Radiation Health Effects

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International Atomic Energy Agency

Content

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- Primary target for cell damage
- Deterministic effects
- Stochastic effects
- Effects of *in-utero* exposure
- Practical application of fundamental knowledge
- Summary

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Facts

- Radiation is a fact of life - all around us, all the time
- There are two classes of radiation
  - Non-ionizing radiation
  - Ionizing radiation

- The origin of the radiation
  - Natural radiation
  - Artificial (human-made) radiation

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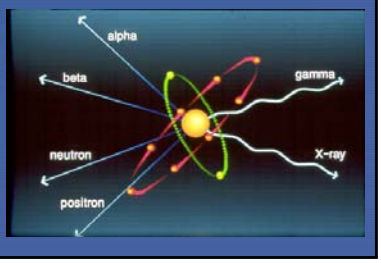
Types of Radiation

- Often considered in three different groups
  - Alpha (α), beta (β)
  - Gamma (γ), X-ray
  - Neutrons



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Discovery of X rays (1895)

Wilhelm Conrad Roentgen

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Discovery of Uranium's Natural Radioactivity

Antoine Henri Becquerel

Marie Curie

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Basic Terms

- Activity: the quantity of radioactive material present at a given time
  - Unit: becquerel (one disintegration per second)
    - Symbol: Bq
  - Old unit: curie (Ci)

More information on terms: IAEA Safety Glossary
http://www-ns.iaea.org/standards/safety-glossary.htm

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Doses and Units

Absorbed dose
Energy imparted by radiation to standard mass of tissue
[unit Gray - Gy]

↓

Equivalent dose
Absorbed dose weighted for the harm of different types of radiation
[unit Sivert - Sv]

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Effective dose
Equivalent dose weighted for the harm of different tissues
[unit Sivert - Sv]

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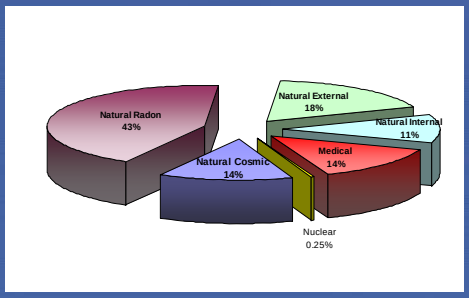
Sources of Ionizing Radiation



Average radiation exposure from all sources: 2.8 mSv/year

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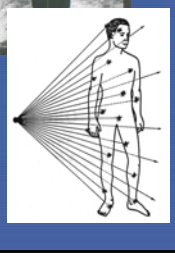
First Medical Findings

- First skin-burn attributed to radiation - 1901
- First radiation induced leukemia described -1911
- First publication describing “a clinical syndrome due to atomic bomb” - 1946



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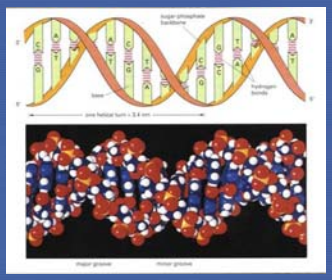
Ionizing Radiation and Human Cell

- Primary target for cell damage from ionizing radiation is deoxyribonucleic acid (DNA) in chromosomes of cell's nuclei



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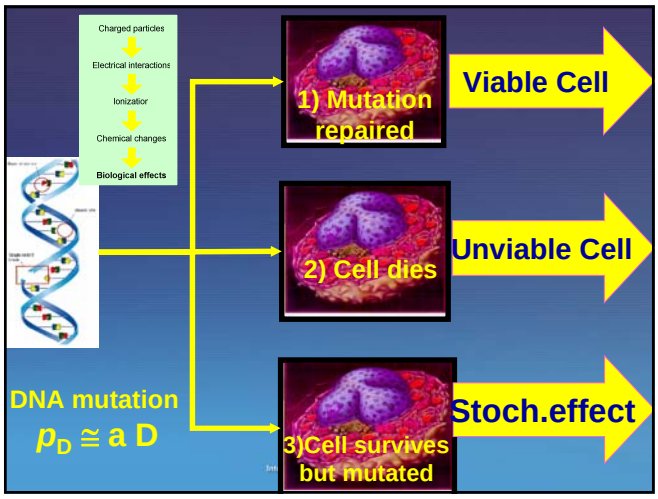

First Possible Outcome: Damage is Repaired

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Second Possible Outcome: Cell Death

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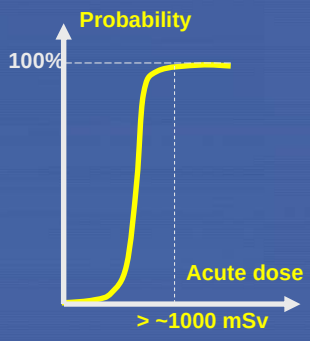
Deterministic Health Effects

- A radiation effect for which generally a threshold level of dose exists above which the severity of the effect is greater for a higher dose
  - many cells die or have function altered
  - occurs when the dose is above given threshold (specific for the given effect)
  - severity increases with the dose



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Deterministic Health Effects

- Data on deterministic health effects are collected from observation of:
  - side effects of radiotherapy
  - effects on the early radiologists
  - effects amongst survivors of the atomic bombs at Hiroshima and Nagasaki in Japan
  - consequences of severe accidents
    - In 1944-2004:
      - 428 registered emergencies (REAC/TS Registry of radiation accidents)
      - ~ 3000 overexposed people (whole body dose >0.25 Sv, H skin > 6 Sv, or H other organ > 0.75 Sv)
      - 134 fatalities

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Deterministic Health Effects

Organ or tissue	Dose in less than 2 days, Gy	Deterministic effects	
		Type of effect	Time of occurrence
Whole body (bone marrow)	1	Acute Radiation Syndrome (ARS)	1 – 2 months
Skin	3	Erythema	1 – 3 weeks
Thyroid	5	Hypothyroidism	1st – several years
Lens of the eye	2	Cataract	6 months - several years
Gonads	3	Permanent sterility	weeks

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Deterministic Health Effects

- **Chernobyl experience:**
  - **Acute Radiation Syndrome and Radiation burns**

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Deterministic Health Effects After Chernobyl

- Very high doses on-site
- 134 cases of ARS among responders (fire fighters and recovery operation workers):
  - 28 died in 1986 from a combination of high external doses of γ-exposure (2.2-16 Gy) and skin burns due to β-emitters
  - 17 died in 1987-2004 from various causes, not all linked to radiation
- No cases of acute radiation syndrome have been recorded among the general public

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Deterministic Effects

- Radiation burns - recent experience

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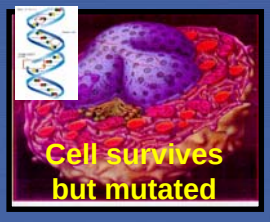
Third Possible Outcome: Viable but Mutated Cell



Stochastic effects

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Stochastic Health Effects

- A radiation-induced health effect, occurring without a threshold level of dose:
  - probability is proportional to the dose
  - severity is independent of the dose
- Stochastic health effects:
  - Radiation-induced cancers
  - Hereditary effects
- Late appearance (years)
- Latency period:
  - Several years for cancer
  - Hundreds of years for hereditary effects

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Sources of Data on Stochastic Health Effects

- Occupational exposure
  - Early radiologist and medical physicists
  - Radium-dial painters
  - U-miners, nuclear industry workers
- A-bomb victims
- Overexposed from accidents
- Irradiated for medical reasons

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Studies of Japanese A-bomb Survivors

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Cohort of Hiroshima & Nagasaki (Life Span Study, LSS)

- Primary source of information:
  - 86,500 individuals of:
    - both sexes and
    - all ages
  - dosimetric data over a range of doses
    - Average dose – 0.27 Sv
    - ~ 6,000 individuals exposed in dose > 0.1 Sv
    - ~ 700 individuals exposed in dose > 1 Sv

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LSS Solid Cancer Mortality

- 47 years of follow-up (1950-1997)
- Observed: 9,335 fatal cases of solid cancer
- Expected: ~8,895 fatal cases of solid cancer
  - i.e. ~440 cancers (5%) attributable to radiation

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(Preston et al, *Radiat Res* 160:381-407, 2003)

Summary of Epidemiological Estimates Cancer Risks

- Cancer mortality risk for fatal solid cancers

~0.005% per mSv

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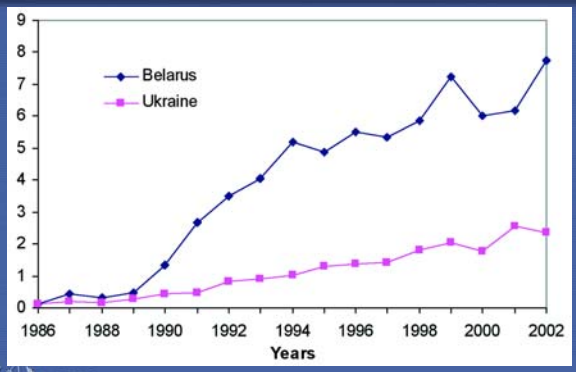
Radiation-Induced Cancers: Chernobyl Experience

Incidence Rate of Thyroid Cancer per 100,000 Children and Adolescents as of 1986



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(after Jacob et al., 2005)

Other Radiation-Induced Cancers

- "Liquidators"
  - Doubling of leukaemia morbidity in workers with D>150 mGy
  - Some increase of mortality (~5%) caused by solid cancers and cardiovascular diseases
  - Increased cataract frequency
  - doses recorded in the Registries range up to about 500 mGy, with an average of ~ 100 mGy

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Other Radiation-Induced Cancers (2)

- General public
  - No increase of leukaemia
  - No increase of solid cancers except of thyroid cancer in children and adolescents (considered above)
  - Effective dose during 1986-2005 range from a few mSv to some hundred mSv with an average dose 10 - 20 mSv

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Hereditary Effects

- Effects to be observed in offspring born after one or both parents had been irradiated prior to conception
- Radiation exposure does not induce new types of mutations in the germ cells but increase the incidence of spontaneous mutations

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Hereditary Effects

- Descendents of Hiroshima and Nagasaki survivors were studied
- A cohort of 31,150 children born to parents who were within 2 km of the hypocenter at the time of the bombing was compared with a control cohort of 41,066 children

But, no statistical abnormalities were detected

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Hereditary Effects

- In the absence of human data the estimation of hereditary effects are based on animal studies
- Risks to offspring following prenatal exposure:
  - Total risk = 0.0003 - 0.0005% per mGy to the first generation
  - Constitutes 0.4-0.6% of baseline frequency

(UNSCEAR 2001 Report
Hereditary Effects of Radiation)

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Typical Effects of Radiation on Embryo/Foetus

- Death of the embryo or fetus
- Induction of:
  - malformation
  - growth retardation
  - functional disturbance
  - cancer
- Factors influencing the probability of effects
  - Dose for embryo or fœtus
  - Gestation status at the time of exposure

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Severe Mental Retardation

- A study of about 1,600 children exposed in-utero at Hiroshima and Nagasaki to various radiation doses and at various developmental stages:
  - excess mental retardation was at a maximum between 8 and 15 weeks
  - Risk: 0.05% per mSv (8-15 weeks)

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From Fundamental Knowledge to Practical Application

In Summary

- Radiation may cause two types of health effects: deterministic (e.g., radiation burns) and stochastic (e.g., radiation-induced cancer)
- Our knowledge of these effects forms the basis for the system of radiation safety and for response to radiation emergencies

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Thank you

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