

EFFECTS OF LOW RADIATION DOSES

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What are low radiation doses ?

Natural Background		
Source or mode	Average dose annual (mSv)	Typical range of annual dose (mSv)
Inhalation (radon gas)	1.26	0.2 – 10
External terrestrial	0.48	0.3 – 1
Ingestion	0.29	0.2 - 1
Cosmic radiation	0.39	0.3 - 1
Total natural	2.4	1 - 13

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Source or mode	Typical dose (mSv)
10 hour aeroplane flight	0.03
Chest x-ray	0.05
CT scan	10
Annual dose from natural background	2.4
Annual dose to nuclear worker	1
Annual cosmic radiation at sea level	0.4
Annual cosmic Mexico City (2 300m)	0.8
Chernobyl recovery workers in 1986	150

Source or mode	Typical dose rate (μ Sv/h)
External natural background	0.06 - 0.2
Natural background (total)	0.3 - 1.5
Aeroplane flight	3
10 second chest X-ray	20 000
20 second CT scan	800 000

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Dose limitation	mSv
Exemption / Clearance	0.01
Facility dose constraint	0.3
Public dose limit	1
Worker dose limit	20

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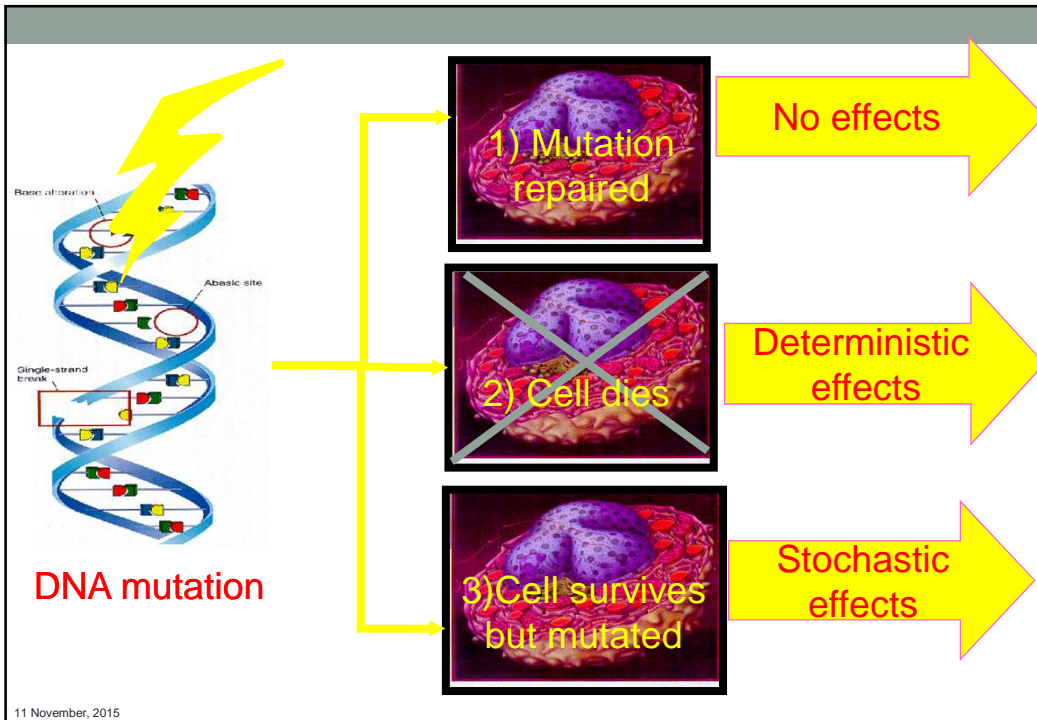
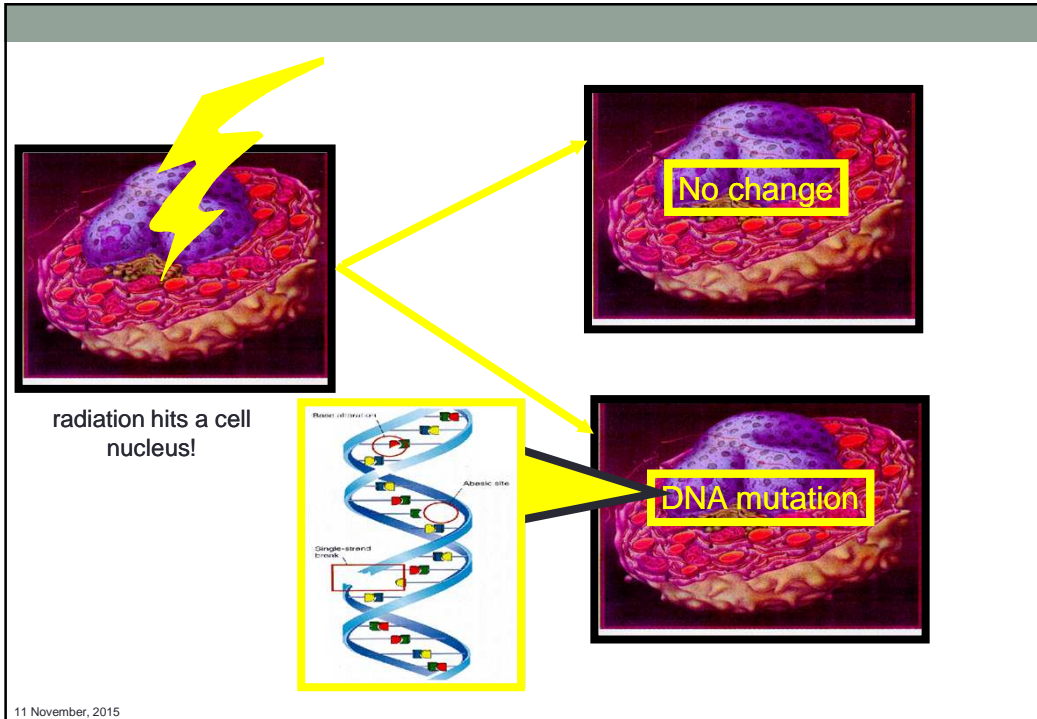
Indicative dose (mSv)	Effects on human health
Up to 10	No direct evidence of human health effects
10 - 1 000	No early effects; increased incidence of certain cancers in exposed populations at higher doses
1 000 - 10 000	Radiation sickness (risk of death); increased incidence of certain cancers in exposed populations
Above 10 000	Fatal always

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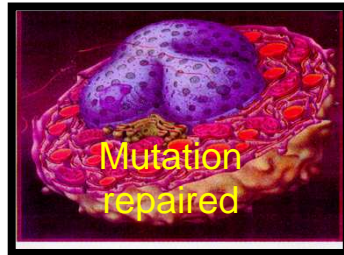
Types of effects

- Deterministic and stochastic effects
 - Deterministic include, lymphocyte depletion, cataract formation, skin erythema, hair loss, sterility and acute radiation syndrome – severity increases with dose above a threshold around 100 mSv
 - Stochastic effects include cancer, and hereditary disorders – incidence increases with the amount of exposure, no threshold

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First possible outcome: Mutation is repaired

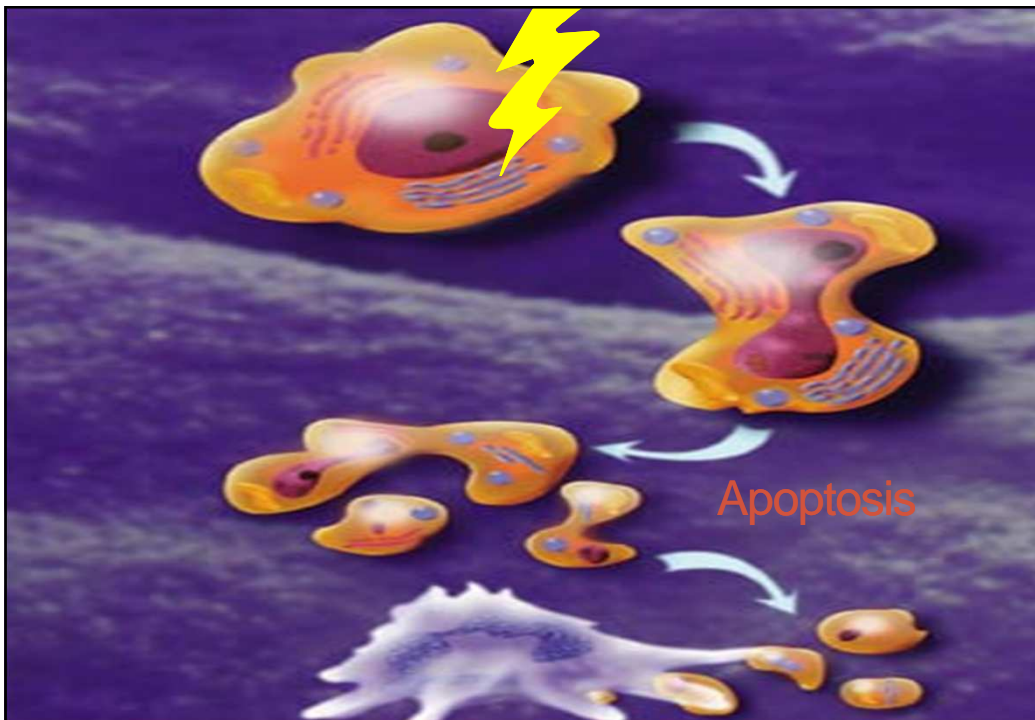


Viable Cell

Second possible outcome: Cell death



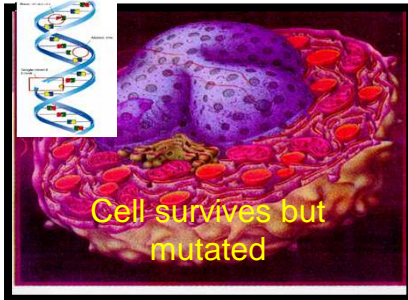
Non viable Cell



If many cells are killed ($\pm 10^9$ per day) \Rightarrow *deterministic effects*:
burns, organ failure, death

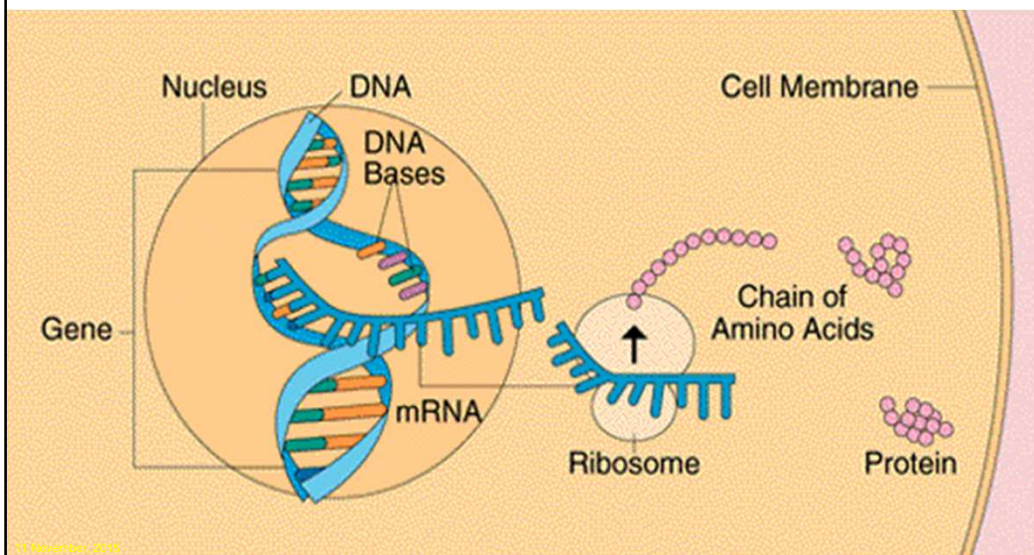


Third possible outcome: Viable mutated cell

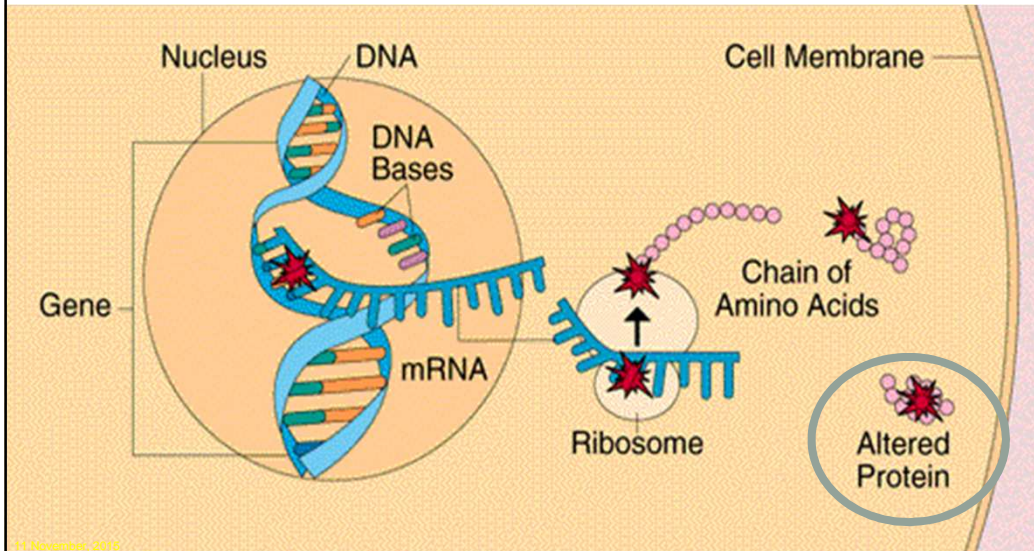


Altered process

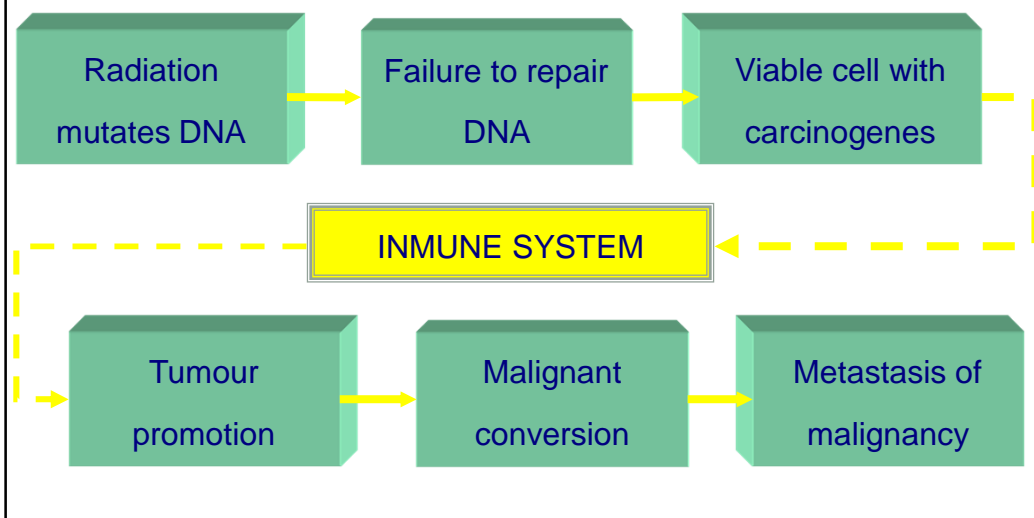
Normal process



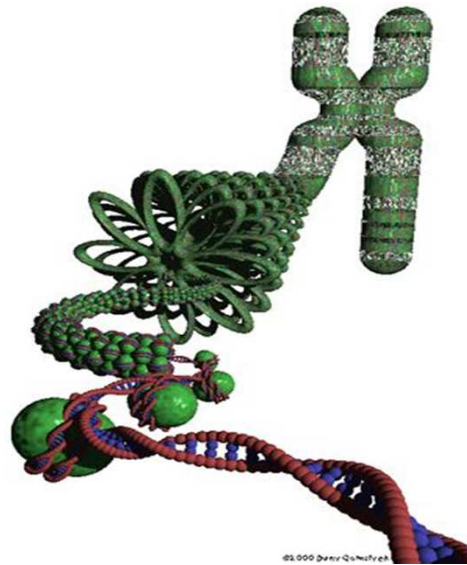
Altered process



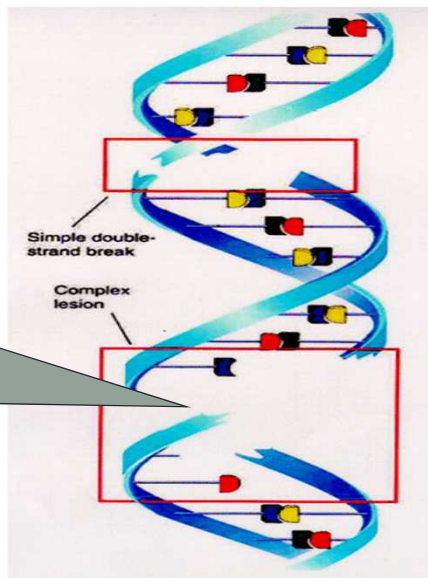
Radiation-induced cancer

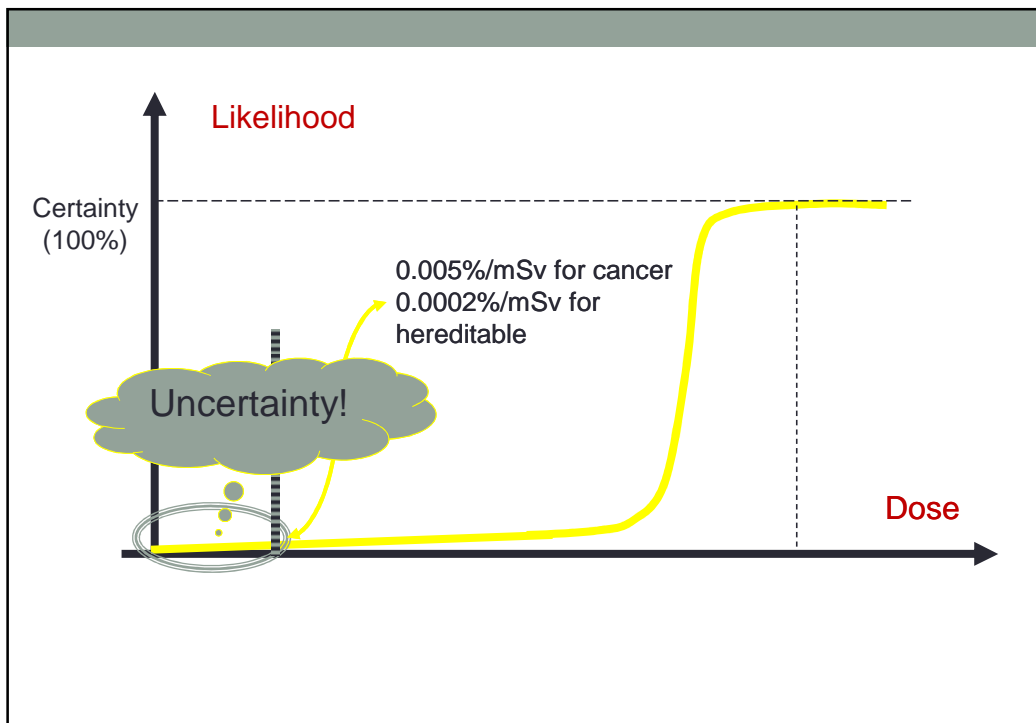
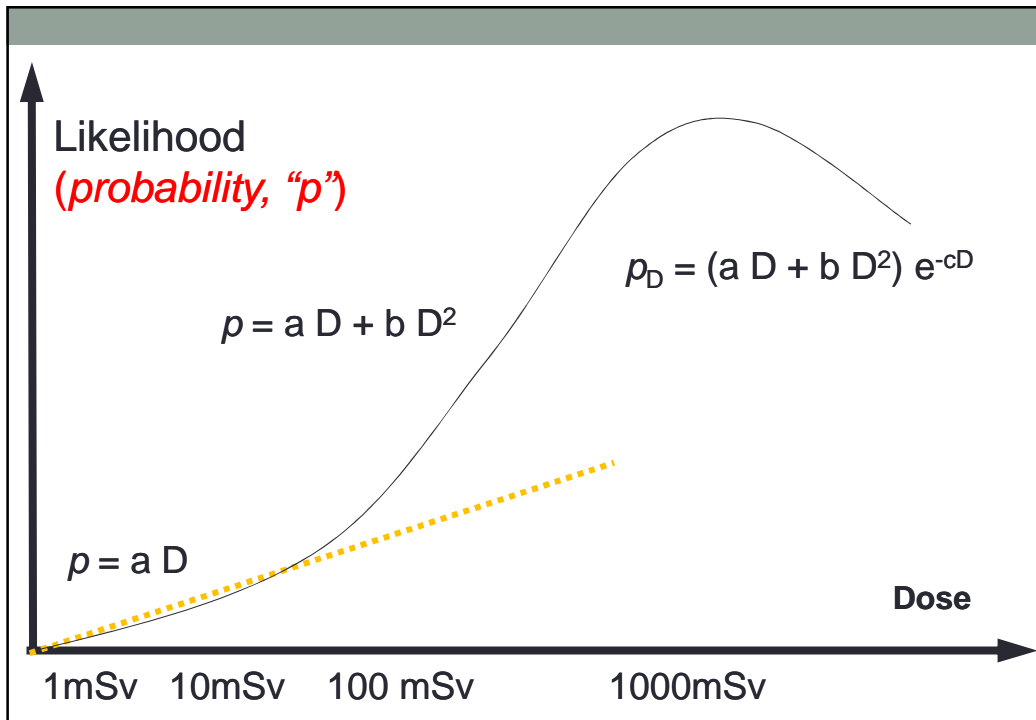


Condensing the DNA
into chromosomes:
a complex structure

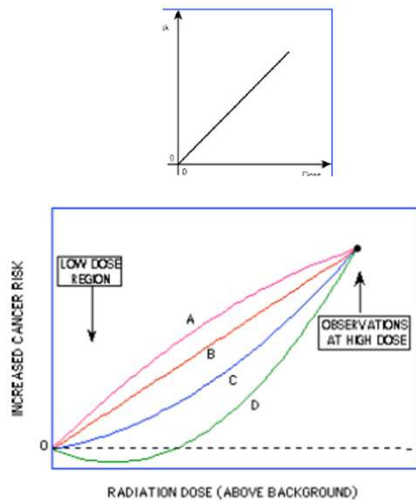


Clastogenic
double-strand
lesions are
typical after
radiation exposure.



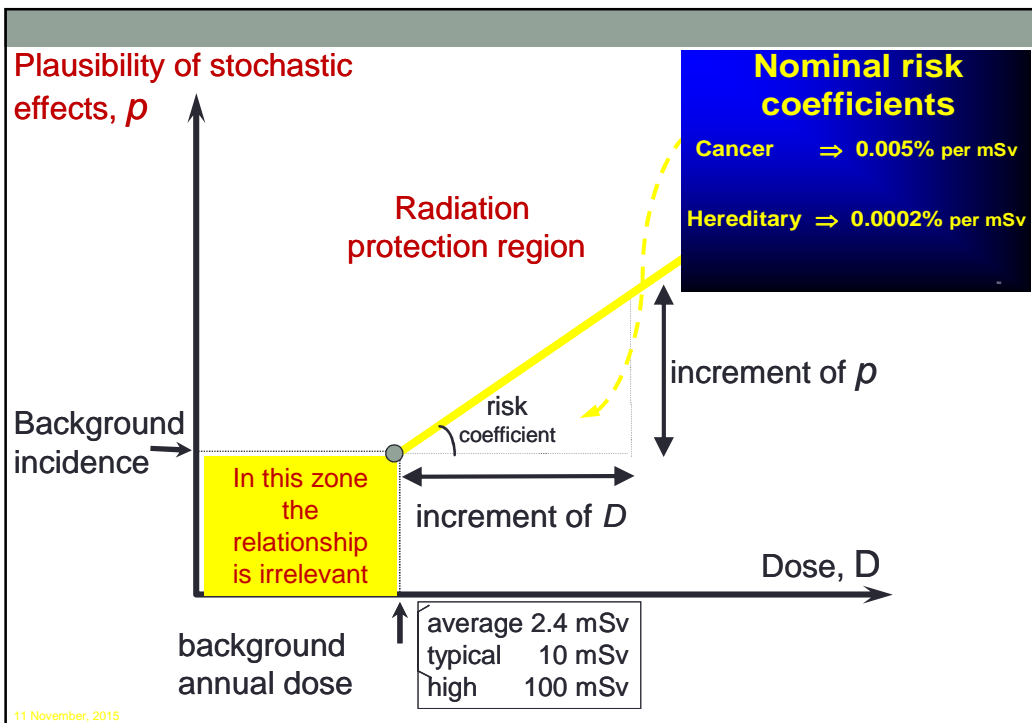


Linear No Threshold (LNT) Hypothesis

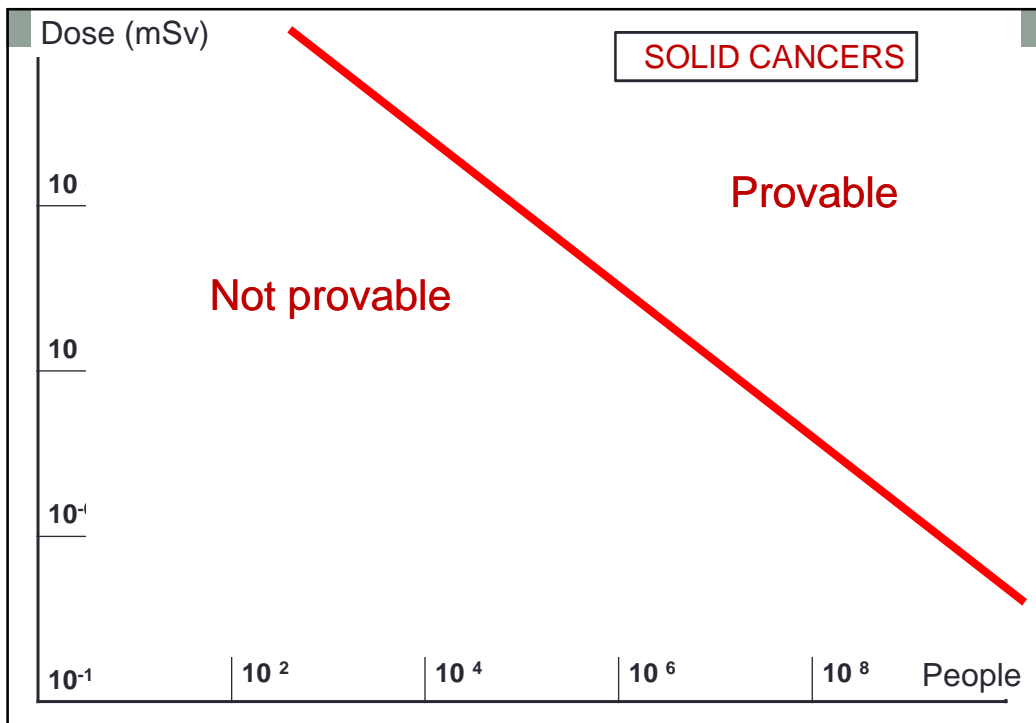
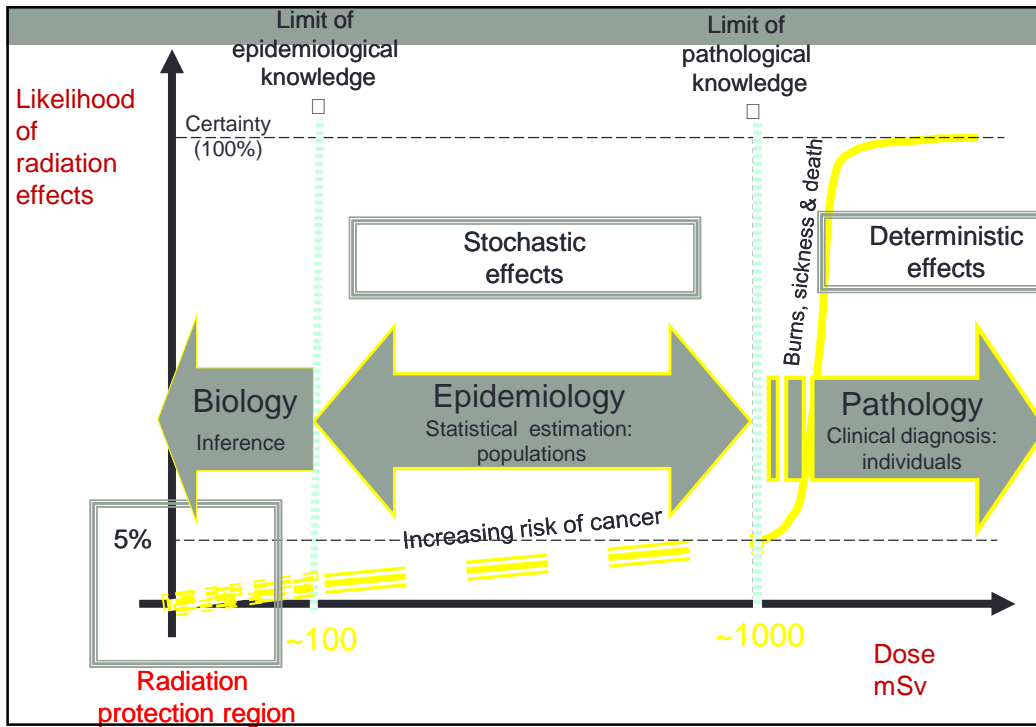


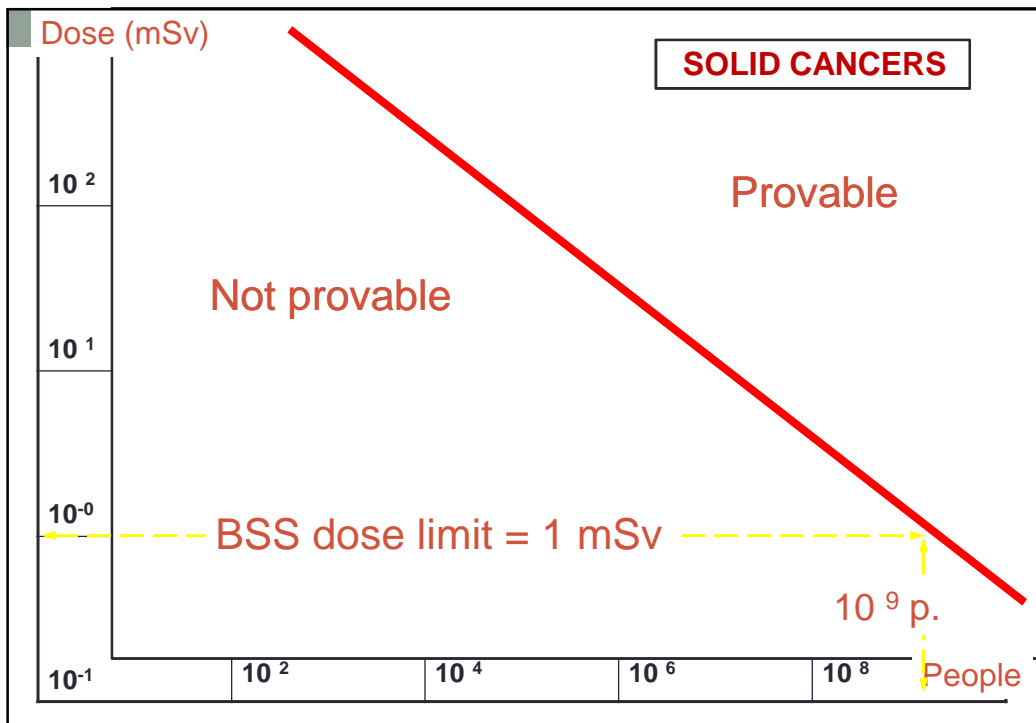
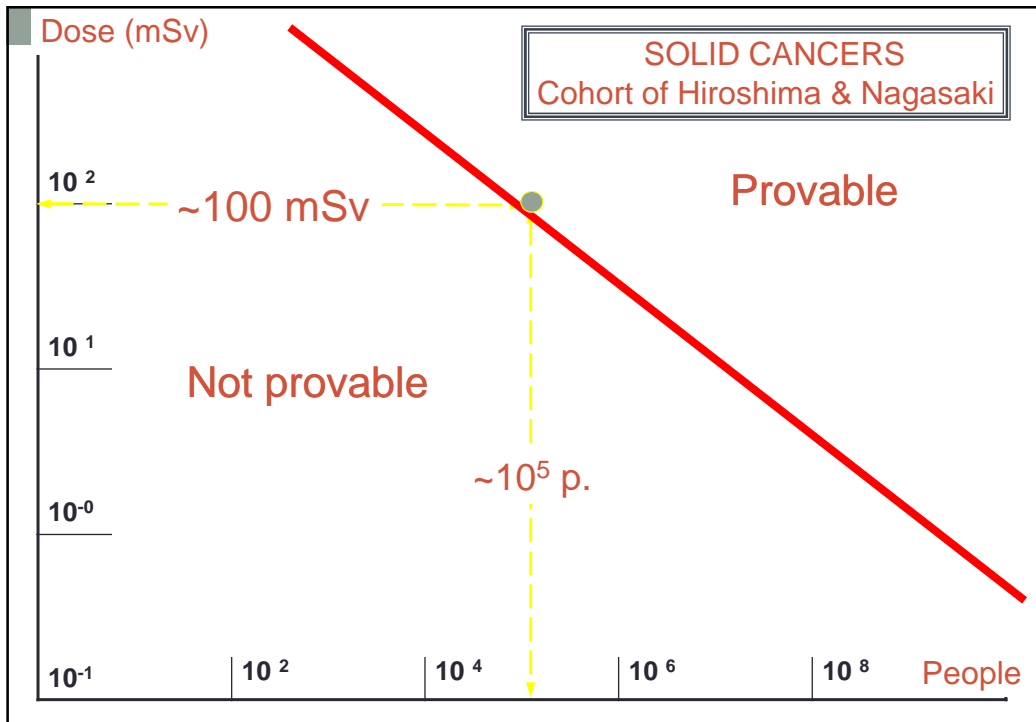
- ✓ A: Increased risk for low doses (BE, GI).
- ✓ B: linear threshold model.
- ✓ C: Decreased risk for low doses.
- ✓ D: U-shape hormetic curve (AR).

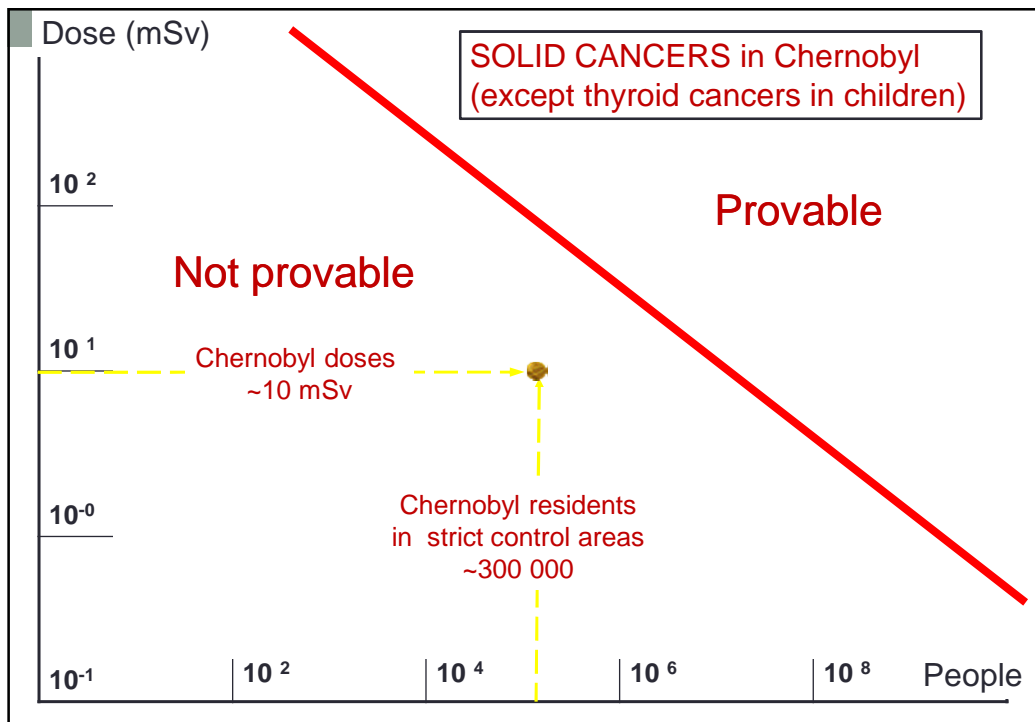
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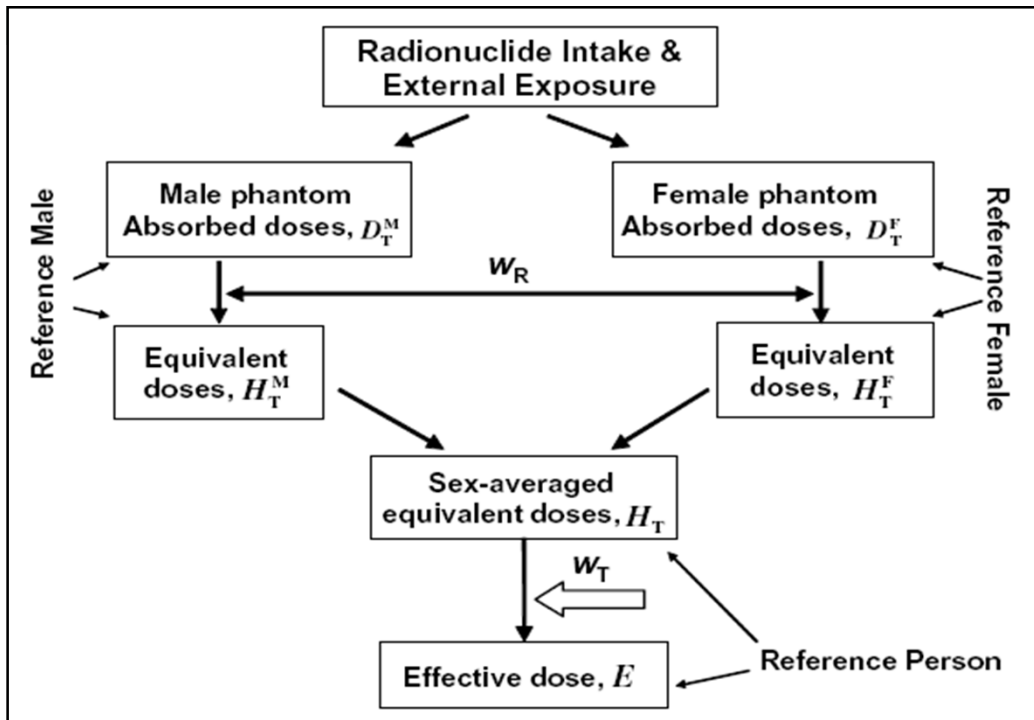




Compounding radio/biological factors

- Relative Biological Effectiveness (RBE)
- Latency period
- Non targeted effects
- Other health effects
- Genomic instability
- Adaptive response
- Committed dose
- Collective dose
- Prediction of impact

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Detriment-adjusted nominal risk coefficients

[% Sv⁻¹]

Nominal Population	Cancer & leukæmia	Hereditary	Total
Whole	5.5	0.2	5.7
Adult	4.1	0.1	4.2

**Low-dose nominal cancer risk estimate ~5%Sv⁻¹
(for a reference person)**

Prediction of Impact

1. World population = 6 706 993 152 (July 2008)
 2. Medical per caput dose = 0.4mSv/year
 3. 2 682 797 person Sv/year
 4. x 5%/Sv = 134,139 persons/year
- Is really diagnostic radiology responsible of the manslaughter of 134,140 persons every year?
 - Calculation not meaningful nor appropriate
 - Detriment-adjusted Nominal Risk Coefficients

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Detriment-adjusted Nominal Risk Coefficients

- **Risk Coefficient:** A numeral, expressed in % Sv⁻¹, which multiplied by dose quantifies the plausibility of harm.
- **Nominal:** The stated numeral does not necessarily correspond to its real value: it relates to hypothetical (not real) people who are averaged over age and sex.
- **Detriment-adjusted:** The numeral is multidimensional, expressing plausible expectation of harm, including *inter alia* weighted plausibility of fatal and non-fatal harm, and life-lost should the harm actually occur.

Probability \neq Provability

Risk \neq Consequence

Attribution of nominal risk \neq Attributing actual effects

Thesis

1. RISK of health effects can be attributed to low-dose radiation exposure; therefore: *radiation protection standards are needed*
2. HEALTH EFFECTS cannot be attributed to low-dose radiation exposure; therefore: *actual harm can not be assigned to low-dose radiation exposure situations*

Summary

- Equivalent and effective dose include biological judgements
- High LET radiation leads to clustered DNA-damage - less repaired
- DNA most important target, repair efficient, damage initiator for cell death, mutation and possibly cancer
- Genetic disposition important for DNA repair / individual sensitivity
- No threshold linear dose response assumed for stochastic effects
- Cancer in exposed populations doses $>$ 100 mSv
- Low dose cancer risk extrapolated from higher dose estimates
- Risk differs between sexes, ages, genetic disposition
- Dose limitation based on nominal risk of health effects

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