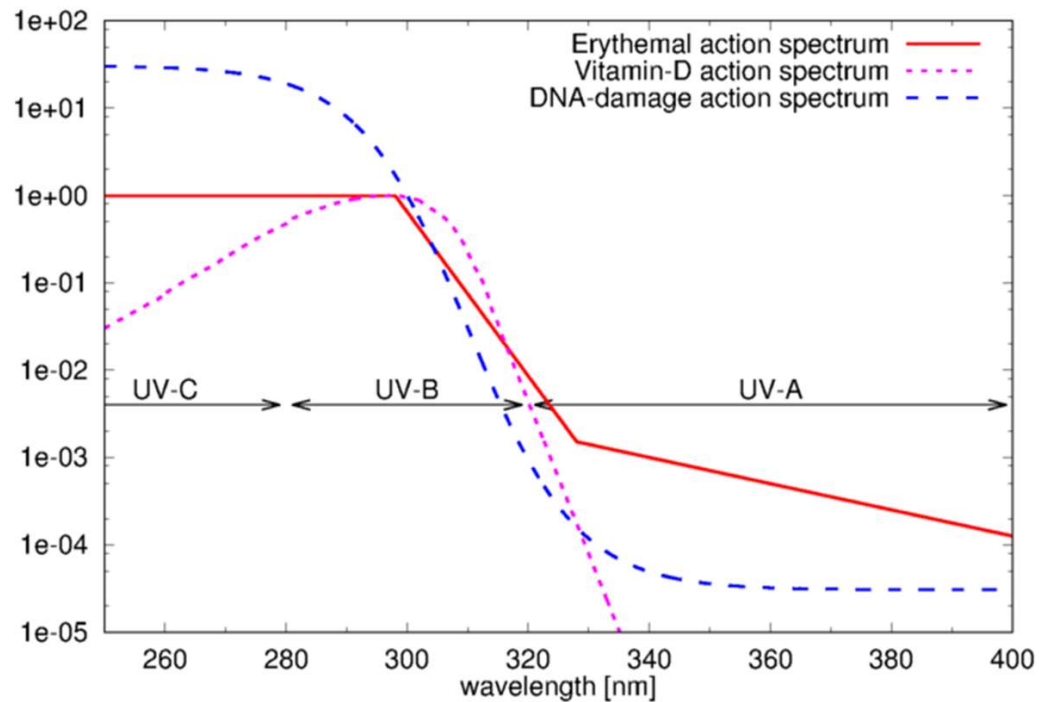
- Penetration of the radiation into the skin
- Short wavelength UV – lower penetration but higher energy
- Long wavelength UV – higher penetration but lower energy



UV radiation

UV Action spectra

Direct
genotoxic
effects - high
biological
efficacy

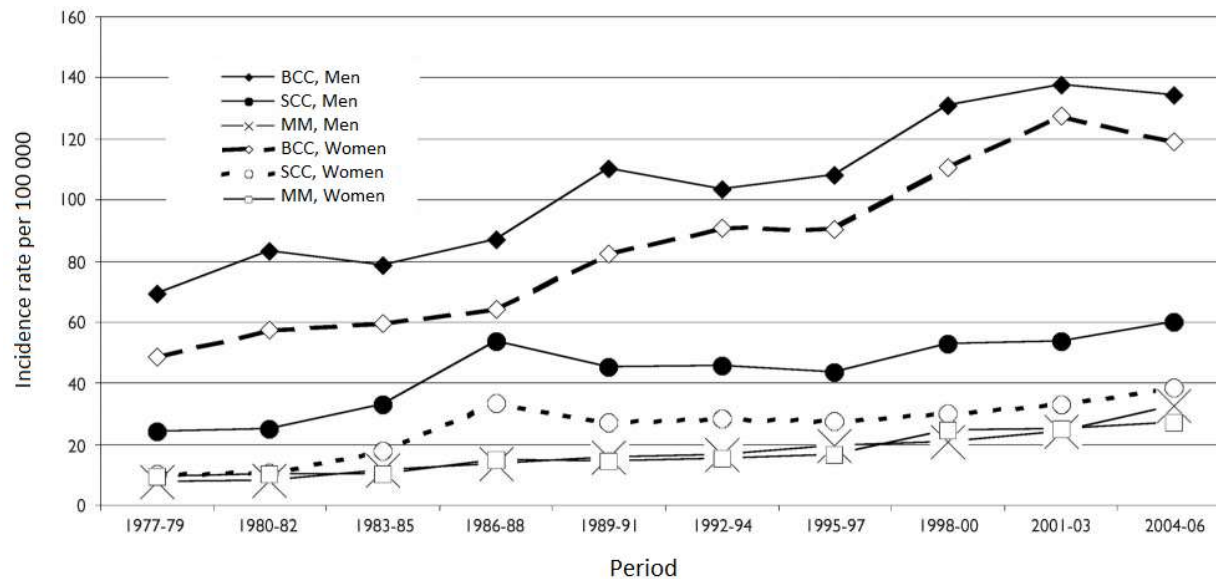


Indirect effects -
low biological
efficacy

UV radiation

Health effects (skin)

- Incidence of skin cancer (Vaud)



- Skin cancer
 - About 30'000 cases/year in Switzerland
 - 90% carcinomas (BCC and SCC)
 - 10% melanomas
- Other effects
 - Erythema, skin pigmentation, vitamin D, aging of the skin

Case study

The printing industry

A 69-year-old truck driver visits his doctor with thickened skin and pronounced wrinkles on the left side of his face.

Question (4.3c)

What happened, can you formulate an hypothesis ?

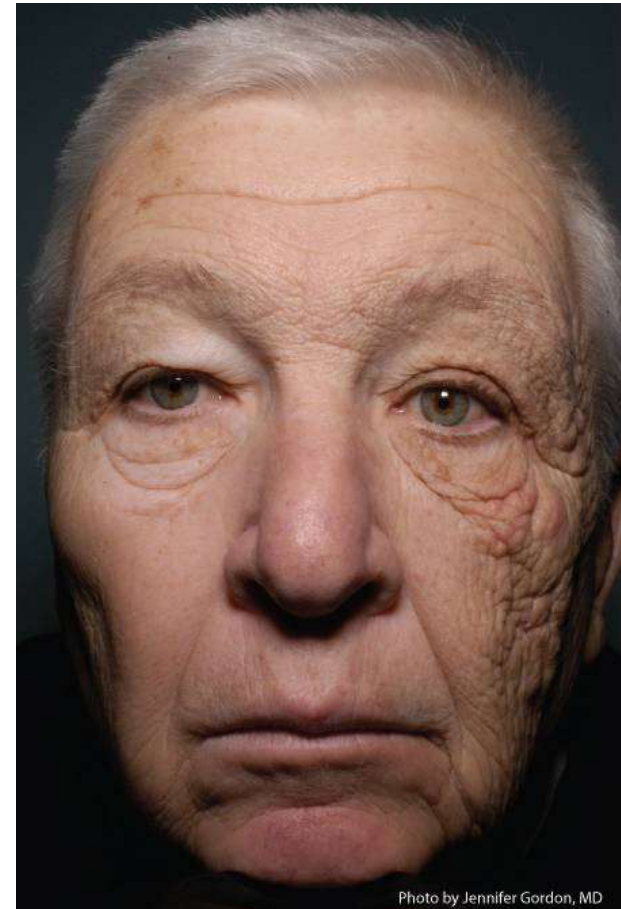
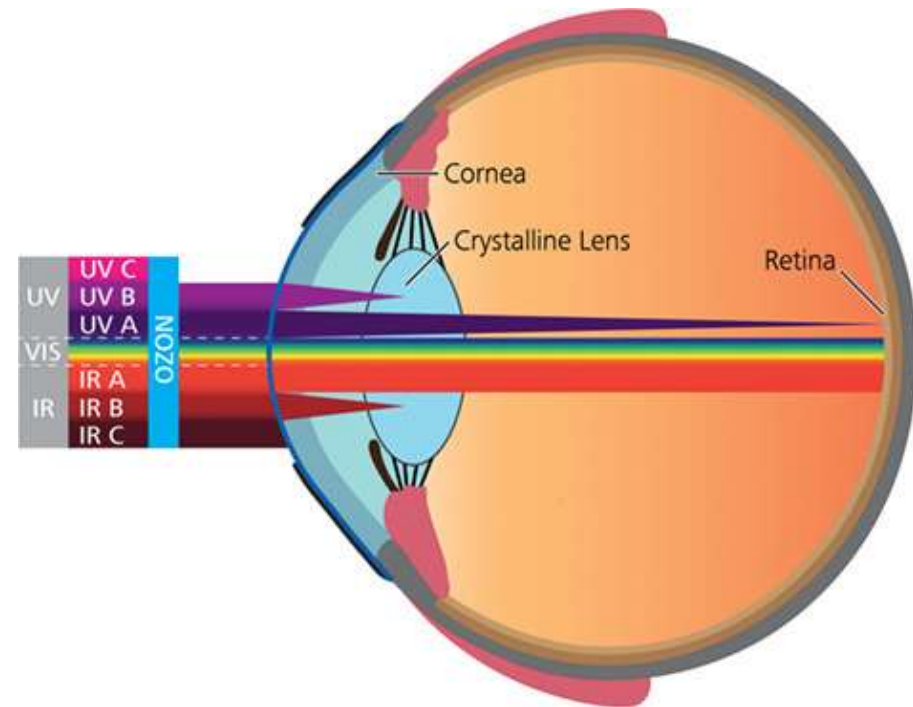


Photo by Jennifer Gordon, MD

UV radiation

Eye exposure

- Penetration into the eye:
 - UVB is absorbed in the cornea and lens
 - Only visible and blue light reach the retina
- Possible health effects:
 - Cataract, eye melanoma, age-related macula degeneration

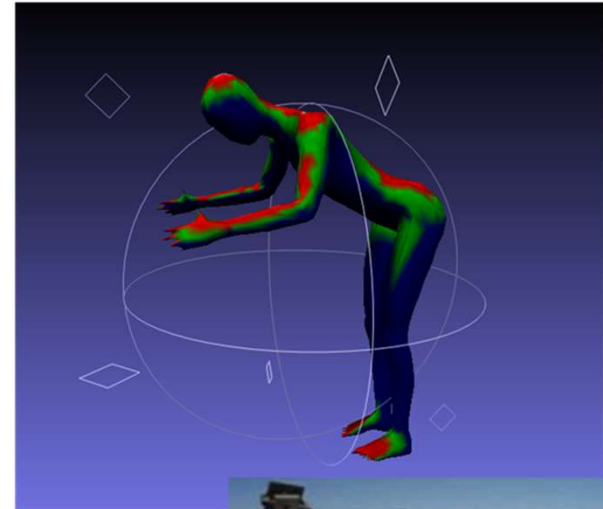


UV radiation

Exposure assessment



- UV dosimetry
 - Individual (+) Precision (+)
 - Resources (-), anatomical variability (-)
- UV Modelling
 - 3D model, using ground irradiance data
 - Wide scale modelling (+), resource's (+)
 - Effects of local and individual factors (-)

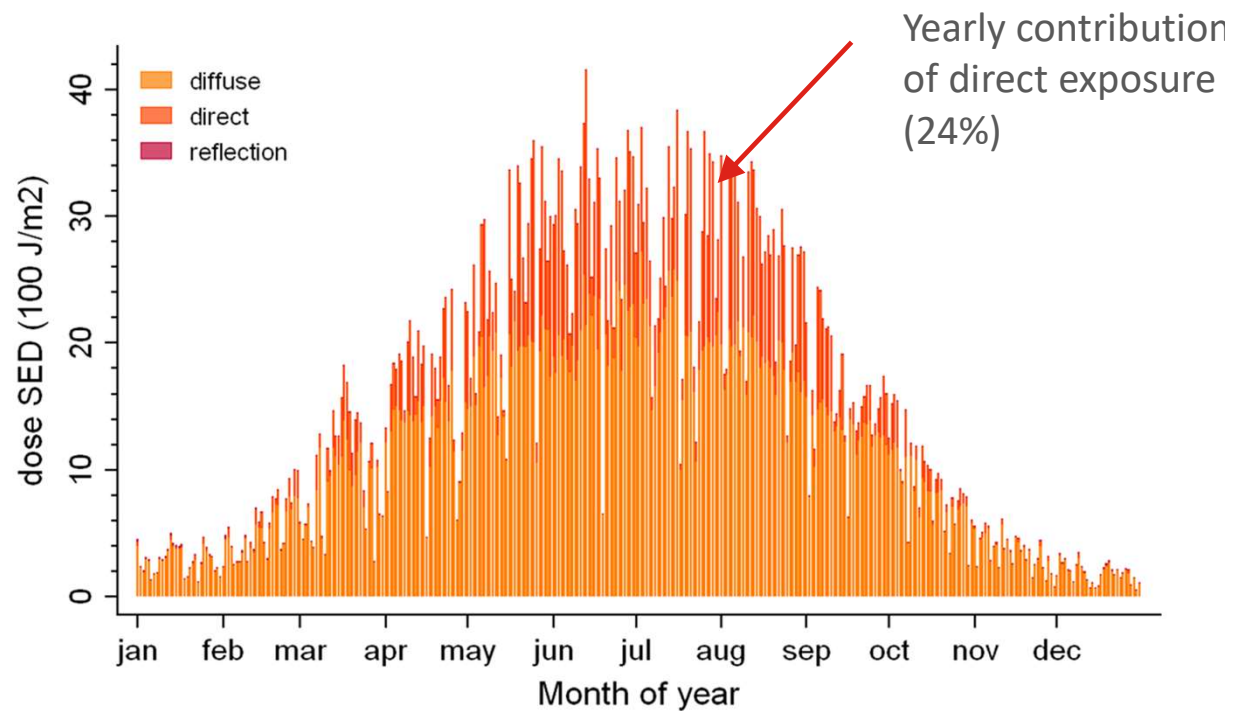


UV radiation

Exposure assessment (modelling)

- Daily exposure
 - 8 am-5pm
 - standing individual
 - No UV protection
 - By radiation component
 - Standard Erythemal dose (SED)
- **Top of shoulders**

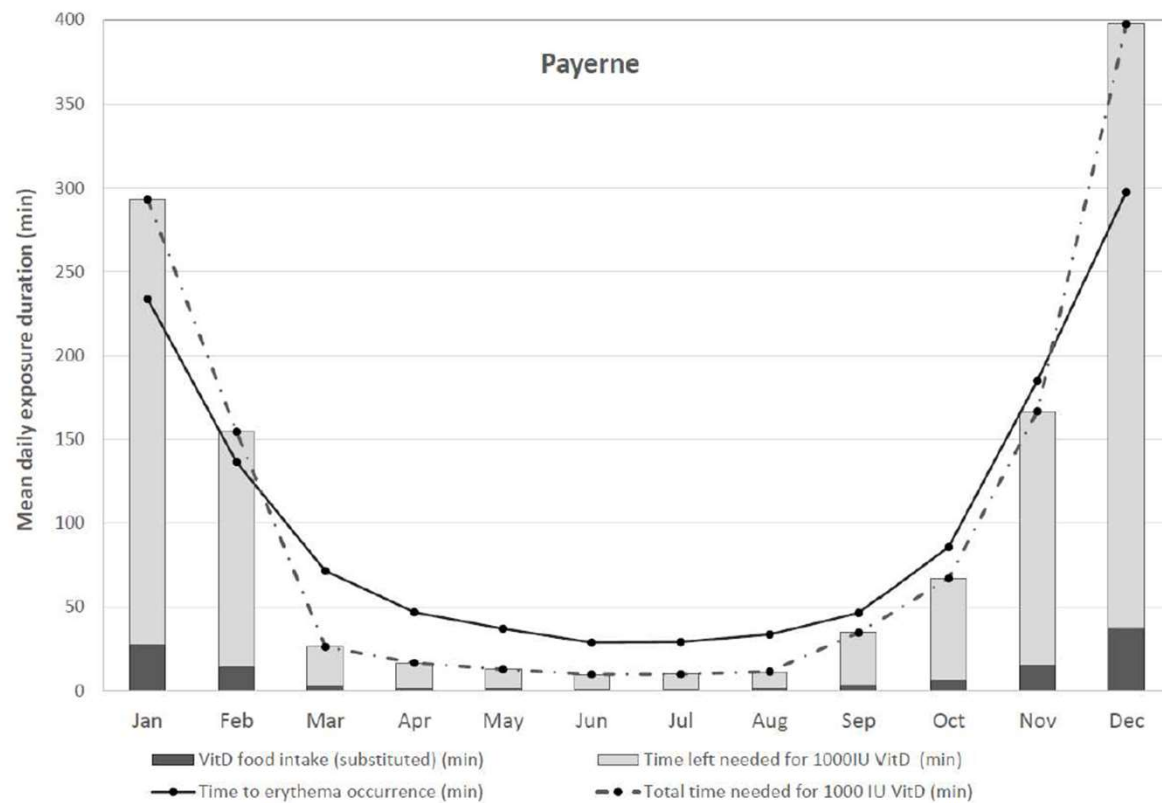
ICNIRP recommendation:
0.3 SED



UV radiation

Vitamin D vs. Erythema

- Comparison of daily exposure times
 - To get an erythema
 - To get enough vitamin D



Case study

Outdoor construction work

An exposure simulation was used to estimate the daily UV-erythemal dose to the face of a construction worker on 4 different (typical) days of the year.

Question (4.3 d)

What periods of the year and conditions correspond to Figures 1-4?

Can you explain the reason for the small contribution of direct irradiation to the total dose?

What phenomena are responsible for the "reflected" exposure peaks in situation 3? What are the associated risks?

