Radiation biology

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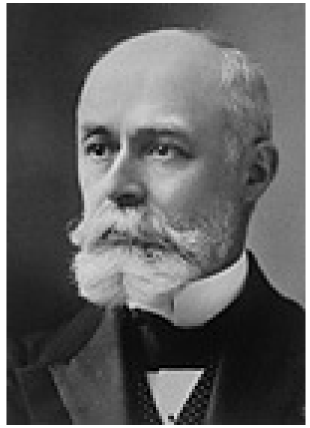
Radiation Biology

Wilhelm Conrad Röntgen
1845-1923

1895 – x-radiation

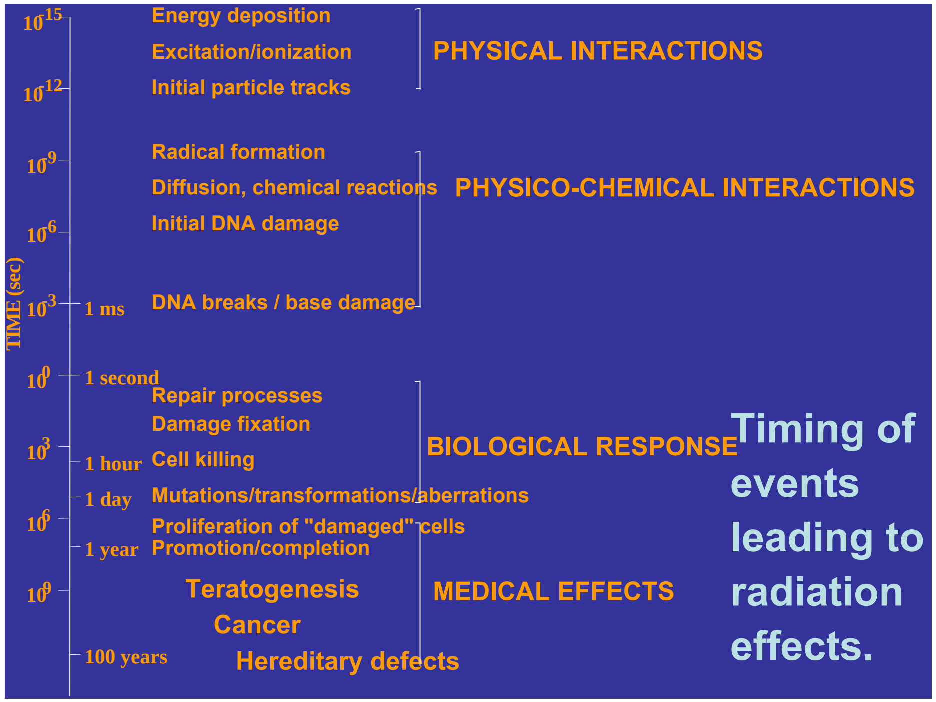


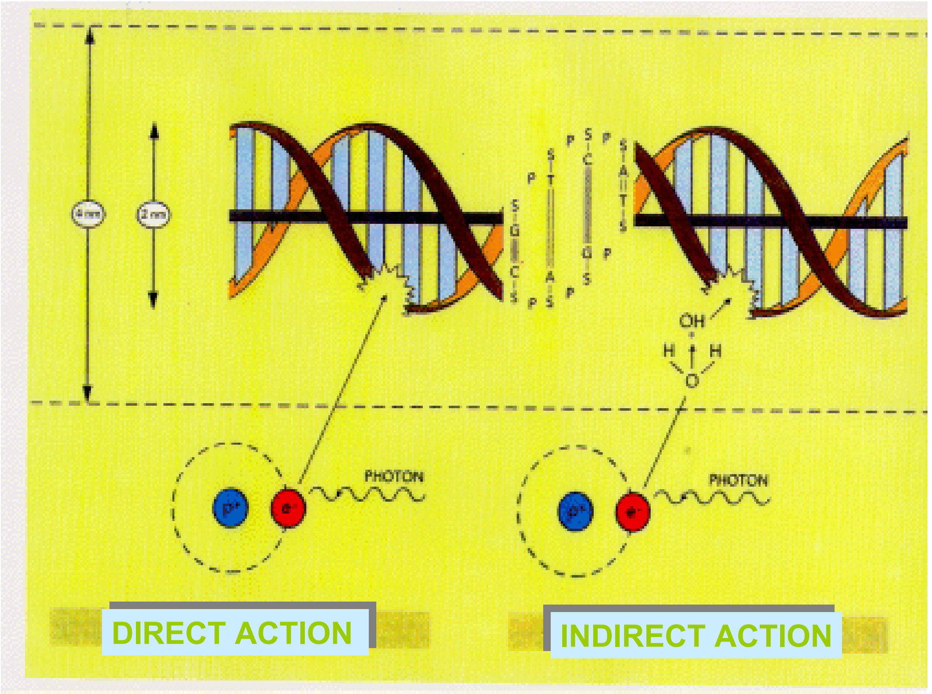
Antoine Henri Becquerel
1852-1908

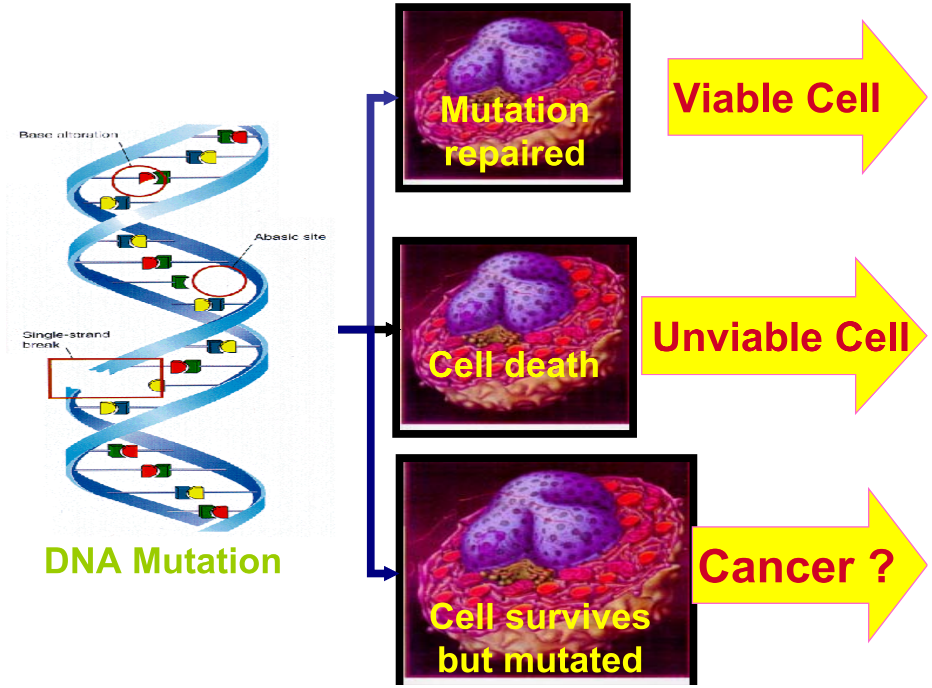
1896 - radioactivity

Grotthus (1815) - Draper (1845)

Only the absorbed radiation can cause physical or chemical effect
(and as a consequence, biological effect)



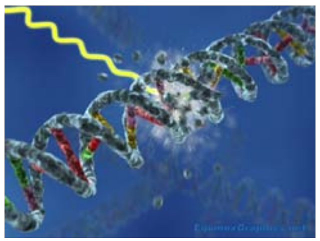


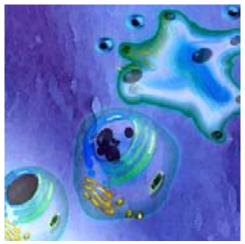


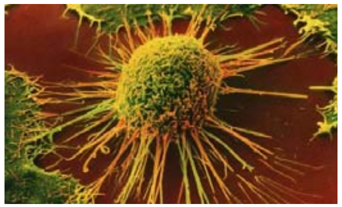
Outcomes after cell exposure

DAMAGE TO DNA

DAMAGE REPAIRED	CELL NECROSIS OR APOPTOSIS	TRANSFORMED CELL







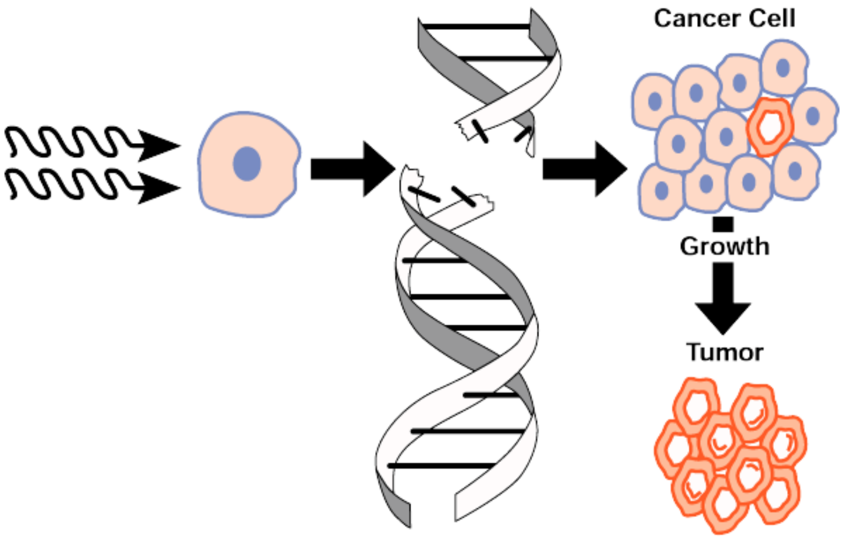


Figure 1. Development of cancer from mutation produced by ionizing radiation.

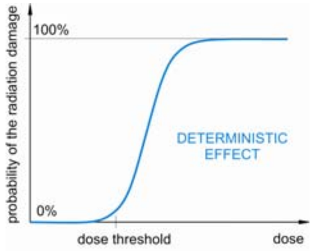
Types of radiation damages

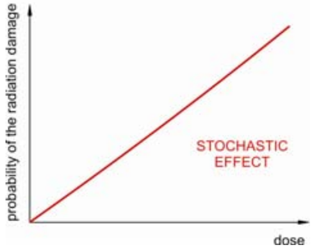
Deterministic (Threshold/non-stochastic)

- Existence of a dose threshold value (below this dose, the effect is not observable)
- Severity of the effect increases with dose
- A large number of cells are involved
- e.g. cataract, radiation sickness

Stochastic (Non-Threshold)

- No threshold
- Probability of the effect increases with dose
- Generally occurs with a single cell
- e.g. cancer, genetic effects





Bergonié-Tribondeau law (1906)
(radiosensitivity law)

(Jean A. Bergonié, French radiologist, 1857-1925;
Louis F.A. Tribondeau, French physician, 1872-1918)

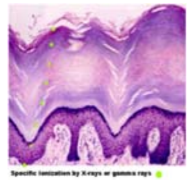
The radiosensitivity of a tissue depends on the number of undifferentiated cells in the tissue, their mitotic activity, and the length of time they are actively proliferating.

Radiosensitivity(RS)

High RS	Medium RS	Low RS
Bone Marrow Spleen Thymus Lymphatic nodes Gonads Eye lens Lymphocytes (exception to the RS laws)	Skin Mesoderm organs (liver, heart, lungs…)	Muscle Bones Nervous system

Factors affecting the radiosensitivity

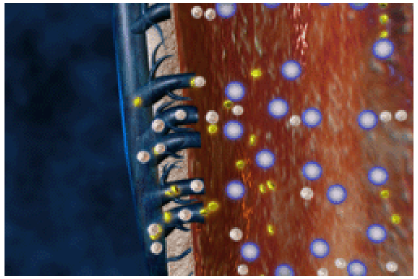
- Physical
  - LET (linear energy transfer): ⇑ RS
  - Dose rate: ⇑ RS
- Chemical
  - Increase RS: OXYGEN, cytotoxic drugs.
  - Decrease RS: SULFURE (cys, cysteamine…)
- Biological
  - Cycle status:
    - ⇑ RS: G2, M
    - ⇓ RS: S
  - Repair of damage (sub-lethal damage may be repaired e.g. fractionated dose)



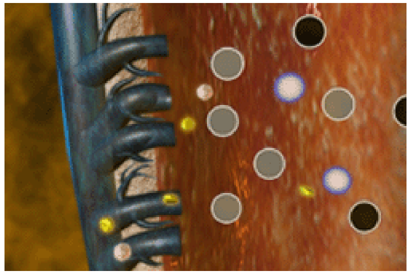
The three classic Acute Radiation Syndromes are:

Bone marrow syndrome (sometimes referred to as hematopoietic syndrome) the full syndrome will usually occur with a dose between 0.7 and 10 Gy (70 – 1000 rads) though mild symptoms may occur as low as 0.3 Gy.

The survival rate of patients with this syndrome decreases with increasing dose. The primary cause of death is the destruction of the bone marrow, resulting in infection and hemorrhage.



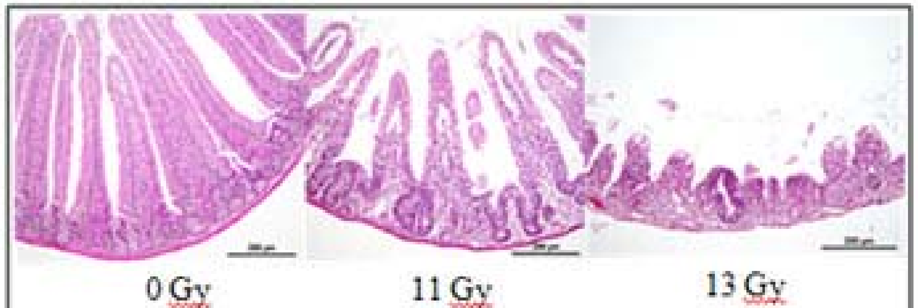
healthy



damaged

Gastrointestinal (GI) syndrome: the full syndrome will usually occur with a dose greater than approximately 10 Gy although some symptoms may occur as low as 6 Gy.

Survival is extremely unlikely with this syndrome. Destructive and irreparable changes in the GI tract and bone marrow usually cause infection, dehydration, and electrolyte imbalance. Death usually occurs within 2 weeks.



Mouse jejunum: 4 day after irradiation at 0, 11 and 13 Gy

Cardiovascular (CV)/ Central Nervous System (CNS) syndrome: the full syndrome will usually occur with a dose greater than approximately 50 Gy although some symptoms may occur as low as 20 Gy.
Death occurs within 3 days. Death likely is due to collapse of the circulatory system as well as increased pressure in the confining cranial vault as the result of increased fluid content caused by edema, vasculitis, and meningitis

Cutaneous radiation syndrome

The concept of cutaneous radiation syndrome (CRS) was introduced in recent years to describe the complex pathological syndrome that results from acute radiation exposure to the skin.
Acute radiation syndrome (ARS) usually will be accompanied by some skin damage. It is also possible to receive a damaging dose to the skin without symptoms of ARS, especially with acute exposures to beta radiation or X-rays. Sometimes this occurs when radioactive materials contaminate skin or clothes.

Acute radiation dermatitis

6,5 hours local exposure to Iridium-192 source
(β,γ-radiating) approx. 0,9 TBq

day 2: early blister, erythema

day 9: extended erosion, inflammation

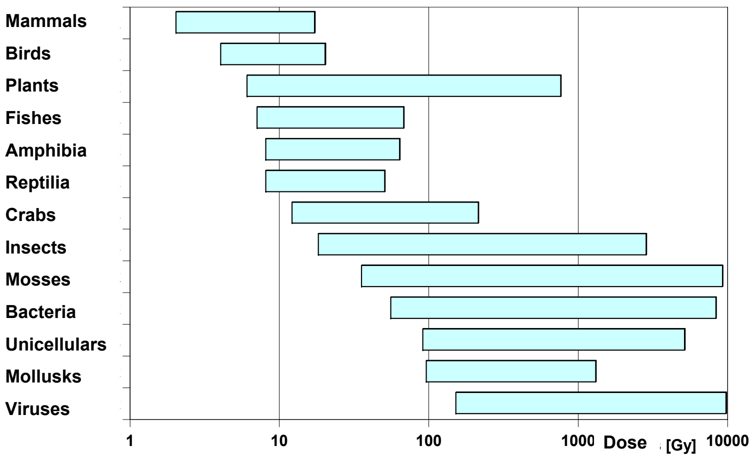
Turai e.a., *BMJ 2004, 328: 568-572*

Acute Radiation Exposure

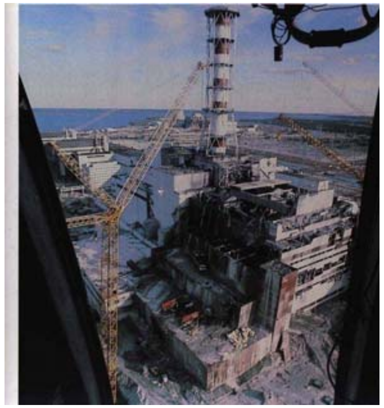
Effects of large, whole-body radiation doses

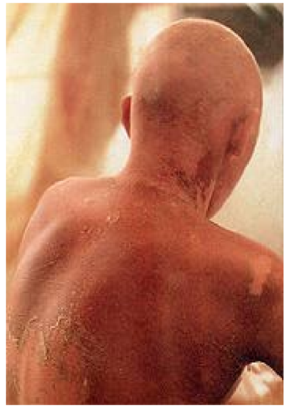
Effect	Dose (Sv)
No observable effect	0- 0.25
Slight blood changes	0.25-1
Significant reduction in blood platelets and white blood cells (temporary)	1-2
Severe blood damage, nausea, hair loss, hemorrhage, death in many cases	2-5
Death in less than two months for over 80%	> 6

LD_{50} for acute irradiation

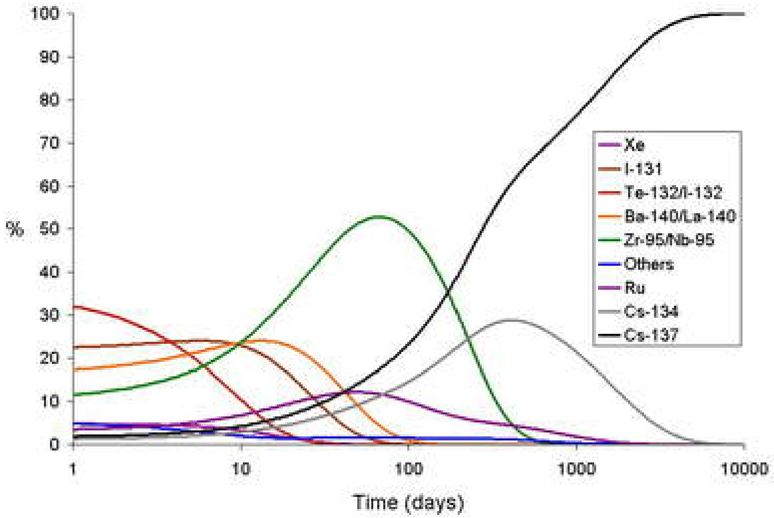


Chernobyl accident



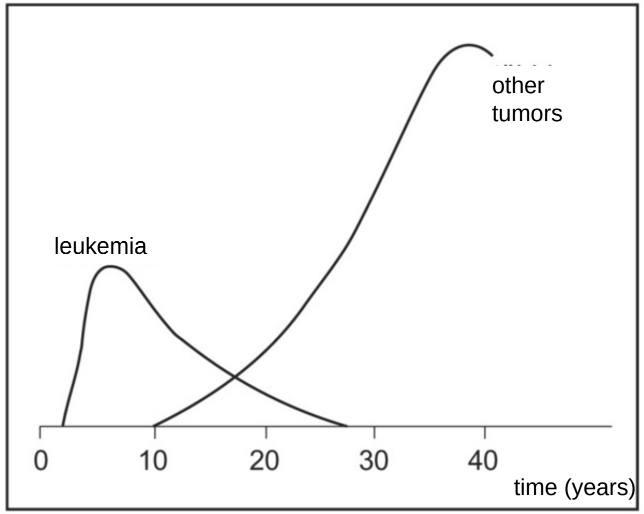


The percentage of nuclids in the function of time in air pollution after Chernobyl accident



Late radiation effects

production of cancer



Thyroid Cancer in Children in the Chernobyl Region

Region	No of Cases before the accident	No of Cases after the accident
Belarus	(1977-1985) 7	(1986-1994) 390
Ukraine	(1981-1985) 24	(1986-1995) 220
Russia (Bryansk and Kaluga region only)		(1986-1995) 62

The data represent incidences (not mortality) and are preliminary results.
Most excess cancers occurred since 1993.
Thyroid cancer has a high rate of cure >90%, but many of the cancers found are of the aggressive papillary type.