

HEALTH EFFECTS OF IONIZING RADIATION



Sources of Radiation

- medical imaging methods
- therapeutic use
- involuntary irradiation (often illegal manipulation)
- atomic power station accident (public exposure)
- nuclear weapons

- Ionizing radiation is any form of electromagnetic waves or particulates that carry sufficient energy to produce ions in matter.
- Electromagnetic waves travel in streams of energy called photons, which collide randomly with either an electron or the nucleus of an atom.
- They include x-rays and gamma rays.



Radiation Characteristic

- **radiation characteristic**

- contact with radiation particles → ionized molecules and atoms

- **ionized particles:** α , β particles, protons – direct ionizing effects
 - **nonionized particles:** photons of electromagnetic radiation, neutrons – ionize with interactions with electrons or nuclei
 - **corpuscular** (α , β particles, neutrons, protons) or **electromagnetic radiation** of short wave lengths (X-ray and gamma rays) – radiations of shorter lengths are more vivid (and also the ionizing is smaller)

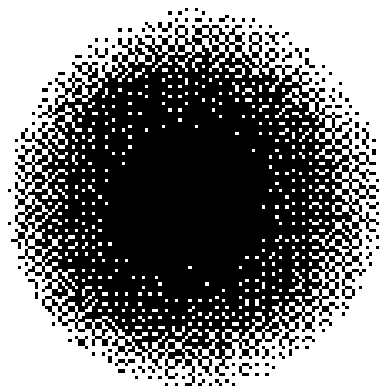
- **α and β radiation**

- effective in the inner irradiation

- **gamma, X-ray, neutrons**

- infiltrate deep in the body tissues and affect organs

Radiation Source



Alpha Particles

Stopped by a sheet of paper

Beta Particles

Stopped by a layer of clothing or by a few millimeters of a substance such as aluminium

Gamma Rays

Stopped by several feet of concrete or a few inches of lead

Organic Tissue

The effect of radioactive substances

- **overall condition of the body**
 - age, state of the CNS, the composition of food, disease ...
- chemical properties of radioactive substances
- **radiosensitivity of cells** - directly proportional to their metabolic and reproductive activity
 - *sensitive*: cells, bone marrow nuclear cells, intestinal epithelium, stem cells and glands of the skin
 - *resistant*: the cells of muscle, nerve, bone, connective
- **radiation intensity, the amount of absorbed radiation**, exposure time, external or internal radiation contamination, local/general operation, location of the irradiated site

Radiation Dose

- derivation of the risk as the probability of damage
- **dose ionizing radiation**
 - specific value - transmitted energy per unit weight
 - Unit: J/kg (Gray - Gy)
- **equivalent dose**
 - normalized (corrected by the relevant factor) due to different types of radiation (which have different biological effectiveness)
 - Unit: J/kg (in this sievert - Sv)
- **effective dose**
 - standardization due to the sensitivity of tissues (the late emergence of cancer and genetic features)
 - Unit: J/kg (Sv)

”For higher doses and acute effects are used units of Gy, for low dose and the risk of cancer units Sv“

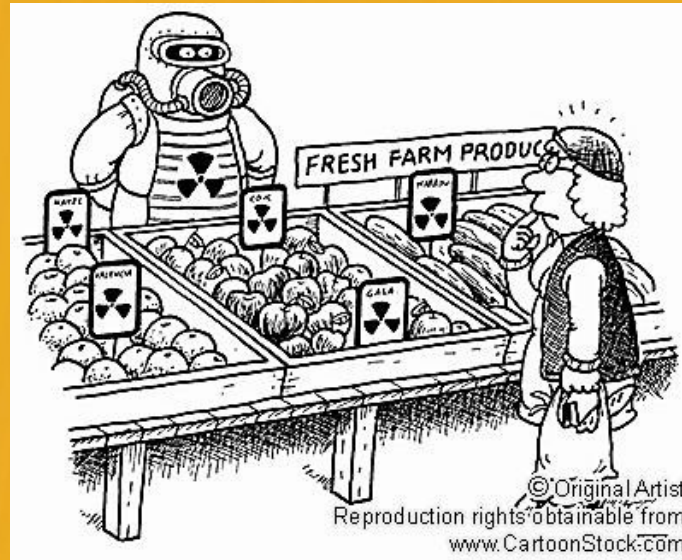
Radiation effects can be classified as

1. **stochastic effects**

those that vary in frequency but not severity with dose, and

2. **deterministic (non-stochastic) effects**

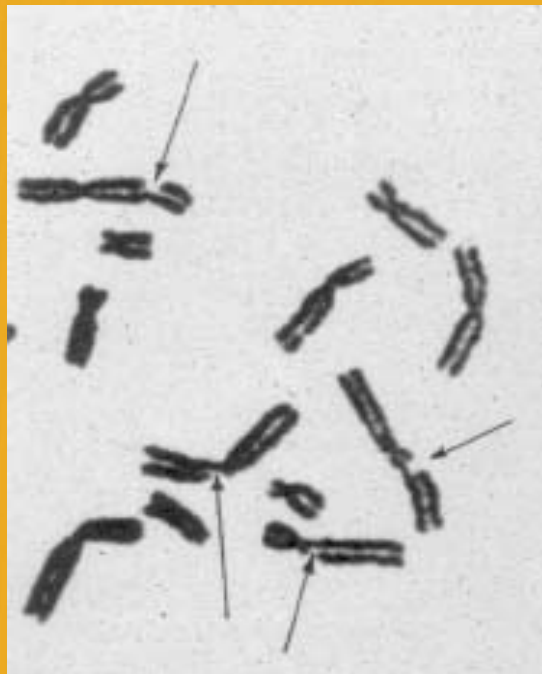
which vary in both frequency and severity with dose.



- **non-stochastic (deterministic) effects**
 - they occur in certain doses – **everybody is involved**
 - **threshold doses** for specific types of damage
 - acute radiation disease, radiation cataract: may occur even in **2 Gy**
 - late skin erythema: 6 Gy
 - radiation burns
- **stochastic effects**
 - **higher probability of cancer and genetic disorders development** (also in smaller doses)
 - **statistic regularity**, existence of no liminal doses is supposed!
 - connection between radiation dosis and symptoms development is supposed (but in small doses can it be not documented)
 - risk coefficients
- natural radiation background in CR: **3,6 mSv**, world average: 2,4 mSv

Biological effects of radiation

- Acute radiation syndromes, radiation dermatitis, cataracts, pulmonary fibrosis and infertility are deterministic effects.
- Cancer and genetic damage (birth defects) are stochastic effects.



Biological effects of radiation

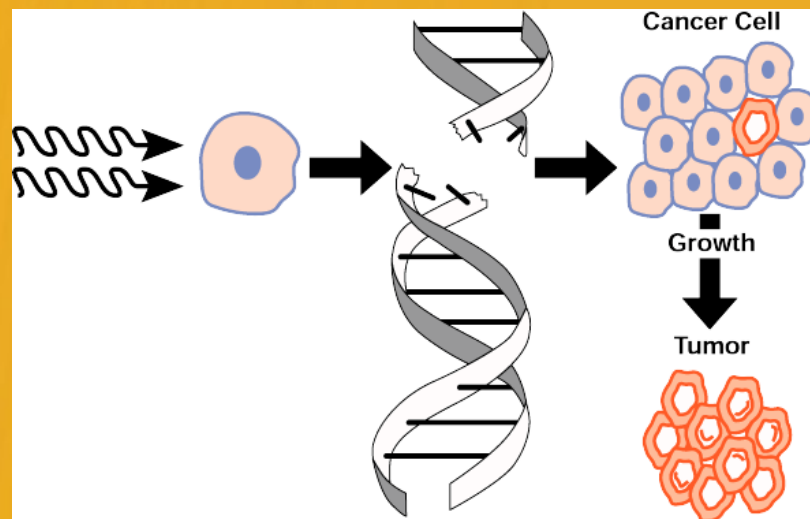
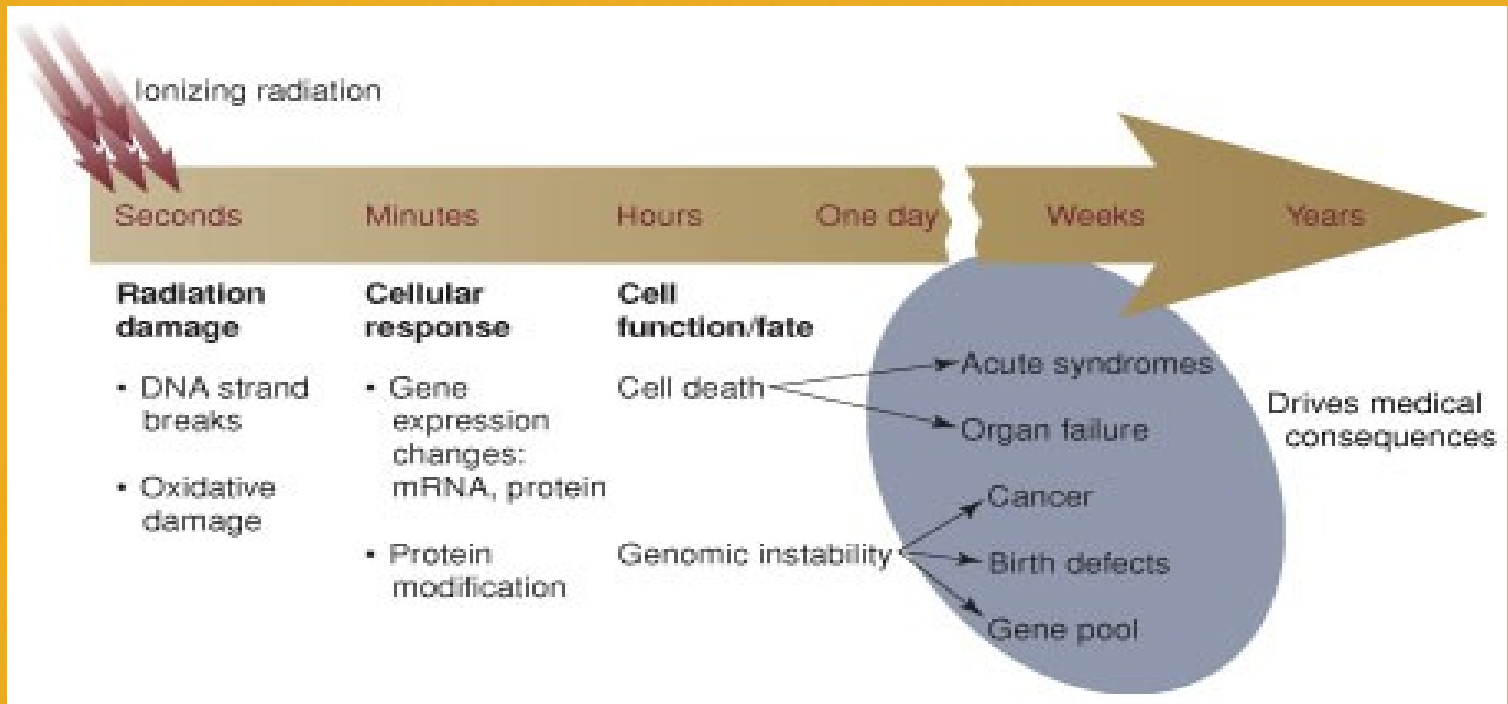


Figure 1. Development of cancer from mutation produced by ionizing radiation.

Prevention during Medical Examination

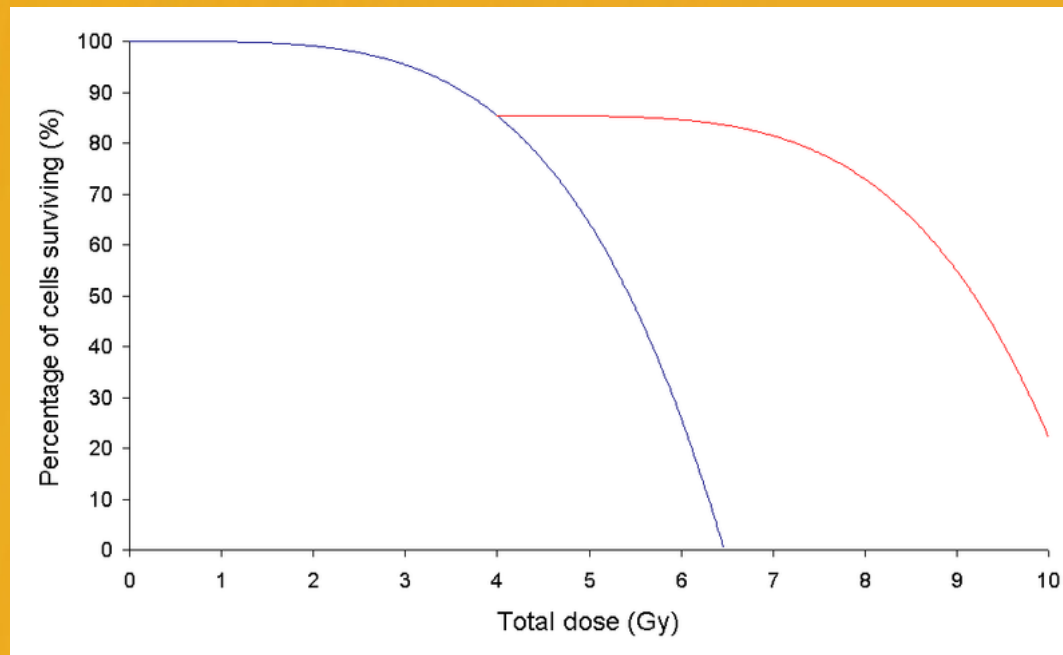
- **personal**
 - doses (0,8 mSv/year)
 - note the amount of the natural radiation background (CR: 3,6 mSv)
- **patients**
 - no limital doses
 - *the doctor's responsibility for the correct indication*
 - X-ray: 0,72 mSv
 - nuclear medicine: 0,09 mSv

Acute radiation syndromes

- occur with large whole body exposures of 1 Gy or more within 1-2 days.
- The LD50 is estimated to be 3 to 4 Gy.
- Conventionally, the acute radiation syndromes are divided into
 - the hematopoietic
 - gastrointestinal and
 - central nervous (CNS) syndromes.
- The hematopoietic and gastrointestinal syndromes are caused by depletion of stem cells.
- In the CNS syndrome the principal damage is to membranes.

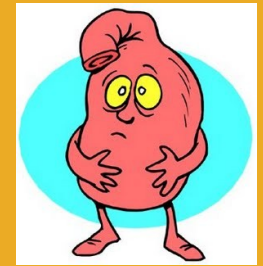
- It is important to understand that the syndromes are not discrete:
the damages to gut, bone marrow, and vasculature interact.
- Symptoms and time course vary with total dose and with dose-rate.
- Prodromal symptoms include nausea, vomiting and fatigue.
- Lymphocyte depression at 48 hours has prognostic significance, and suppression of white cells and platelets may occur after a latent period of up to three weeks, and include stomatitis, hair loss, and the complications of marrow suppression.

- Recovery takes months, and mortality is chiefly due to infections.
- Higher acute exposures may lead to earlier death from GI sloughing,
- and extremely high doses lead to death from coma within hours to days.



Forms (increasing dose)

- **hematologic (marrow) form (from 1 – 2 Gy to 10 Gy)**
 - prodromal symptoms (first 48 hours)
 - **gastrointestinal symptoms** (nausea, vomiting, diarrhoea)
 - vomiting – leading symptom, time of onset, frequency (severity evaluating)
 - **latency** (a few days)
 - **full development of the state**
 - marked impairment of the general state
 - fevers, sepsis, immunity failure, mucose and skin hemorrhage
 - peak in the 2. and 4. week – **deepest drop in neutrophil count, medullary aplasia** (lymfocytes are most vulnerable – they can decrease even in 1 Gy in 48 hours to 50 %)
 - **nasopharyngeal syndrome** – oral and pharyngeal mucose defects
 - hemorrhages, ulceration, necroses
 - skin changes and epilation
 - **radiation pneumonitis**
 - 1 – 3 months latency



- **gastrointestinal form (10 – 20 Gy)**
 - doses about 10 Gy
 - developed symptoms: **4. day**
 - **intestinal epithelium necrosis** (intestinal perforation may occur)
 - cruel diarrhoea with fluid loss and mineral imbalance, intestinal hemorrhage, dangerous surgical complications
- **toxemic (vascular) form (20 – 80 Gy)**
 - developing from the gastrointestinal form
 - intestinal microflora penetrates into the vascular system, releasing of the toxins, products of the cell necrosis cumulate
- **central nervous form**
 - rarely, quick appearance of coma and death (in very high radiation doses)
 - significant morphologic brain changes (tremor, cramps, coma)
 - death: 40 hours after the exposure
 - more than 1000 Gy – „death under the ray“ (also in the case of solitary head exposure)

Acute Radiation Damage

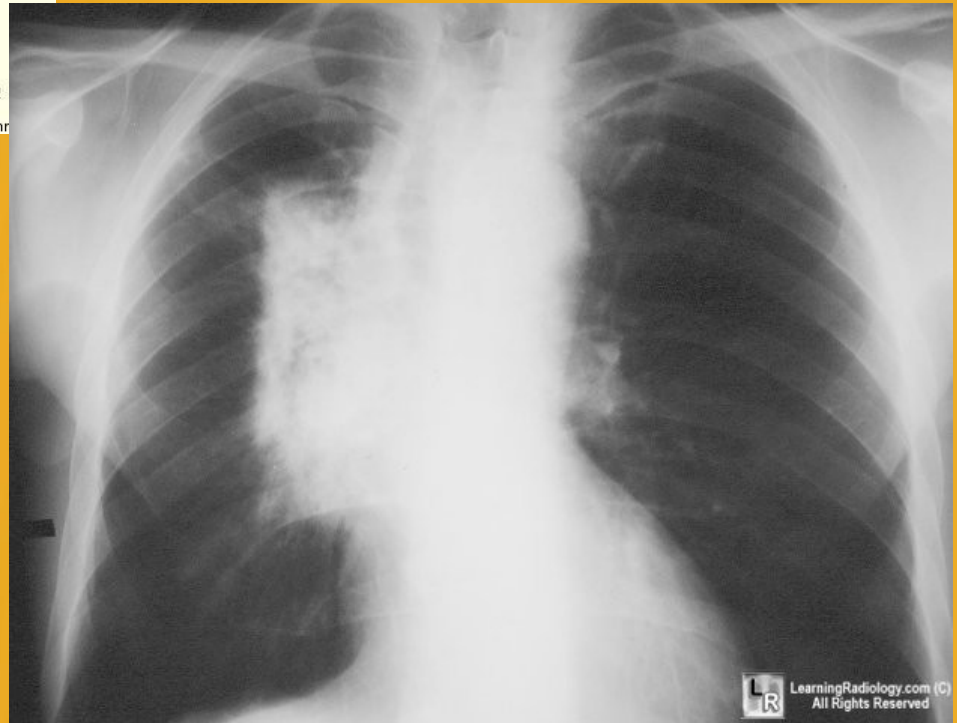


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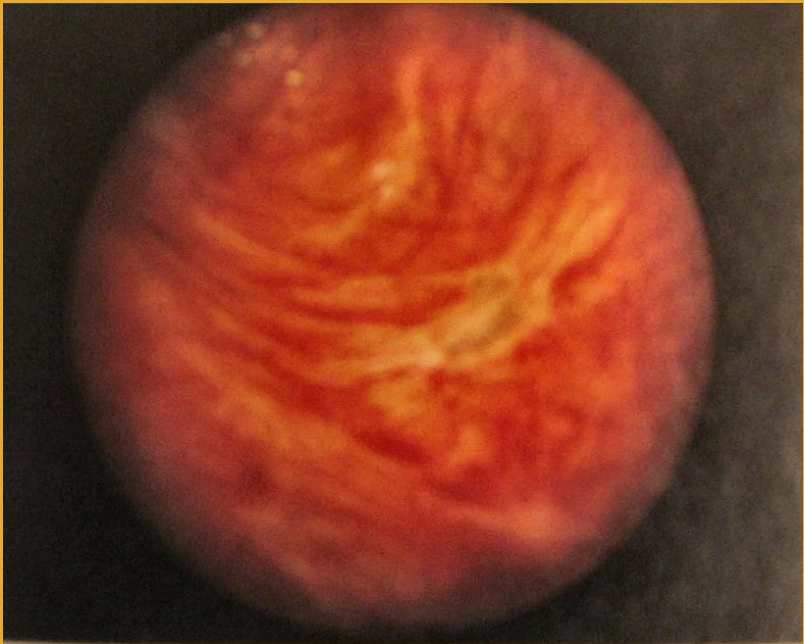
Acute Radiation Pneumonitis



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Acute Radiation Enteritis



Acute Radiation Colitis



Diagnosis

- history taking – clinical state evaluating
- ***think about the possibility*** of this type of ethiology!
- **severity** of the whole-body exposure, dose estimation, and also information about the localization and type of the radiation source
- examination of chromosomal aberrations in peripheral blood

Treatment

- estimate geometric inhomogeneity of radiation and distribution of the doses
- ***less danger of delay (latency period)***
- shock management
- antiemetics
- **in 12 hours** after exposure: no vomiting and in 48 hours: no drop in lymphocytes (under $1 \cdot 10^9/l$) – ***danger of death can be excluded***

Chronic Radiation Sickness

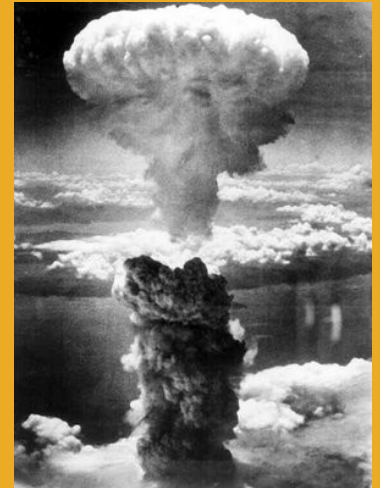
- **not all authors accept this category**
- **etiology**
 - **chronic** lower radiation doses exposure
 - lower velocity of doses
 - result of adverse development of acute radiation sickness
 - inner radionuclides (therapeutic)
- **three stadiums were described**
 - in the last of them – severe bone marrow damage – noted immunity disorders and hemorrhages, often infectious complications
- **local skin damage**
 - lower repeated doses
 - degenerative, proliferative changes
 - skin dryness, epilation, teleangiectasia
 - malignant tumors may develop, basal-cell carcinoma, squamous-cell carcinoma

Chronic radiation dermatitis



Local radiation injury

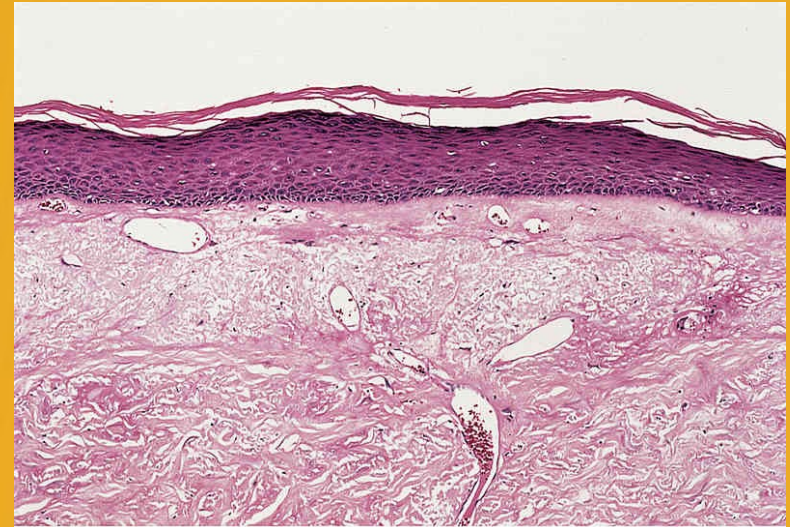
- Local radiation injury includes effects on skin and reproductive organs.
- Radiation cataracts form at the posterior pole of the lens as an initial subcapsular plaque and progress to opacification involving the nucleus of the lens.
- Teratogenic effects depend on dosage and on stage of fetal development. The peak incidence of microcephaly and mental retardation in atomic bomb survivors occurred when in utero exposure took place at 8 to 15 weeks' gestation.



Local Radiation Damage

- in radiation disasters (most often): **radiation dermatitis** (burns)
- critical radiation dose
- **early erythema** – 2 to 3 days after the exposure
- four degrees of severity
 - later erythema – **dry erythematous dermatitis**
 - approximately in 14 days 8 – 12 Gy
 - hair removal (contemporary)
 - **bullous radiodermatitis (wet)** 12 – 20 Gy
 - **erythema with erosions, ulcerations** 20 – 25 Gy
 - **radiation damage** up to 25 Gy
 - very severe degree of damage
 - edema, hematoma in blister base, deep necrosis, secondary infection
 - spontaneous disintegration of scars
 - chronic skin ulcers

Radiation Dermatitis



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Teratogenic effects



- Radioactive substances that enter the body become internal emitters.
- Typical routes include inhalation or ingestion, although wounds and even intact skin may be portals of entry.
- The effective half-life in the body is the combined result of radioactive decay and of excretion.
- Distribution, metabolism and excretion depend on the chemistry of the stable isotope.
- Occupational exposures are at lower levels but are more prolonged.
- Thus, it is the neoplastic risk which is uppermost in most people's minds.

- The latent period between radiation dose and clinical manifestation of cancer can be as short as 2 years for leukemias and bone cancer
- but is typically 10 years or more for other tumours (thyroid cancer, breast cancer in women, lung cancer).
- The protection of persons against ionizing radiations arising from any work activity.
- Control can be summarized in three words:
time – distance - shielding.



Thank you for your attention!