Basis of radiation protection

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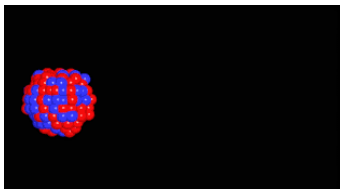
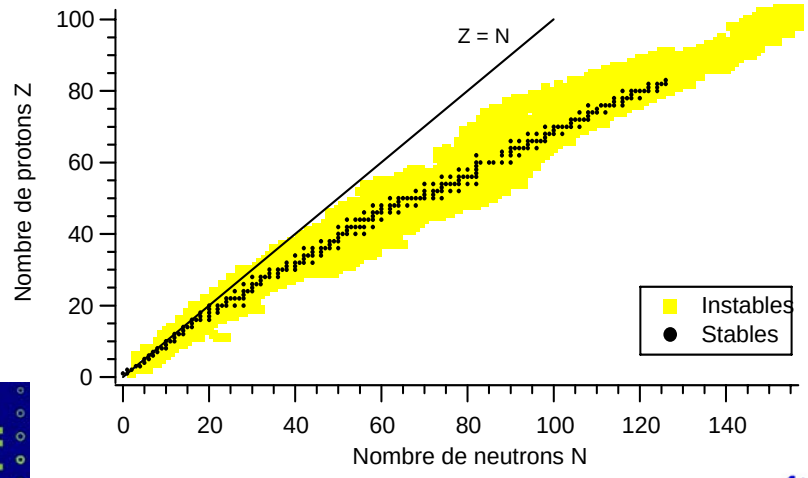
Outline

- Radiation physics
  - Nuclides
  - Radioactive decay
  - Dosimetry
- Radiation protection
  - JOLi - principle
  - Dose limits
  - Population exposure
  - Operational radiation protection
  - Radiation monitoring



Map of the nuclides



Radioactive decay

- Alpha
- Beta
  - Beta -
  - Beta +
  - Electron capture
- Gamma
- X-ray fluorescence
- Auger electron

Shielding

- Alpha
- Beta
  - Beta -
  - Beta +
  - Electron capture
- Gamma
- X-ray fluorescence
- Auger electron

- Which physical quantity characterizes radiation biological effects in matter ?

Absorbed dose

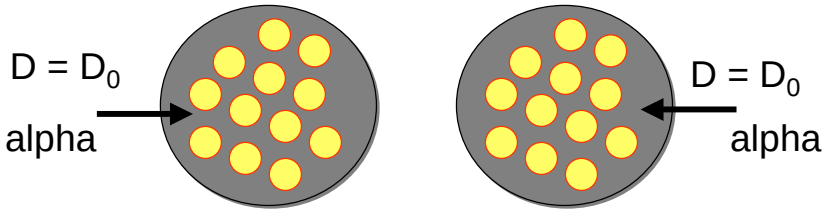
$$D = \frac{d\bar{\varepsilon}}{dm} \quad \left[J \cdot kg^{-1}\right] = [Gy]$$

Absorbed energy per mass unit

Main effect : heat
2 Gy in water → about 0.5 mK

Absorbed dose and biological effects

- The absorbed dose is not always directly related to the biological risks



Equivalent dose

$$H = \sum_R w_R \, D_R \qquad \left[J \cdot kg^{-1} \right] = [Sv]$$

Radiation type

Radiation weighting factor

Absorbed dose delivered to target organ

Dose weighted by a biological factor

Radiation weighting factor w_R

Radiation type	W_R
X-ray, γ , electrons	1
protons	5
neutrons	5-20
α -particules	20

Effective dose

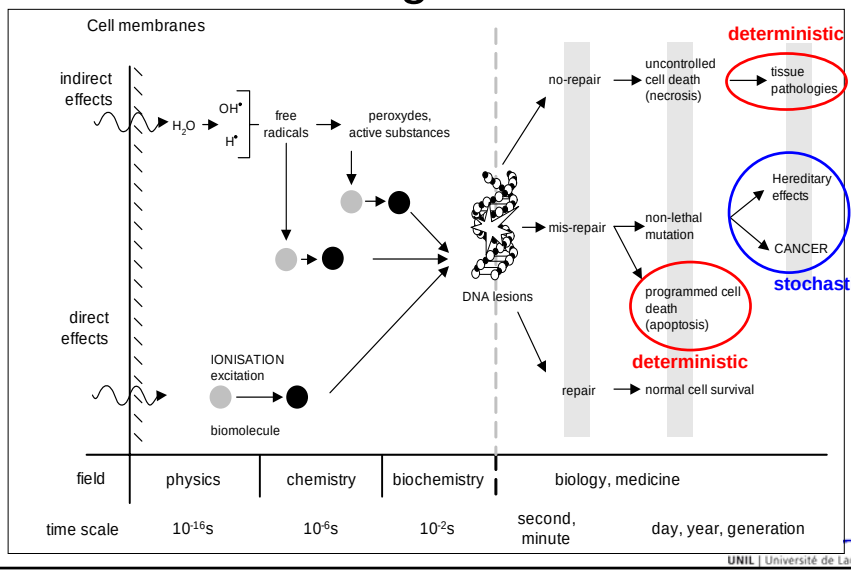
- Synthetic dose indicator

$$E = \sum_T w_T H_T \quad [Sv]$$

tissue weighting factor

Tissue or organ	w_T
Bone surface, skin	0.01
Bladder, breast, liver, oesophagus, thyroide, rest	0.05
Bone marrow, colon, lung, stomac	0.12
Gonads	0.20

Effects of ionizing radiation on living matter



Effects classification

Nature	Deterministic	Stochastic
Mecanism	Loss of functionality	?
Delay	Generally **immediate**	?
Effect of dose variation	Effect severity	?
Dose level	Only at high doses	?
Threshold	Proved	?
Example	Erythema	Cancer induction

Effects of acute whole body radiation

Organ or tissue	Dose range
Bone marrow	1 - 10 Sv
Gastro-intestinal	8 - 15 Sv
Central nervous system	> 50 Sv

Characterization of deterministic effects

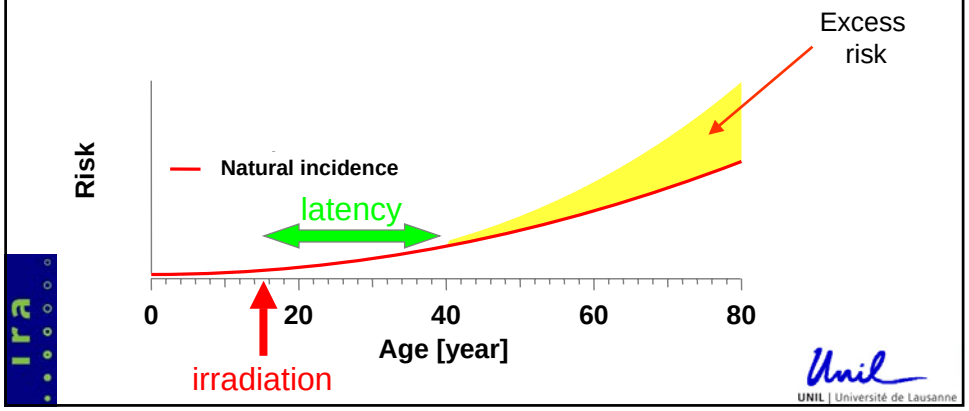
- Threshold dose: 0.5 Sv
- Lethal dose, 50%: 5 Sv

Stochastic effect measurement

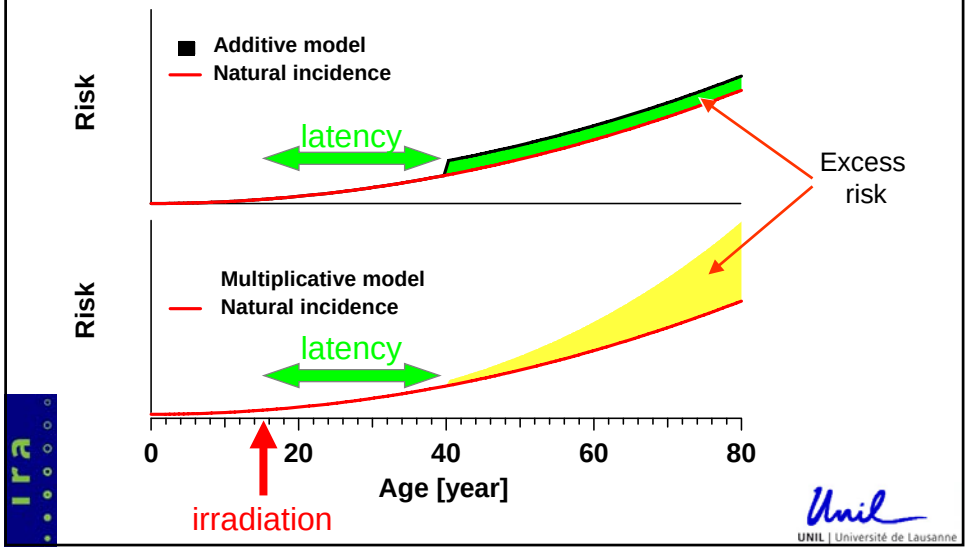
- Risk factor: r
  - Number of excess cases per unit of the representative quantity
- Example
  - Death risk related to road traffic

$$r = \frac{\text{number of road traffic deaths in Switzerland}}{\text{number of km driven}} = \frac{600}{7'000'000 \times 15'000} \cong 10^{-8}\,\text{km}^{-1}$$

Induction model for stochastic effects



Induction model for stochastic effects



Radiation induced cancer

- Epidemiological data
  - Hiroshima & Nagazaki atomic bomb survivors
  - Radiation dose level: 1 Sv
- Latency period
  - Leukemia: 10 y
  - Solid cancer: 20 y
- Multiplicative model
- Low dose extrapolation
  - Reduction factor of 2

Risk factor : 4% Sv^{-1}

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Induction of genetic effects

- Data
  - Animal experiments
- Effect
  - Nonspecific malformations
- Doubling dose
  - 1 Sv

Risk factor: 1% Sv^{-1}

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Total risk factor

- Induction of cancer
- Induction of genetic effects

4% Sv^{-1} **1% Sv^{-1}**

Total risk factor: 5% Sv^{-1}

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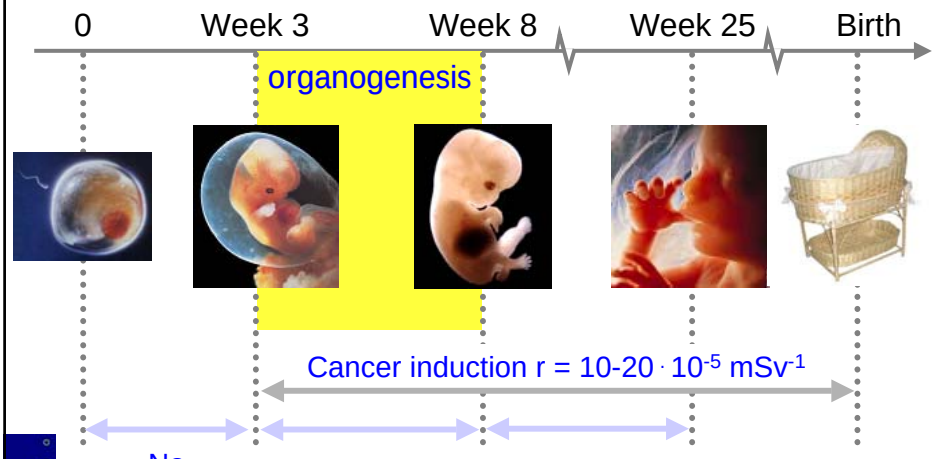
In-utero radiation exposure



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Basic principles of radiation protection

- **J**ustification of activities using radiation
- **O**ptimisation of protection measures
- **Li**mitation of individual doses

- **JOLi**

Limitation of individual doses

- J & O from JOLi could result in accepting high individual doses
- Limitation of the stochastic risk
- Distinction
  - Workers (occupational exposure)
  - Public
  - Patient

Effective dose range

50 Sv	• Lethal dose
5 Sv	• Lethal dose, 50%
500 mSv	• Threshold for deterministic effects
20 mSv	• Dose limit per year for workers
4 mSv	• Annual exposure of the Swiss populatio
1 mSv	• Dose limit per year for public
100 µSv	• De minimis dose for workers
10 µSv	• De minimis dose for public

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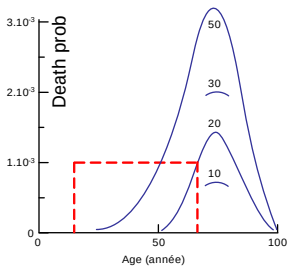
Dose limits for radiation workers

- Age-period : 18 to 65
- Stochastic risk
  - 20 mSv / year



- Deterministic risk
  - Eye lens : 150 mSv / year
  - Skin : 500 mSv / year
  - Extremities : 500 mSv / year

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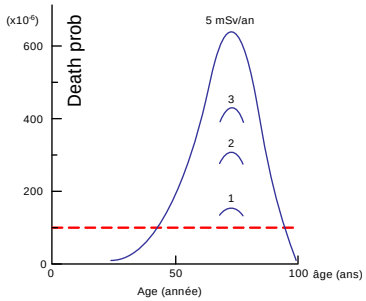
Dose limits for individual members of the public

- Period : whole life
- Stochastic risk
  - 1 mSv / an
- Deterministic risk
  - stochastic limit ok



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Dose limits for patients

- What is the dose limit for a patient receiving a radiological examination?

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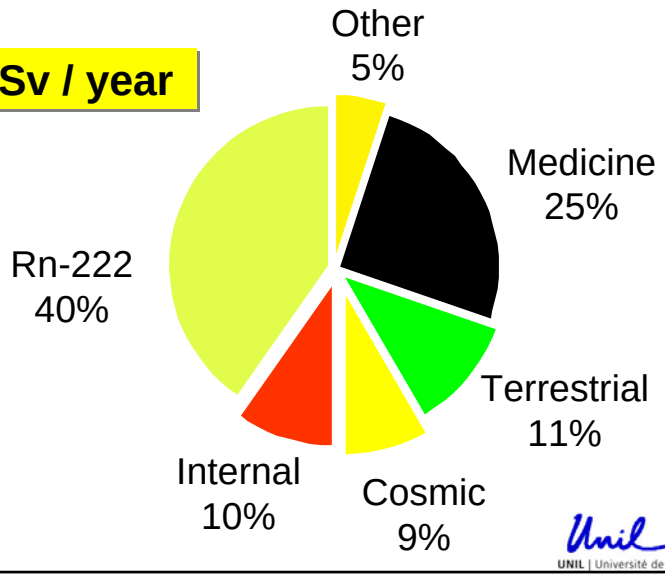
Dose limits for patients

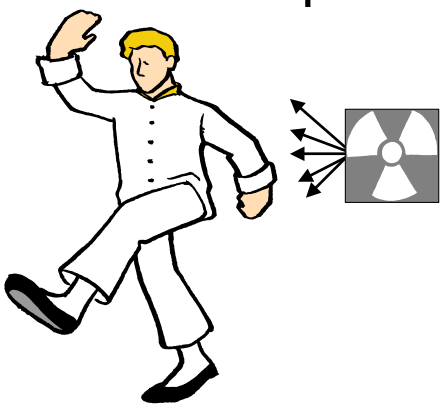
- Cost-benefit analysis done by the doctor
  - indication for radiological examination
- The patient directly benefits from the received dose

Radiation exposure in Switzerland

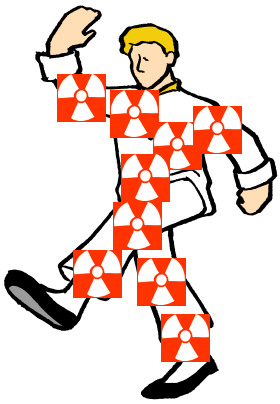
Total: 4 mSv / year



Operational radiation protection



External radiation



Internal contamination

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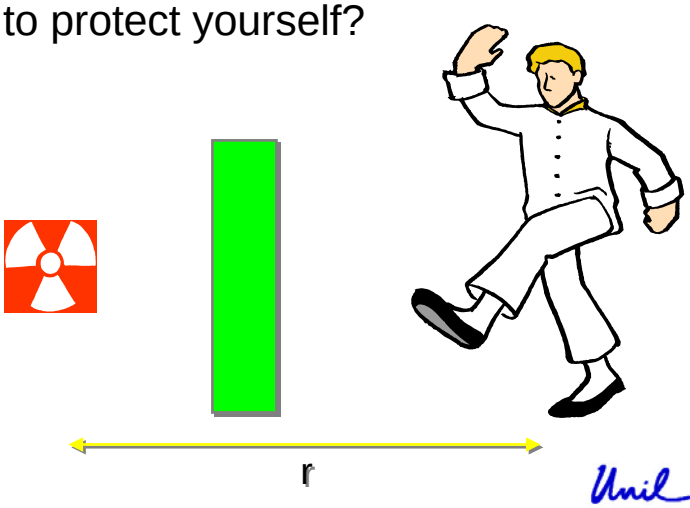
External irradiation

- How to protect yourself?



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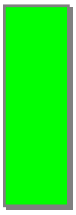
External irradiation

r



Time

Distance

Shielding

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Contamination

- Unsealed sources
- Mainly for liquids and gaz

– How to protect yourself ???

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Contamination

- Unsealed sources
- Mainly for liquids and gaz

- Protection
  - Choice of source
  - Infrastructures
  - Protection of the person
  - Working methods

Protection against contamination

- Choice of the source
  - Half-life
  - Type of emitted radiation
  - Chemical form
- Infrastructures
  - Labs
    - types : A, B or C
- Individual protection
  - Clothing, gloves…

Protection against contamination

- Working methods
  - Smoking ...
  - Gloves
  - Skin puncture ...
  - Mouth pipeting ...
  - Hand monitoring
  - Area and clothing monitoring
  - Hand washing
  - Order in the lab
  - Sources management
  - Collecting tank
  - Radioactive waste container
  - Signs on radioactive products
  - And **anticipation**

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Protection against contamination

summary...

Isolate the person

Confine the substance

Monitor regularly

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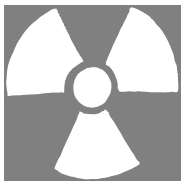
Types of labs

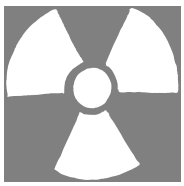
- LA
  - Authorisation limit
  - Inhalation of 20% of LA
    - 1 mSv



- Lab: normal
  < LA
- Lab: C
  < 100 LA
- Lab: B
  < 10,000 LA
- Lab: A
  > 10,000 LA

Radioactive waste

- LE
  - Exemption limit
  - Ingestion of LE
    - 10 μSv



- T < 60 days
  - Disposal and decay
  - Normal trash
- T > 60 days
  - Normal trash below LE
  - Waste disposal plan of the OFSP
  - Zwilag
  - Geological disposal ???

External monitoring

- Personal dosimeters

whole body TLD dosimeter

electronic personal dosimeter

extremity dosimeter

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External monitoring

- Area monitoring instruments

Ambient dose rate

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Intake monitoring

- Whole body counter (WBC)

Intake monitoring

Workplace
foot & hands

Screening of thyroid

Intake monitoring

Dose rate measurement
in front of the stomach

Intake monitoring

- Triage measurements
  - Onsite by own means
- Official intake measurements
  - Only by accredited laboratories

Organization in radiation protection

- ICRP
  - International Commission on Radiological Protection
- Swiss authorities
  - OFSP: medicine & research
  - DSIN: nuclear powerplants
  - SUVA: industry

Swiss regulation

- From the Swiss federal office for public health (OFSP)
  - Regulation regarding radiation protection
  - www.bag.admin.ch/themen/strahlung/02883/02884/index.html?lang=fr
- Radiation Swiss federal ordinance
  - www.admin.ch/ch/f/rs/814_501/