GENERAL RISKS WITH RADIATION

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medical physicists & **biomedical engineers**
- integral part of the health work force,
i.e. are **health professionals**

ISCO–08 Volume I

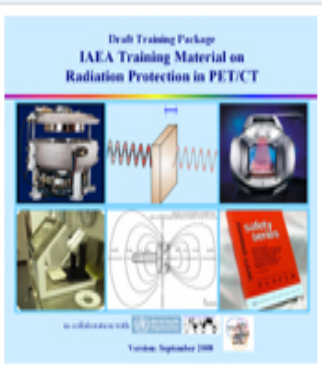
International Labour Office
Geneva

International Standard Classification of Occupations

Structure, group definitions and correspondence tables

Information for
Health Professionals
Member States
Patients and Public

Free Material



- Diagnostic and Interventional Radiology
- Radiotherapy
- Nuclear Medicine
- Prevention of Accidental Exposure in Radiotherapy
- Cardiology
- PET/CT
- Paediatric Radiology
- Digital Radiology
- Doctors using fluoroscopy outside radiology (Urologists, Gastroenterologists, Orthopaedic surgeons etc.)

Español Русский

Posters

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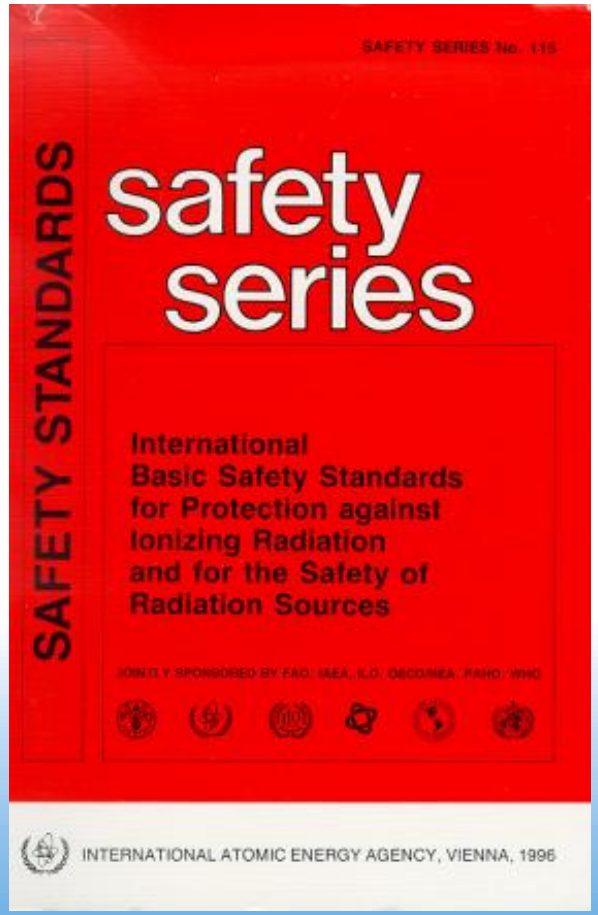
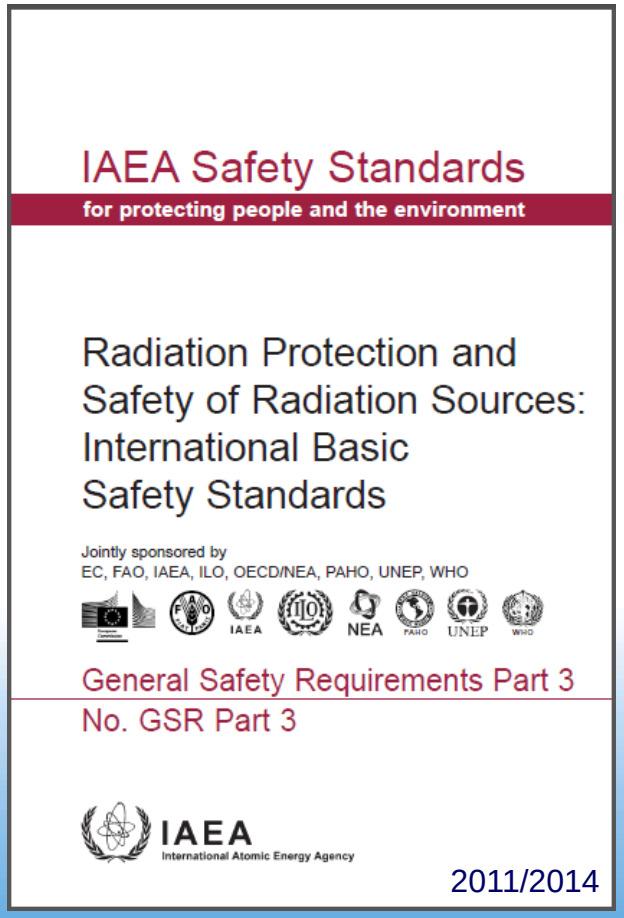




II

(Non-legislative acts)

DIRECTIVES

COUNCIL DIRECTIVE 2013/59/EURATOM

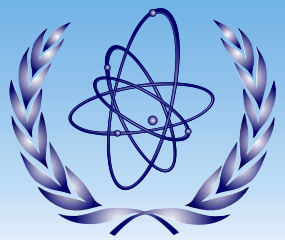
of 5 December 2013

laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation, and repealing Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom

THE COUNCIL OF THE EUROPEAN UNION,

Having regard to the Treaty establishing the European Atomic Energy Community, and in particular Articles 31 and 32 thereof,

(3) Directive 96/29/Euratom establishes the basic safety standards. The provisions of that Directive apply to normal and emergency situations and have been supplemented by more specific legislation.



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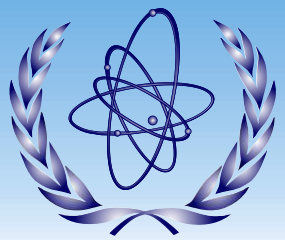
RADIATION PROTECTION IN NUCLEAR MEDICINE

Part 1: Biological effects of ionizing radiation



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Part 1. Biological effects

Module 1.1. Basic concepts

Early Observations of the Effects of Ionizing Radiation

- 1895 X-rays discovered by Roentgen
- 1896 First skin burns reported
- 1896 First use of x-rays in the treatment of cancer
- 1896 Becquerel: Discovery of radioactivity
- 1897 First cases of skin damage reported
- 1902 First report of x-ray induced cancer
- 1911 First report of leukaemia in humans and lung cancer from occupational exposure
- 1911 94 cases of tumour reported in Germany (50 being radiologists)

RISK

Risk is the effect of uncertainty on objectives (ISO*).

An effect is a positive or negative deviation from what is expected.

Uncertainty (or lack of certainty) is a state or condition that involves a deficiency of information and leads to inadequate or incomplete knowledge or understanding.

*International Organization for Standardization

RADIATION RISK

radiation risks

Detrimental health effects of exposure to radiation (including the likelihood of such effects occurring), and any other safety related risks (including those to the environment) that might arise as a direct consequence of:

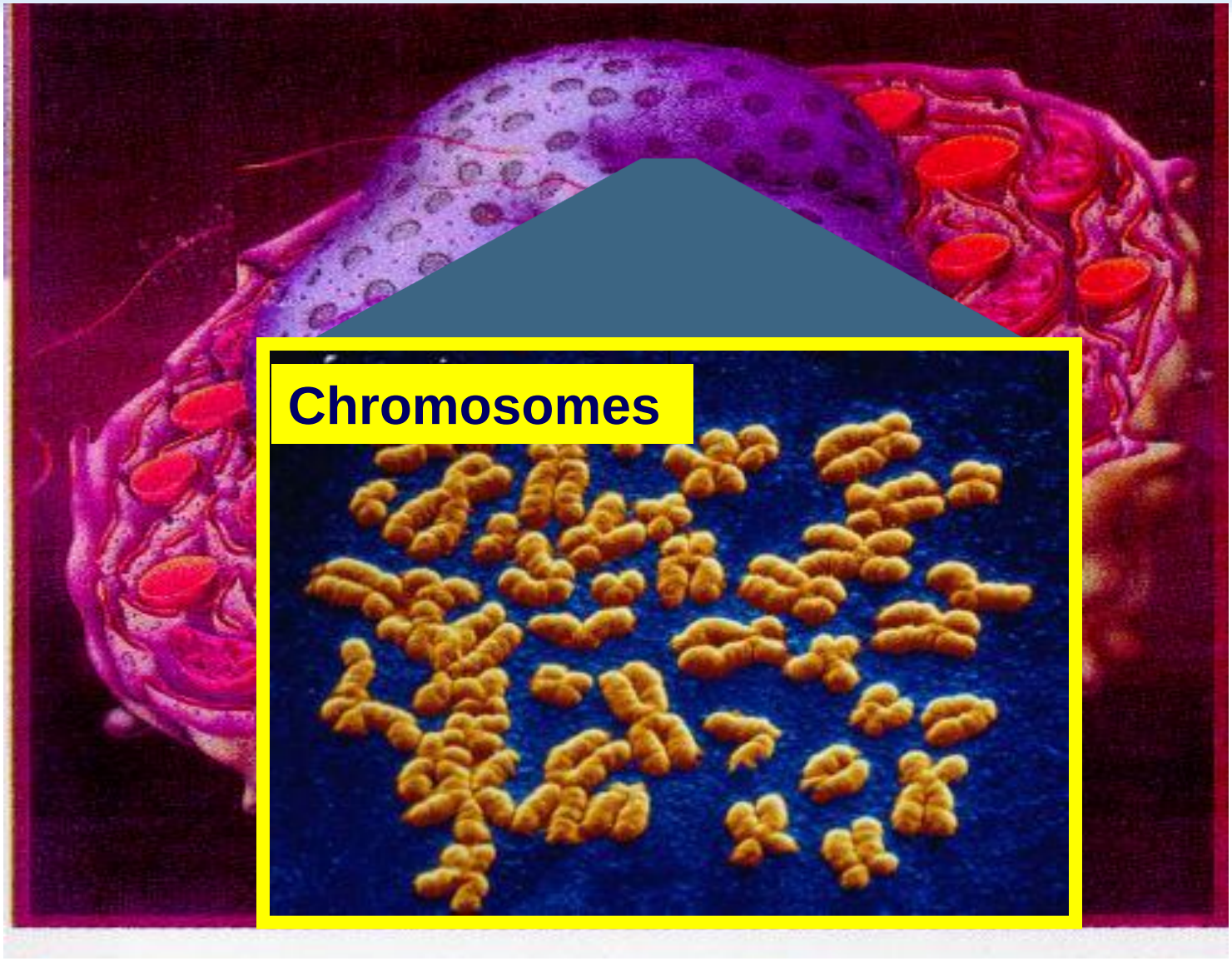
(a) Exposure to radiation;
(b) The presence of radioactive material (including radioactive waste) or its release to the environment;
(c) A loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation.

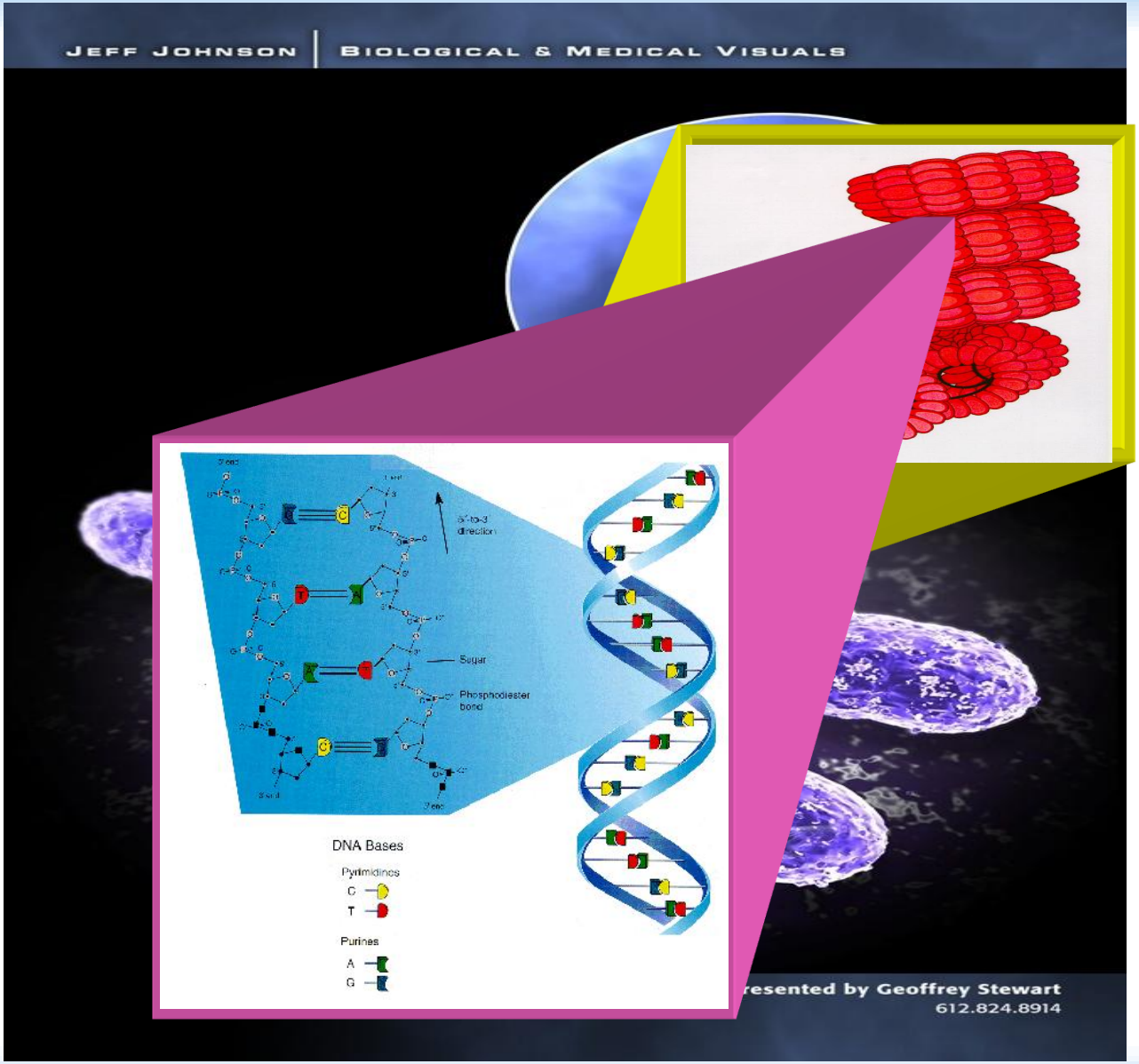
Effects of Radiation Exposure

Information comes from:

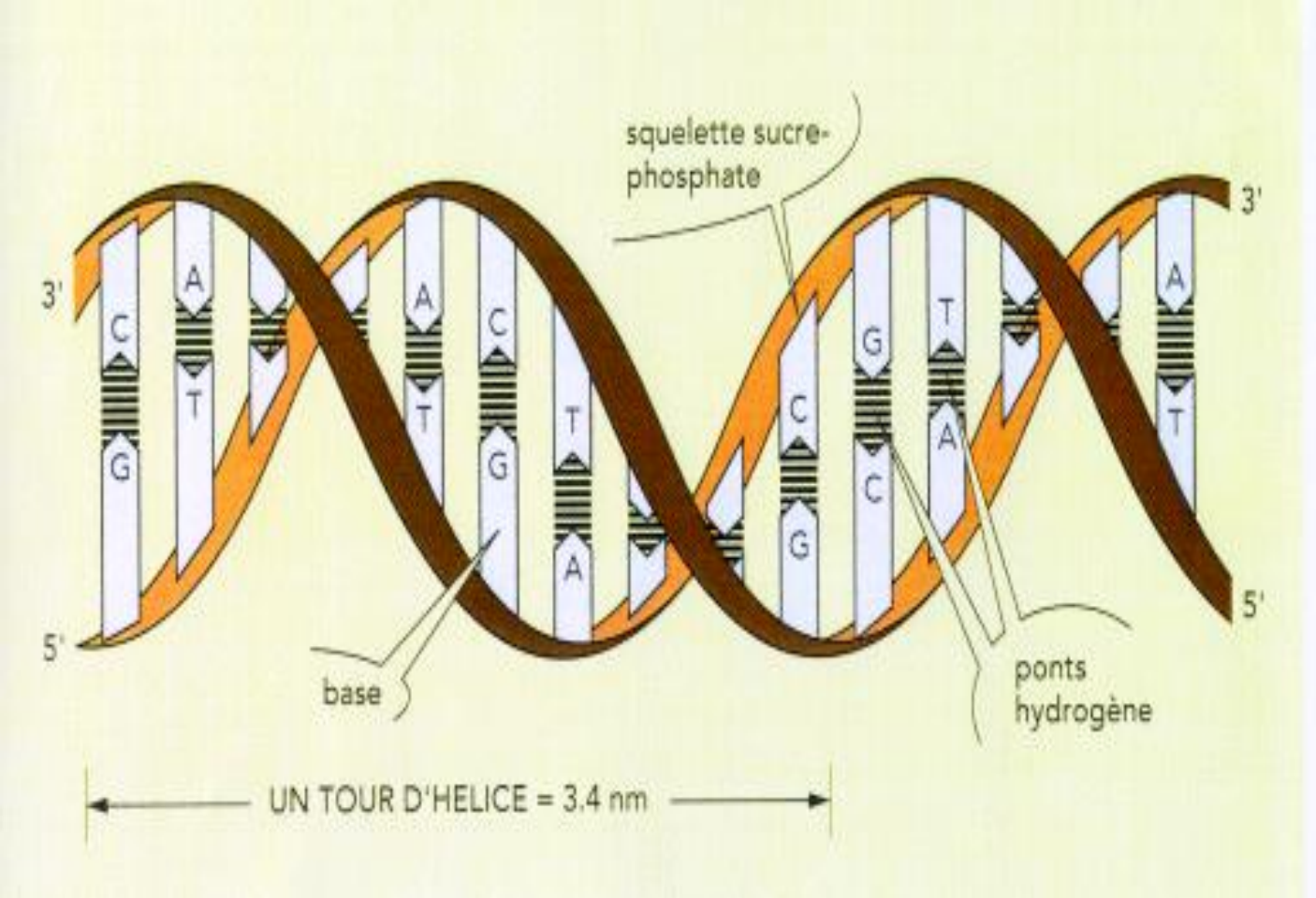
- ✓ **studies of humans (epidemiology)**
- ✓ **studies of animals and plants (experimental radiobiology)**
- ✓ **fundamental studies of cells and their components (cellular and molecular biology)**

The key to understanding the health effects of radiation is the interaction between these sources of information.


Chromosomes

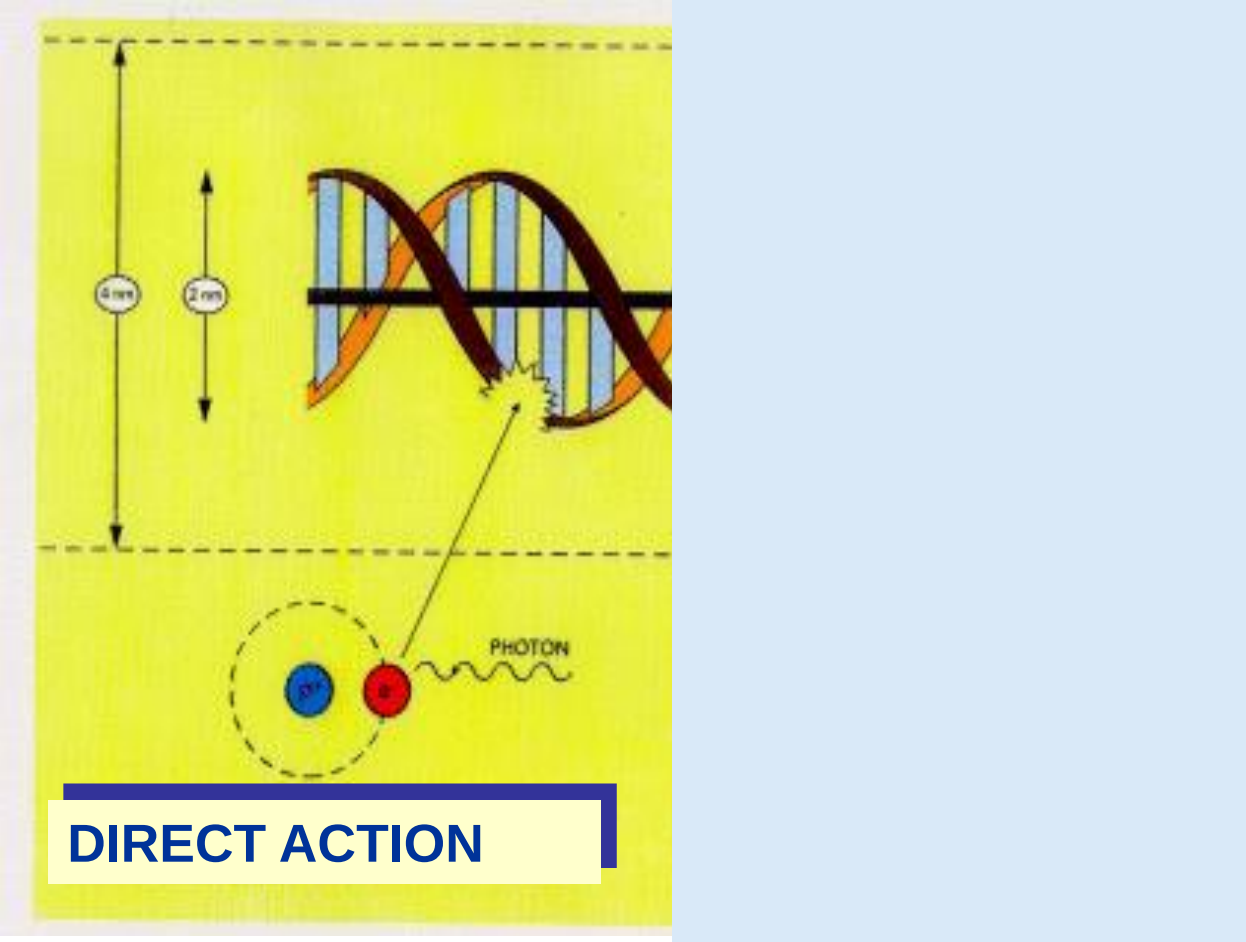

JEFF JOHNSON | BIOLOGICAL & MEDICAL VISUALS
Sugar
Phosphodiester bond
DNA Bases
Pyrimidines
C
T
Purines
A
G
612.824.8914

The critical target: deoxyribonucleic acid - DNA

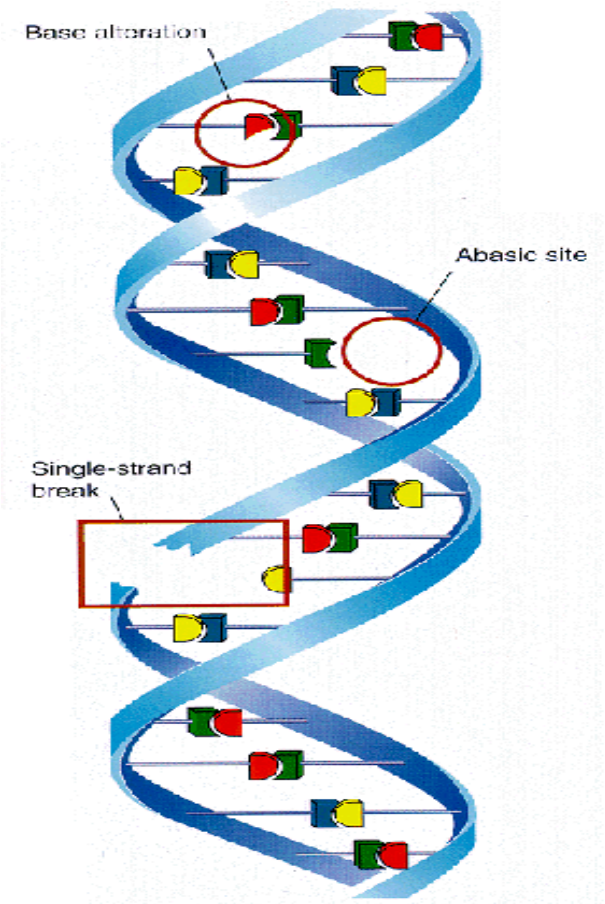


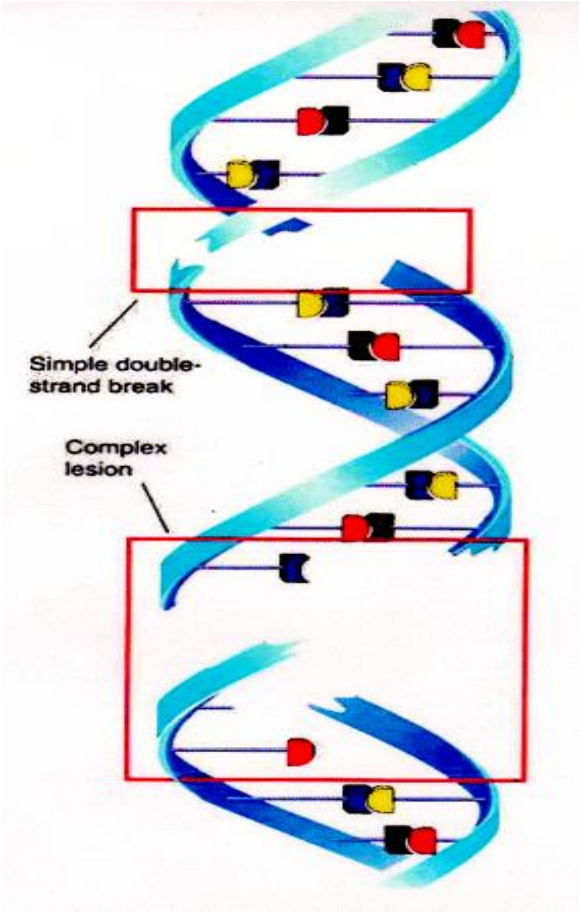
nucleobases: adenine –A; cytosine – C; guanine – G; thymine - T

Interaction of ionizing radiation with DNA

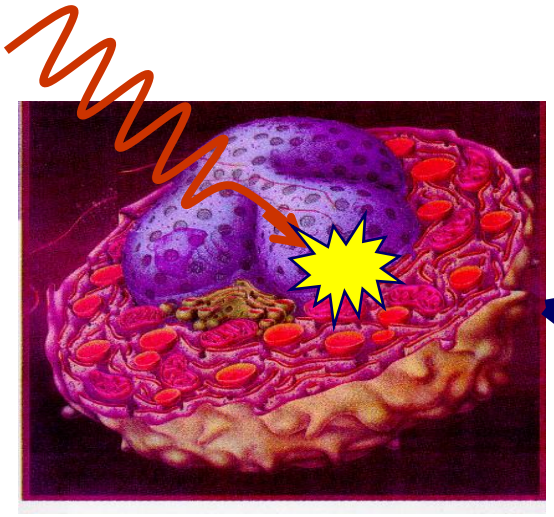


Damage to DNA

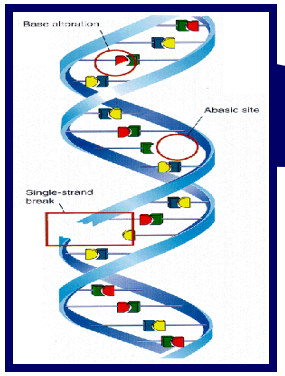


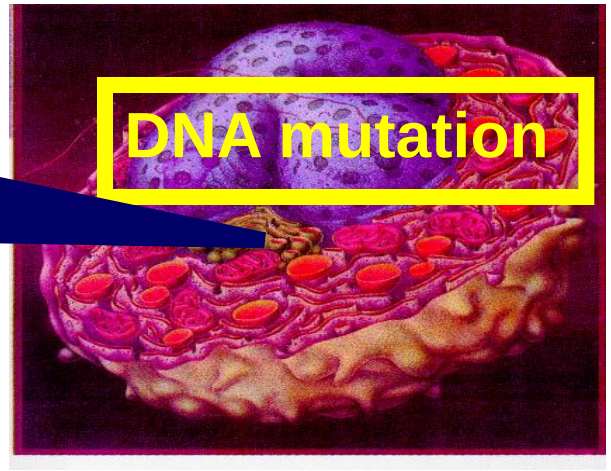


Exposure of the cell

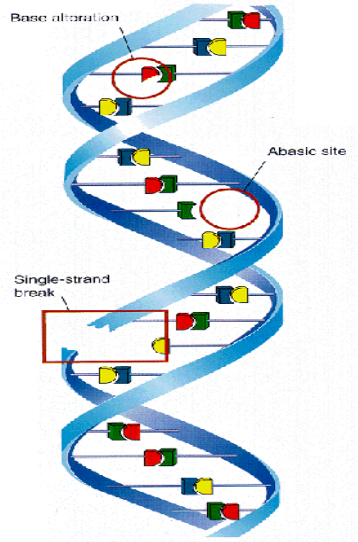


radiation hit cell nucleus!

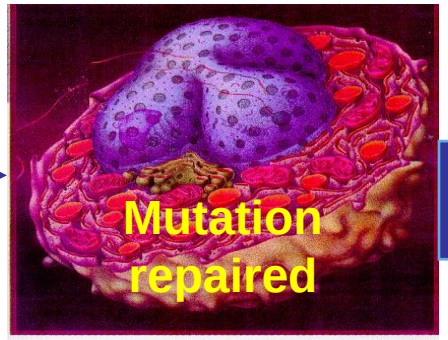




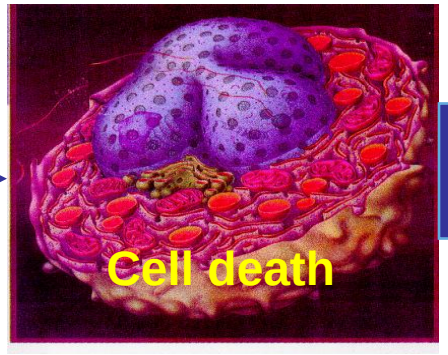
Outcomes after cell exposure



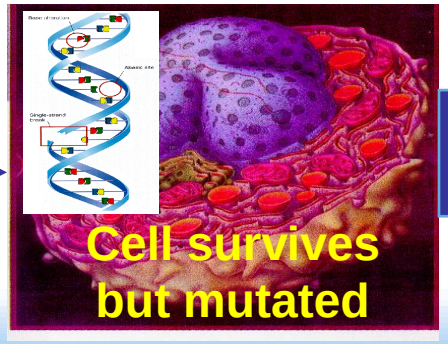
DNA Mutation



Viable Cell



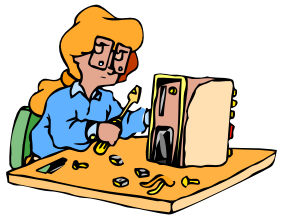
Unviable Cell



Cancer?

Repair

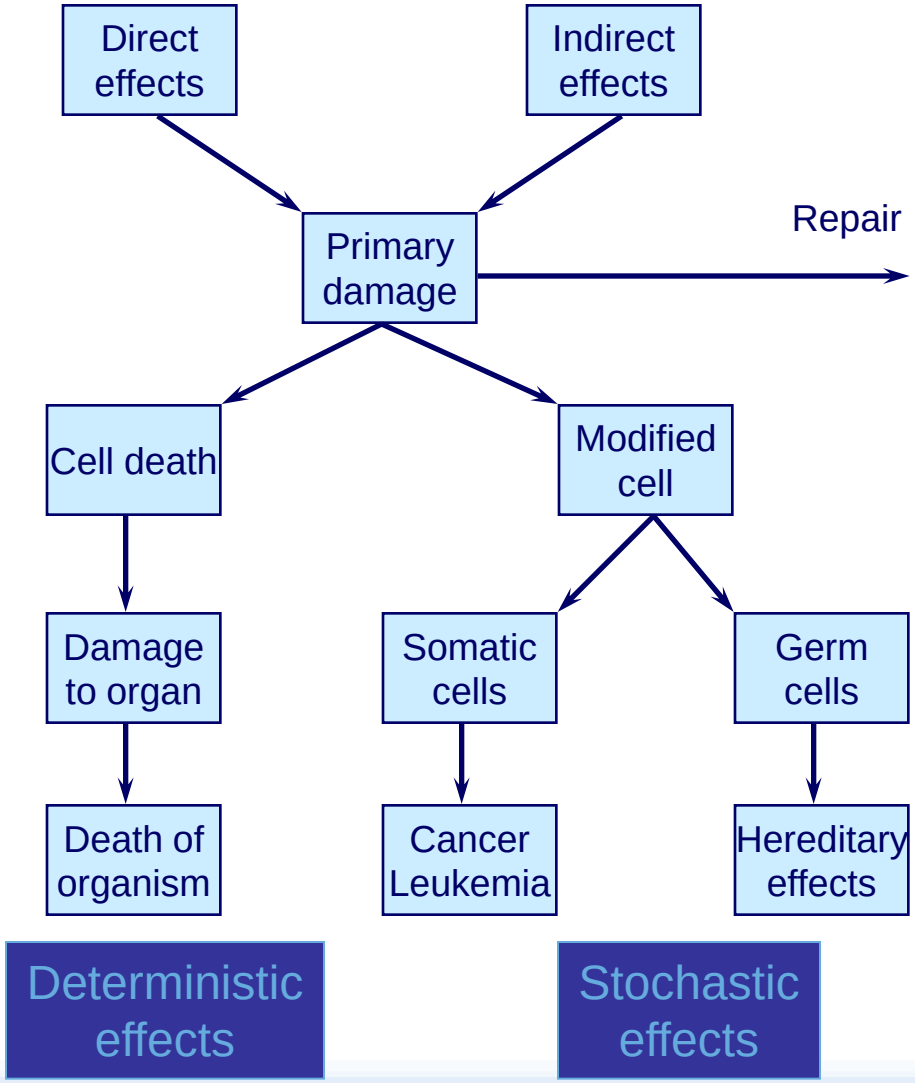
The human body contains about 10^{14} cells. An absorbed dose of 1 mGy per year (natural sources) will produce about 10^{16} ionizations, which means 100 per cell in the body. If we assume that the mass of DNA is 1% of the mass of the cell, the result will be one ionization in the DNA-molecule in every cell in the body each year.



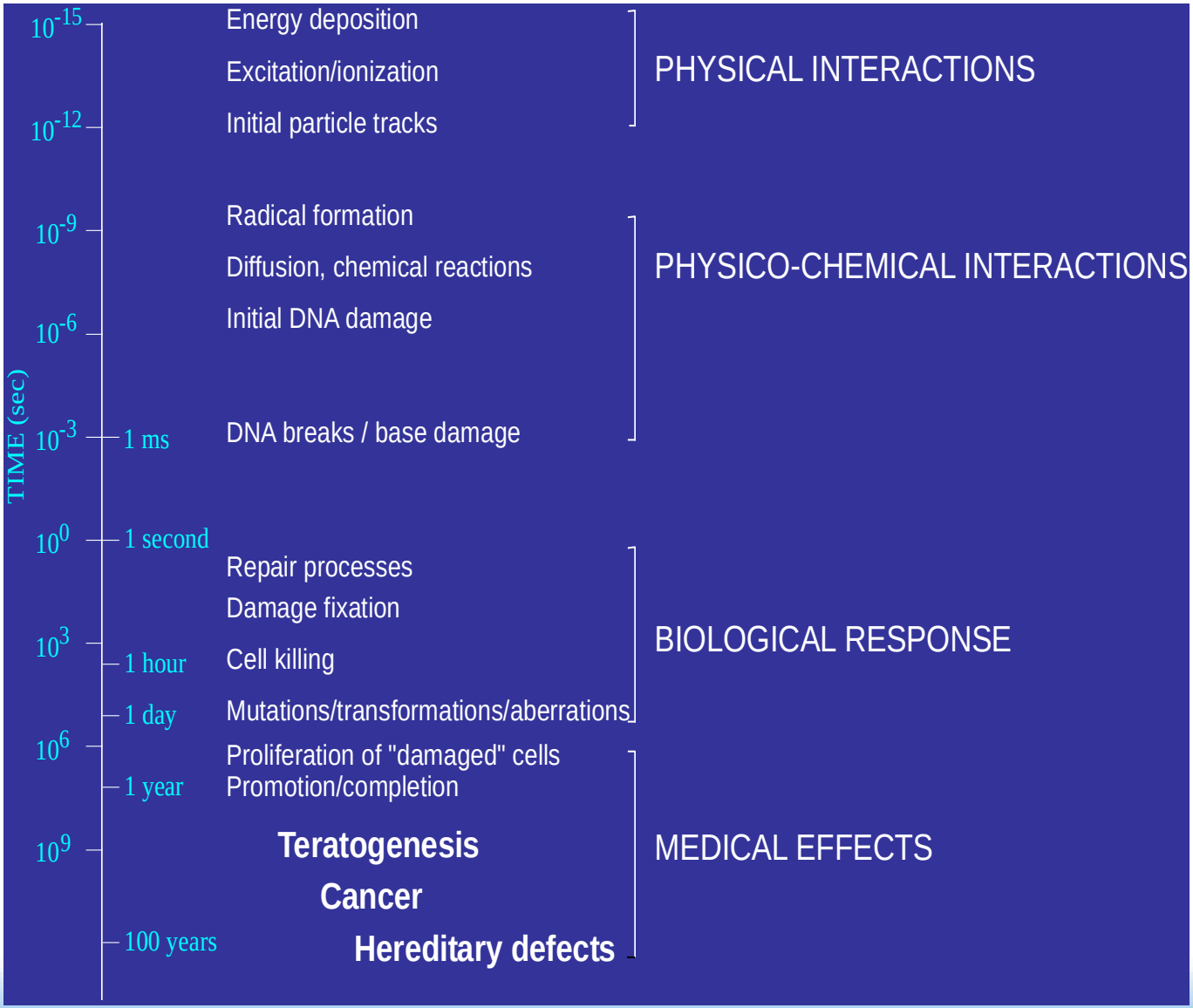
Cell killing
Radiosensitivity (RS)

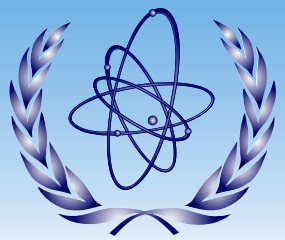
- **RS = Probability of a cell, tissue or organ of suffering an effect per unit of dose.**
- **Bergonie and Tribondeau (1906): "RS LAWS": RS will be greater if the cell:**
  - **is highly mitotic.**
  - **is undifferentiated.**

BIOLOGICAL EFFECTS



Timing of events leading to radiation effects





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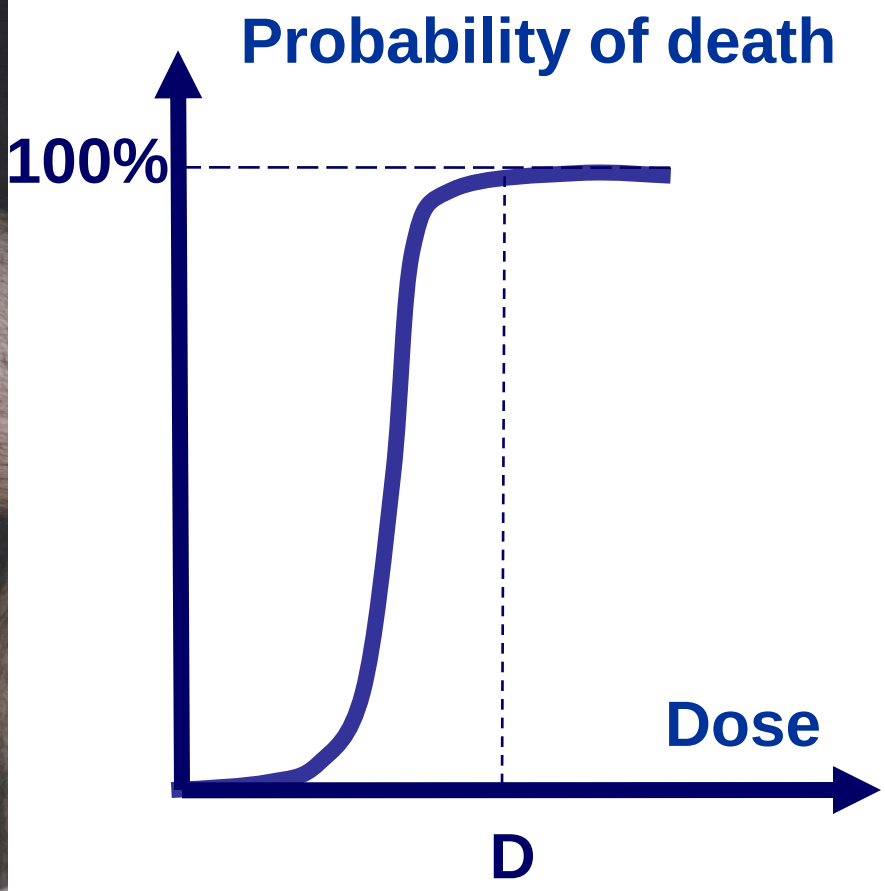
Part 1. Biological effects

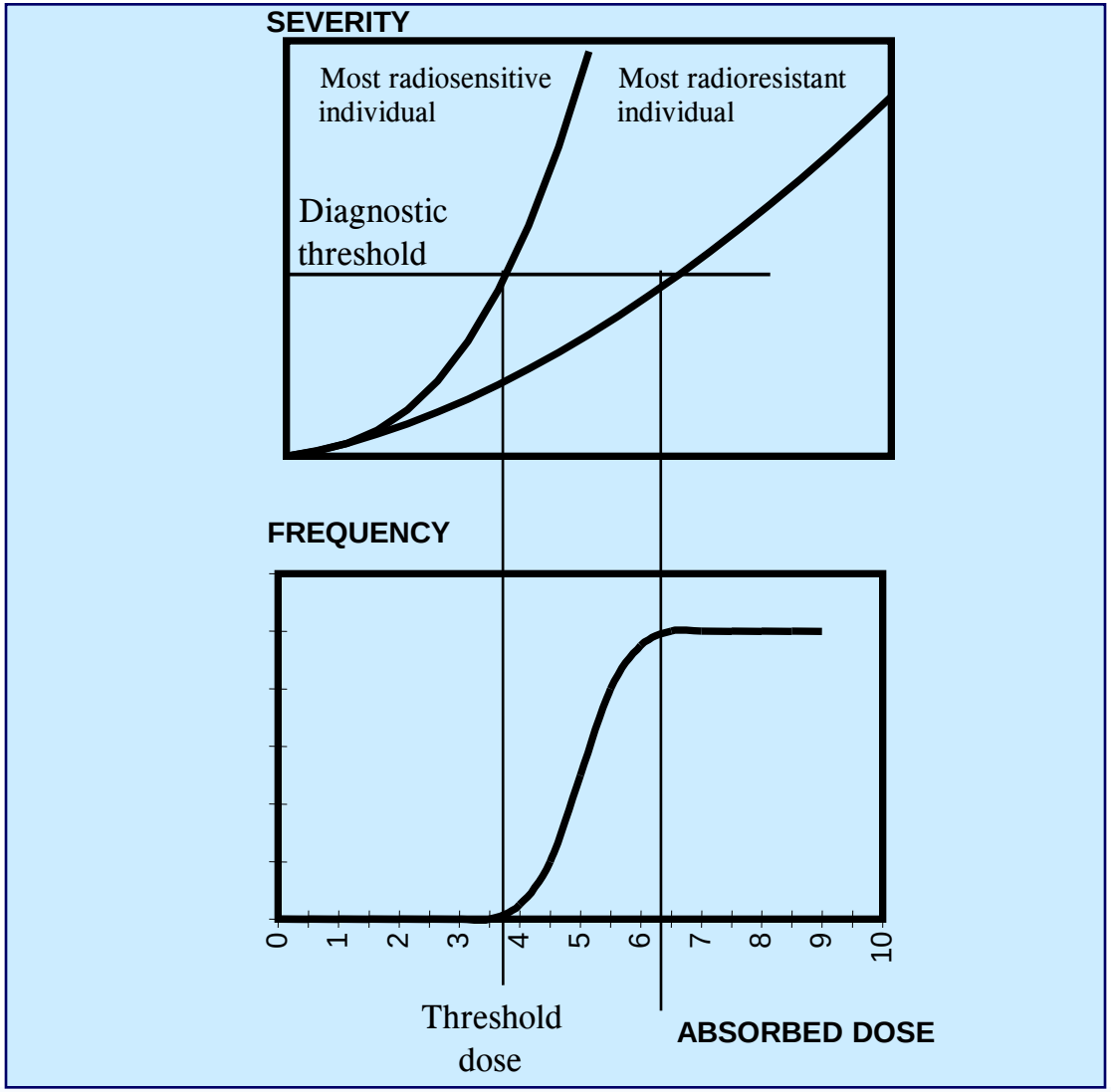
Module 1.2. Deterministic effects

EFFECTS OF CELL DEATH



Deterministic effects

concept of treshold dose



threshold dose - dose needed to create clinically observed injury in the most radiosensitive individual

Threshold Doses for Deterministic Effects

- **Cataracts of the lens of the eye 2-10 Gy**
- **Permanent sterility**
  - **males 3.5-6 Gy**
  - **females 2.5-6 Gy**
- **Temporary sterility**
  - **males 0.15 Gy**
  - **females 0.6 Gy**

Note on threshold values

- **Depend on dose delivery mode:**
  - **single high dose most effective**
  - **fractionation increases threshold dose in most cases significantly**
  - **decreasing the dose rate increases threshold in most cases**
- **Threshold may differ in different persons**

Systemic effects

- **Effects may be morphological and/or functional**
- **Factors:**
  - **Which *Organ***
  - **Which *Dose***
- **Effects**
  - **Immediate (usually *reversible*): < 6 months e.g.: inflammation, bleeding.**
  - **Delayed (usually *irreversible*): > 6 months e.g.: atrophy, sclerosis, fibrosis.**
- **Criteria of dose**
  - **< 1 Gy: LOW DOSE**
  - **1-10 Gy: MODERATE DOSE**
  - **> 10 Gy: HIGH DOSE**
- ***Regeneration* means replacement by the original tissue while *Repair* means replacement by connective tissue.**

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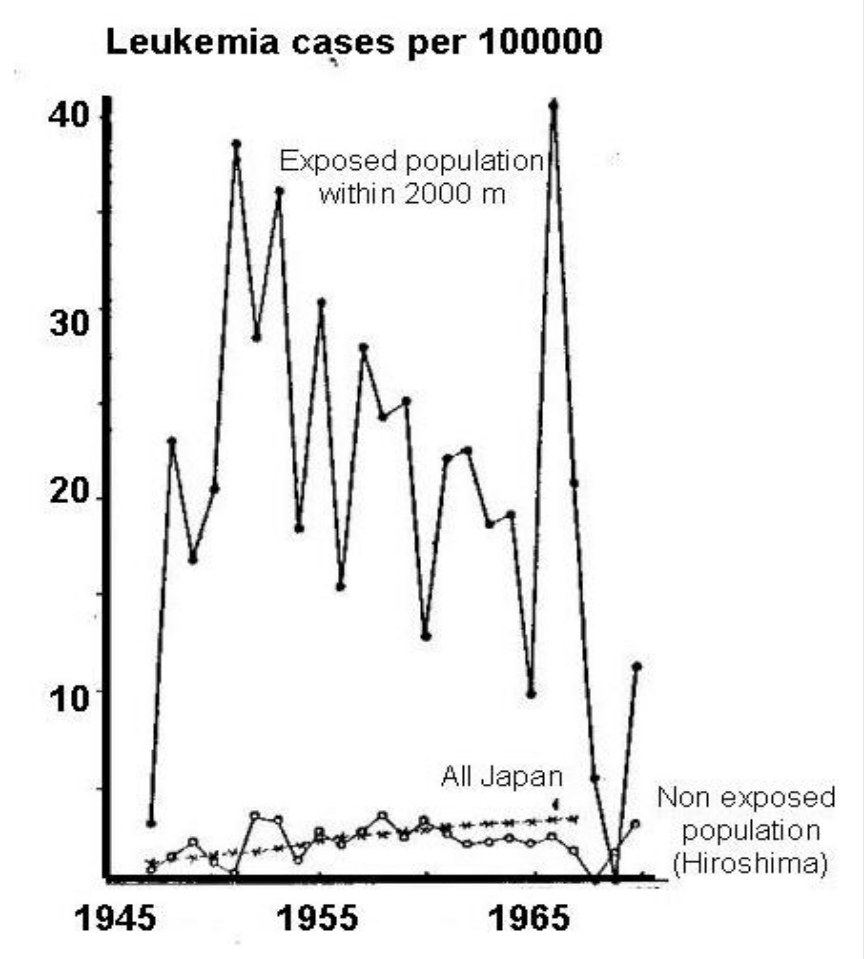
Part 1. Biological effects

Module 1.3. Stochastic effects

STOCHASTIC EFFECTS OF IONIZING RADIATION



significant increase in the frequency of leukemia among the A-bomb survivors in Hiroshima the years following the exposure

STOCHASTIC EFFECTS OF IONIZING RADIATION

Health consequences of Chernobyl accident

- 1800 children diagnosed with thyroid cancer (1998)

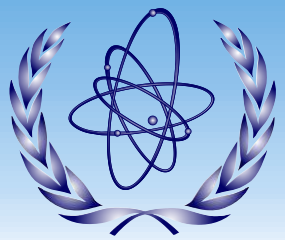
Genetic Effects

- **Ionising radiation is known to cause heritable mutations in many plants and animals**

BUT

- **intensive studies of 70,000 offspring of the atomic bomb survivors have failed to identify an increase in congenital anomalies, cancer, chromosome aberrations in circulating lymphocytes or mutational blood protein changes.**

Neel et al. Am. J. Hum. Genet. 1990, 46:1053-1072



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Part 1. Biological effects

Module 1.4. Effects on embryo and fetus

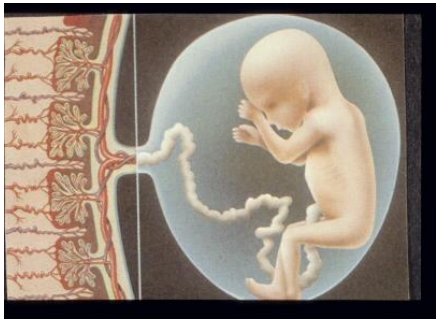
Fetal Radiation Risk

- There are radiation-related risks throughout pregnancy which are related to the stage of pregnancy and absorbed dose
- Radiation risks are most significant during organogenesis (>3-5w after conception) and in the early fetal period, somewhat less in the 2nd trimester, and least in the third trimester

Most risk

Less

Least



Effects on embryo and fetus

Age	Threshold for lethal effects (mGy)	Threshold for malformations (mGy)
1 day	100	No effect
14 days	250	-
18 days	500	250
20 days	>500	250
50 days	>1000	500
50 days to birth	>1000	>500

estimates from animal experiments !

Leukemia and Cancer

- **Radiation has been shown to increase the risk for leukemia and many types of cancer in adults and children**
- **Throughout most of pregnancy, the embryo/fetus is assumed to be at about the same risk for carcinogenic effects as children**

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Part 1. Biological effects

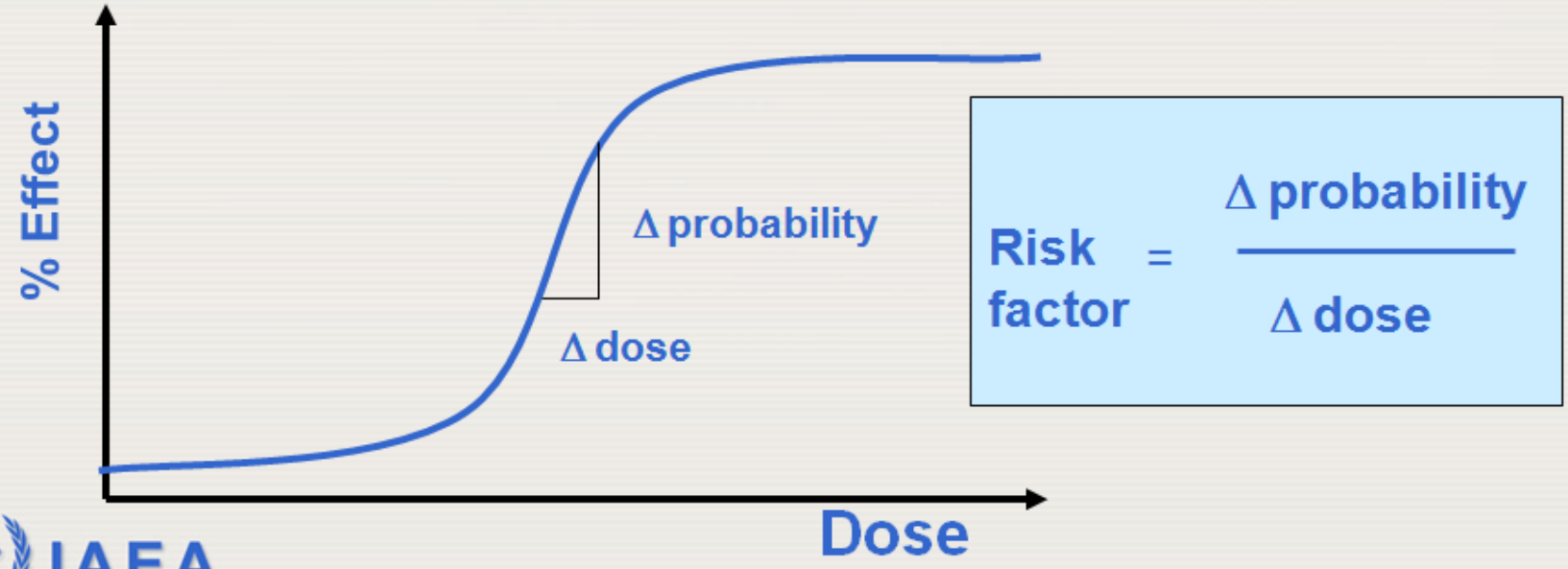
Module 1.5. Risk estimates

Risk Estimates

- **Risk = probability of effect**
- **Different effects can be looked at - one needs to carefully look what effect is considered: e.g. thyroid cancer mortality is NOT identical to thyroid cancer incidence!**
- **Risk estimates usually obtained from high doses and extrapolated to low doses**

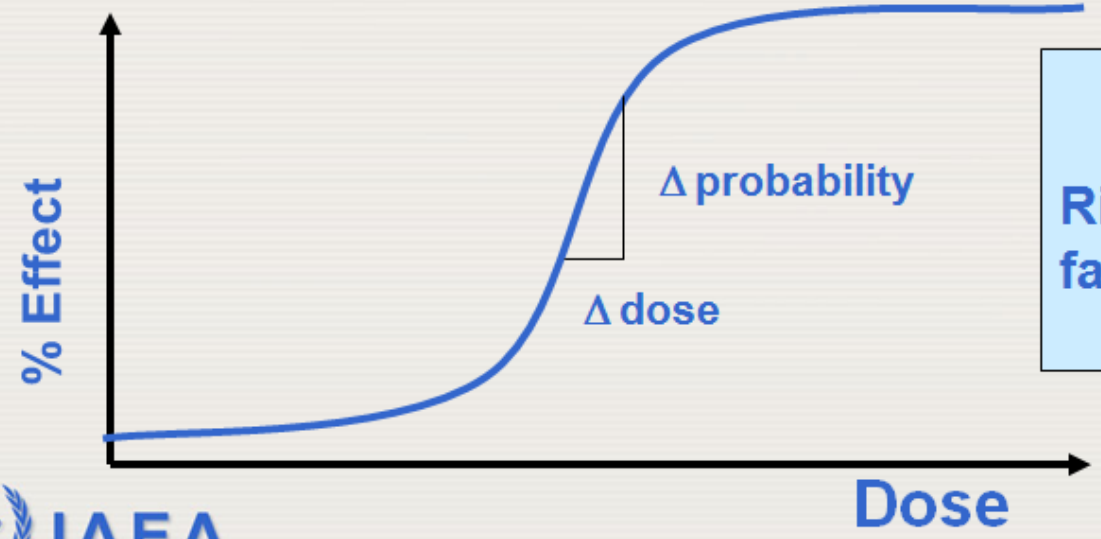
Tissue risk factor (1)

- RISK FACTOR: The quotient of increase in probability of a stochastic effect and the received dose. It is measured in Sv-1 or mSv-1.



Tissue risk factor (2)

- EXAMPLE: A risk factor of 0.005 Sv-1 for bone marrow (lifetime mortality in a population of all ages from specific fatal cancer after exposure to low doses) means that if 1,000 people would receive 1 Sv to the bone marrow, 5 will die from a cancer induced by radiation.



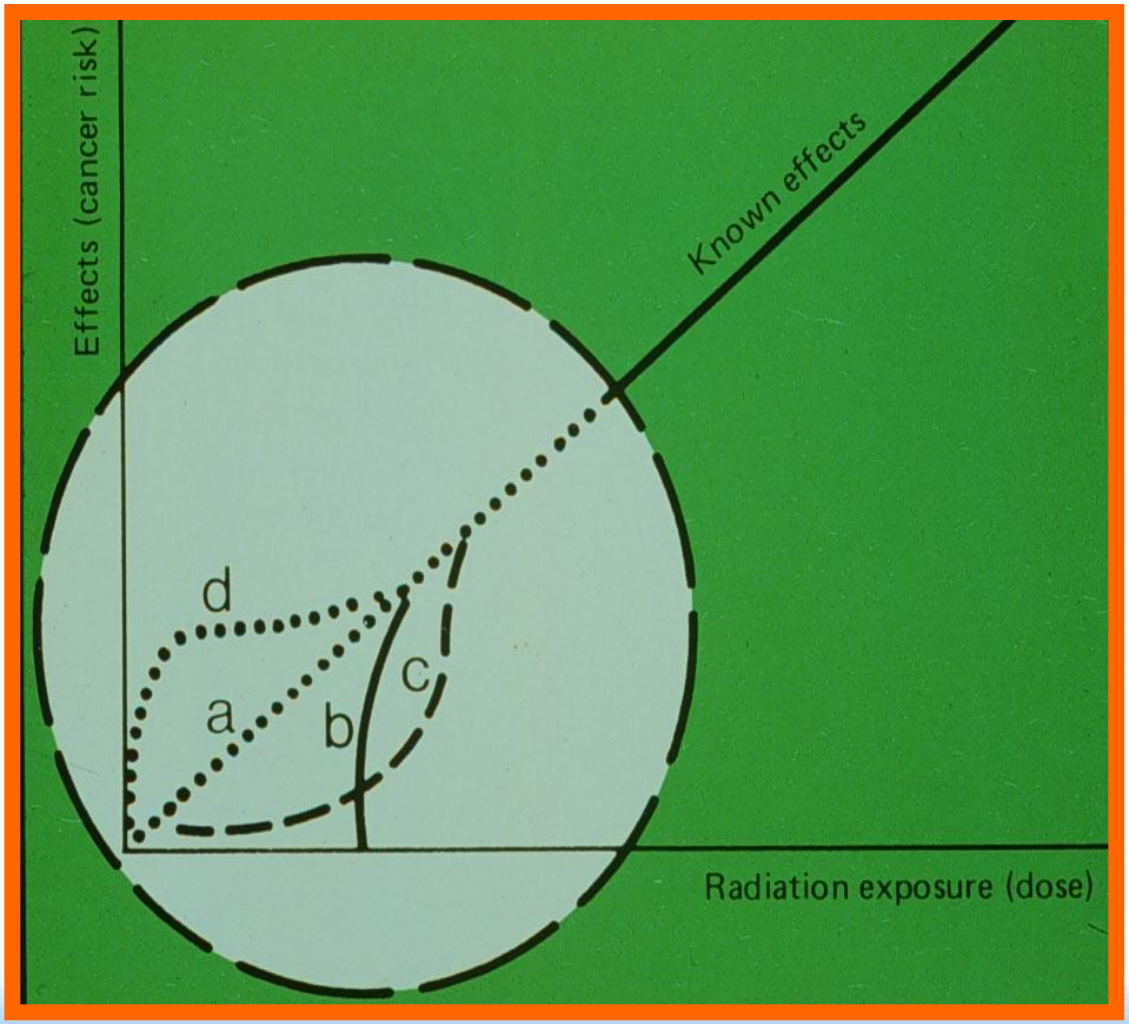
$$\text{Risk factor} = \frac{\Delta \text{ probability}}{\Delta \text{ dose}}$$

EFFECTS AT LOW DOSES

In the latest Hiroshima-Nagasaki Life Span Study (1986-1990), LSS Report 12, (Pierce et al., 1996) find the nominal estimates of risk of dying from radiation induced cancer (5% per Sv) to apply down to a dose of about 50 mSv.
For childhood cancer following fetal irradiation, very similar risk estimates (6% per Sv) are found to apply to doses of 10 mSv (Doll and Wakeford, 1997).

The risk estimates and the uncertainties associated with them are expected to apply at low doses.

What happens at the low-dose end of the graph, below ~20-200 mSv?



a) Linear extrapolation
b) Threshold dose
c) Lower risk per dose for low doses
d) Higher risk per dose for for low doses

The answer should include but not be limited to:

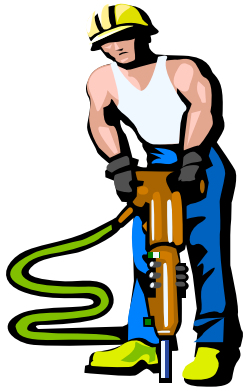
- Close to background radiation - dosimetry difficult
- Limited epidemiological evidence
- Research and experiments with humans are ethically impossible
- The effects are very small (if any)
- It is likely that there is a dose and dose rate effect

RISKS

The following activities are associated with a risk of death that is 1/1000000

- 10 days work in a nuclear medicine department
- smoking 1.4 cigarette
- living 2 days in a polluted city
- traveling 6 min in a canoe
- 1.5 min mountaineering
- traveling 480 km in a car
- traveling 1600 km in an airplane
- living 2 months together with a smoker
- drinking 30 cans of diet soda

RISKS



Expected reduction of life

Unmarried man	3500 days
Smoking man	2250 days
Unmarried woman	1600 days
30% overweight	1300 days
Cancer	980 days
Construction work	300 days
Car accident	207 days
Accident at home	95 days
Administrative work	30 days
Radiological examination	6 days

Summary

- Effects of ionizing radiation may be deterministic and stochastic, immediate or delayed, somatic or genetic
- Some tissues are highly radiosensitive
- Each tissue has its own risk factor
- Risk from exposure may be assessed through such factors

Summary

- Cancer induction is the most significant risk from exposure to ionizing radiation at low doses
- Cancer induction is a stochastic effect
- At high radiation doses also deterministic effects play a role