BSc (MT) Radiography

Biological effects of radiation

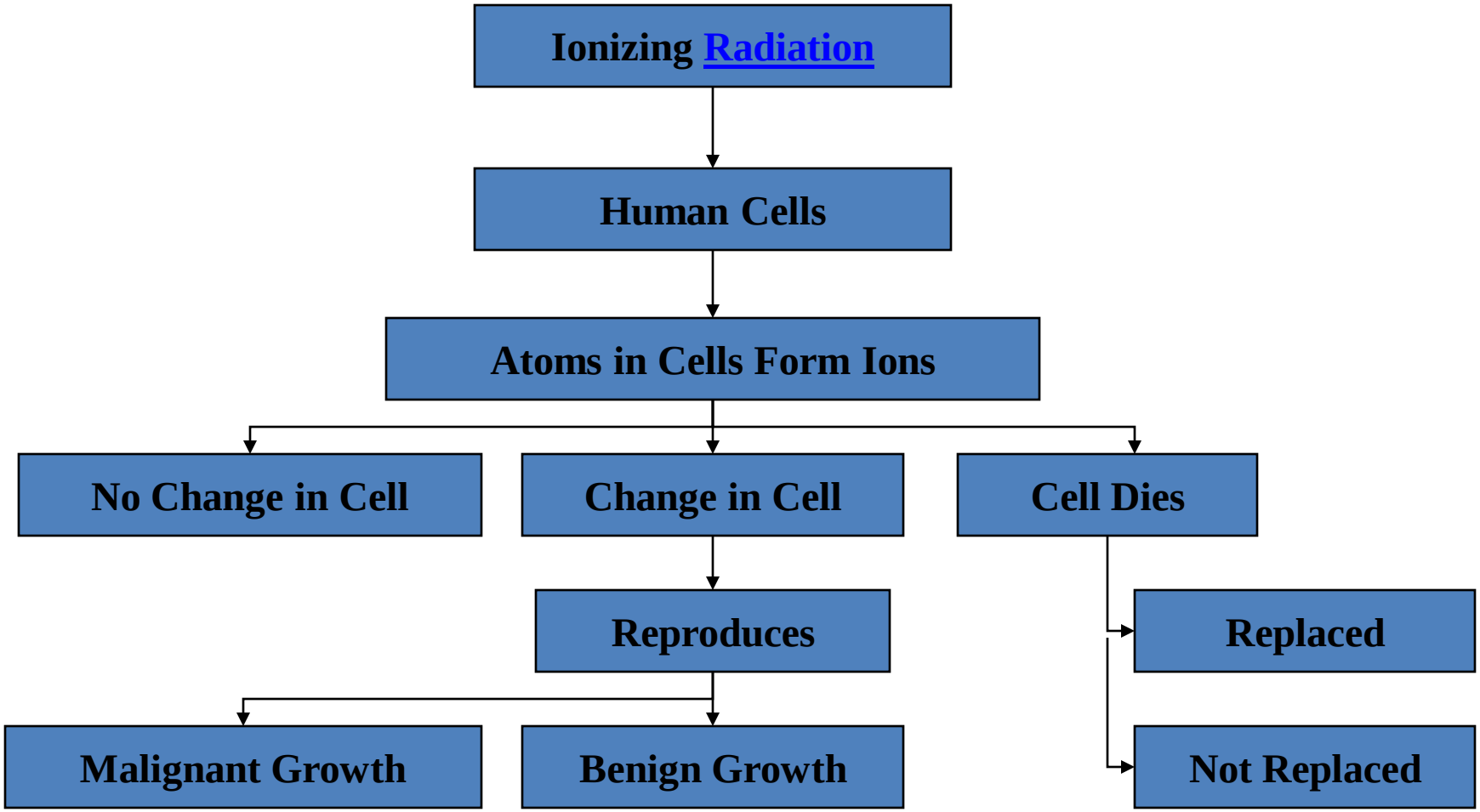
- Dr. Shuchi Bhatt
- HOD, Radio-diagnosis,
- UCMS, Delhi University,
- Delhi

Background Radiation

- As a part of living on earth, people are exposed to radiation from various sources every day

- Some of this radiation comes from:
  - Radon Gas
  - Space (in the form of cosmic rays)
  - The earth (from the rocks and soil)
  - Ourselves (from radioactive carbon and potassium in our bodies)
  - Medical Procedures (X-rays, etc)

Why are we concerned about Radiation?



Biological Effects of Radiation

- Biological Effects of Radiation can be broken into two groups according to how the responses (symptoms or effects) relate to dose (or amount of radiation received)

- The First Group of biological effects are Stochastic Effects
- The Second Group of biological effects are Deterministic Effects

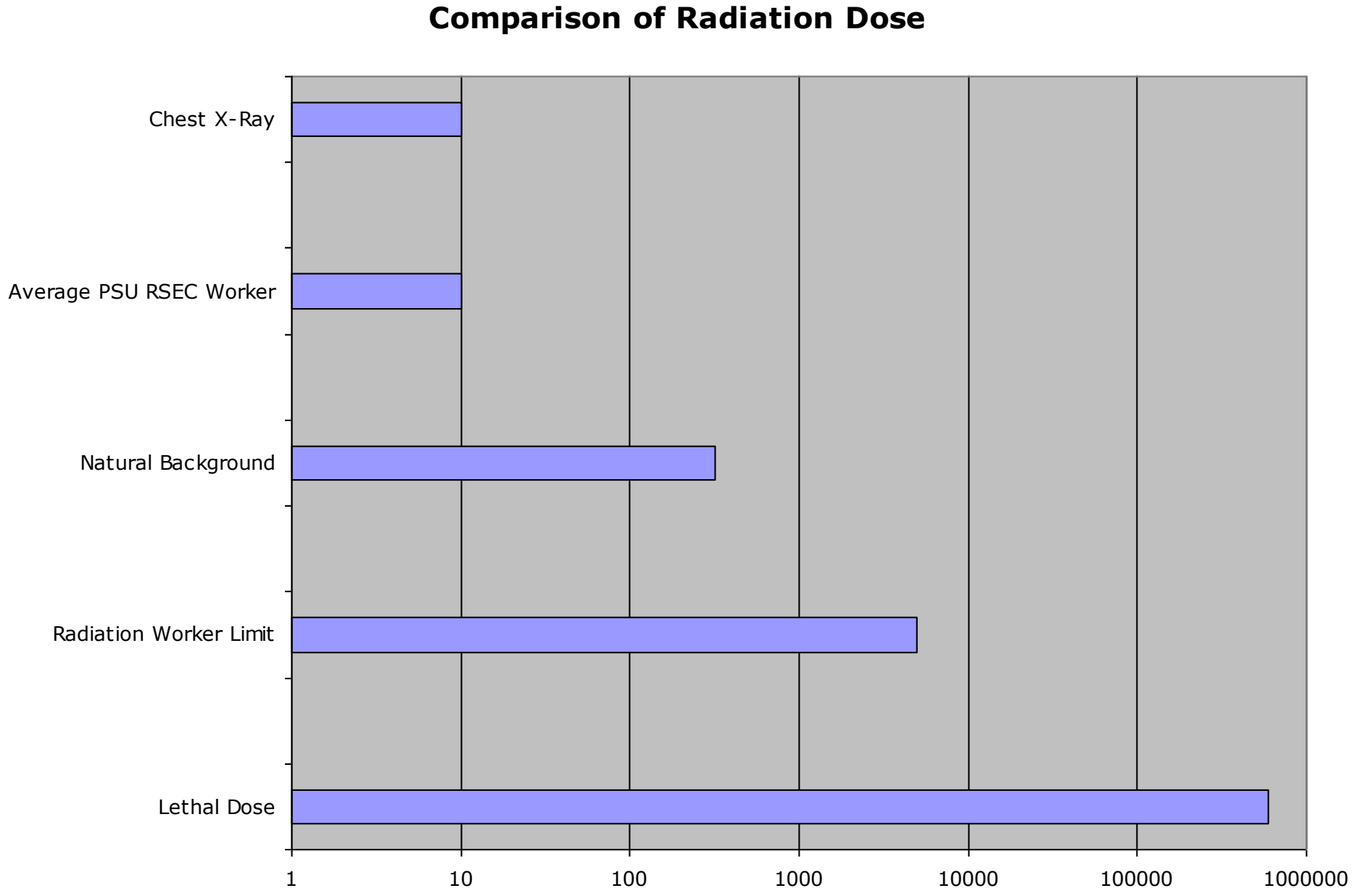
Deterministic Effects

- Deterministic Effects are those responses which increase in severity with increased dose

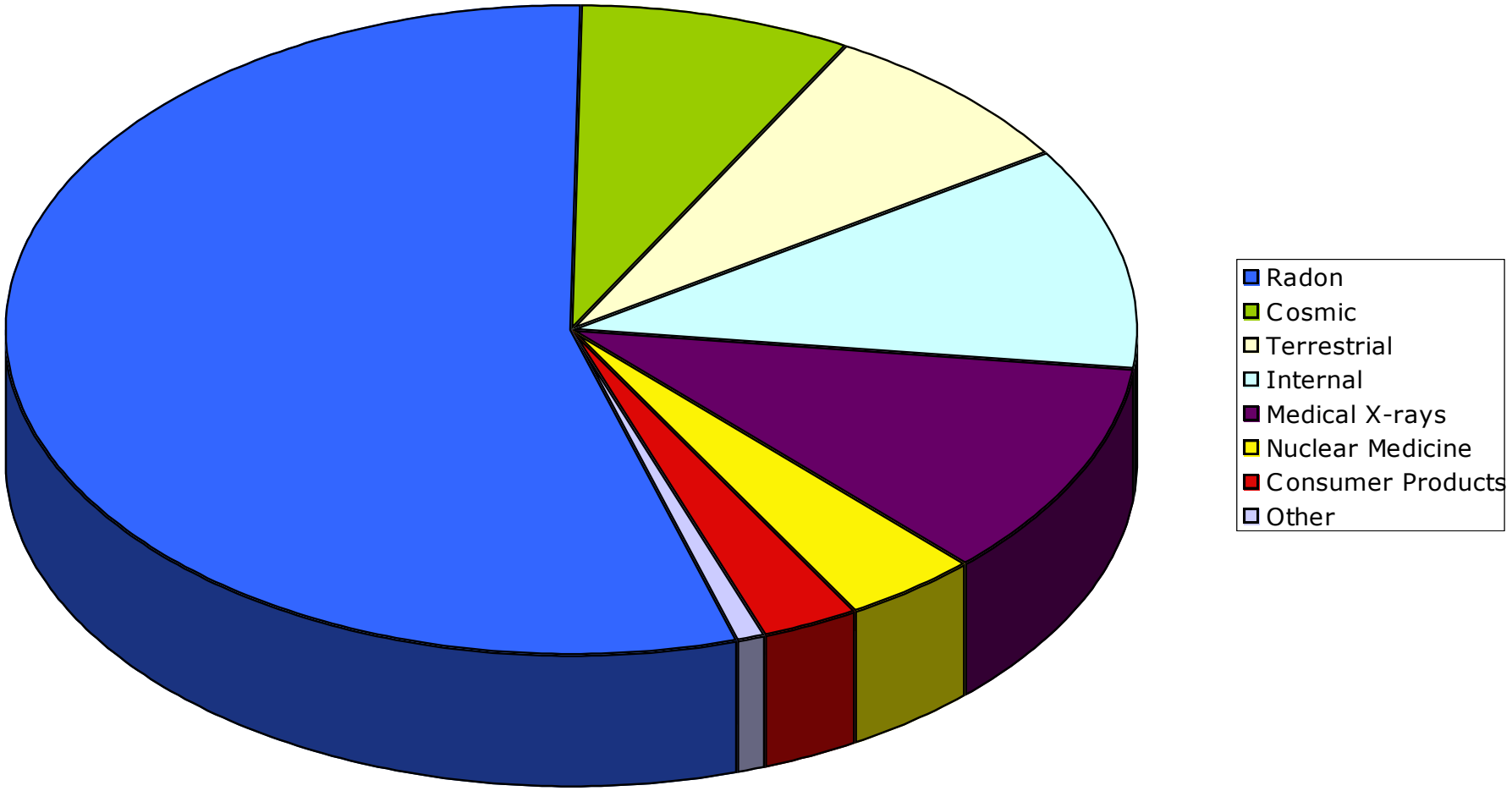
- For example; sunburn. The more you're exposed to the sun, and the higher the 'dose' of sunlight you receive, the more severe the sunburn

Stochastic Effects

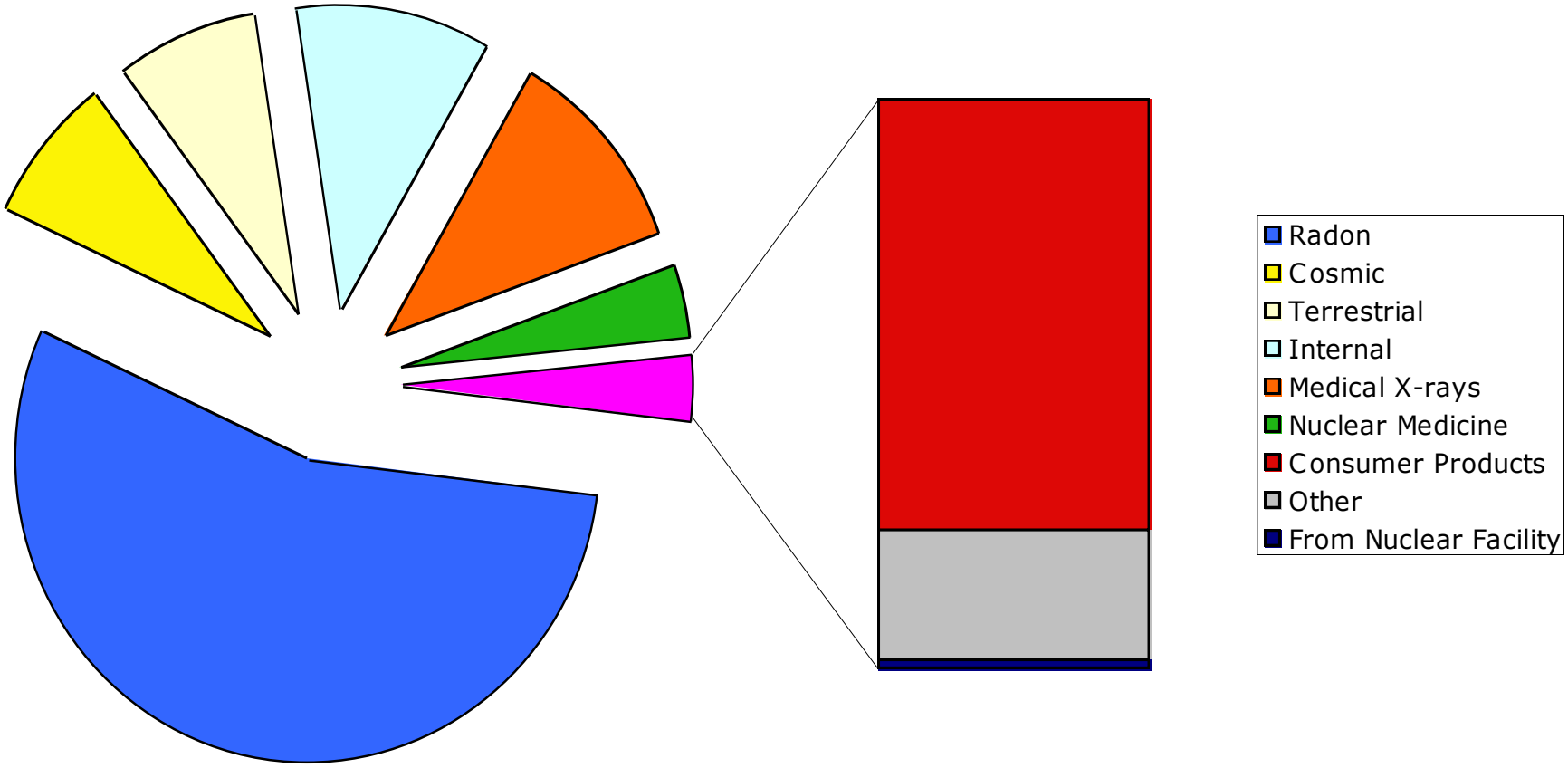
- Stochastic Effects are those effects which have an increased probability of occurrence with increased dose, but whose severity is unchanged
- Example; skin cancer and sunlight. The probability of getting skin cancer increases with increasing exposure to the sun
- Stochastic Effects are like a light switch; they are either present or not present


Comparison of Radiation Dose
Chest X-Ray
Average PSU RSEC Worker
Natural Background
Radiation Worker Limit
Lethal Dose
1
10
100
1000
10000
100000
1000000

Average Annual Dose- United States



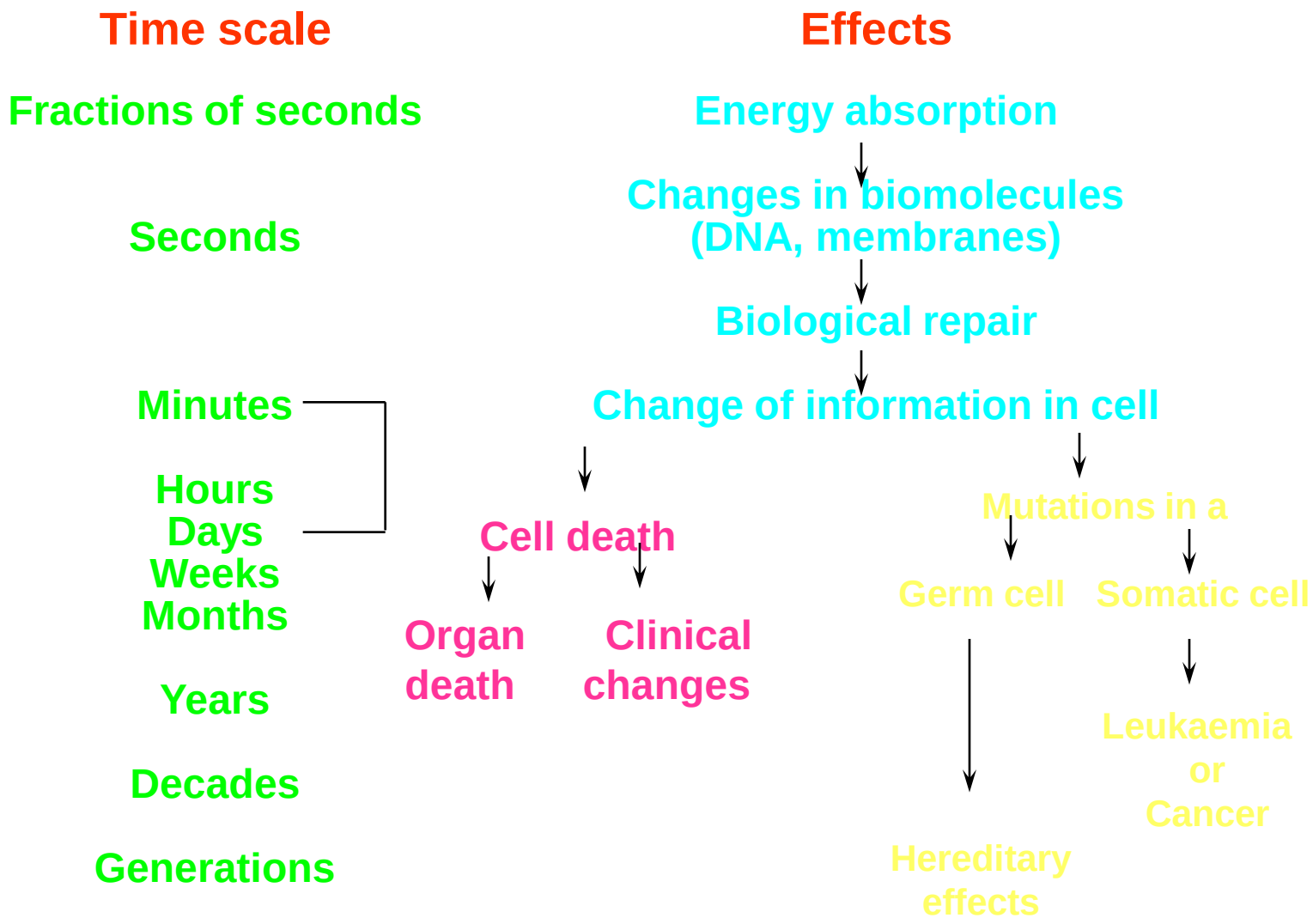
Annual Dose


Radon
Cosmic
Terrestrial
Internal
Medical X-rays
Nuclear Medicine
Consumer Products
Other
From Nuclear Facility

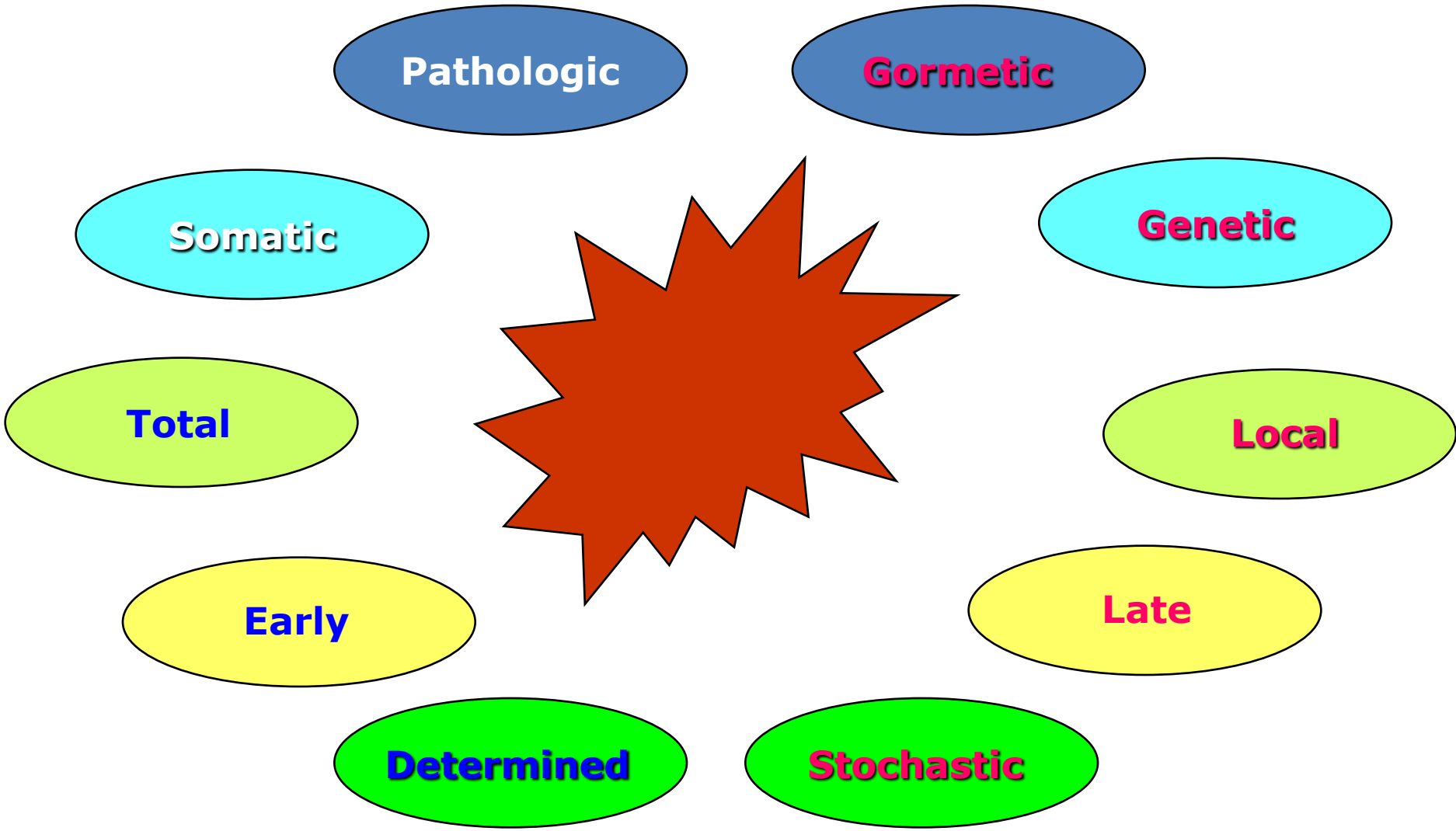
NRC Limits

Subjects Exposed	Time Frame	Dose (mrem)
Nuclear Worker	1 year	5000
General Public (from Nuclear Facility)	1 year	100
Pregnant Woman	9 months	500

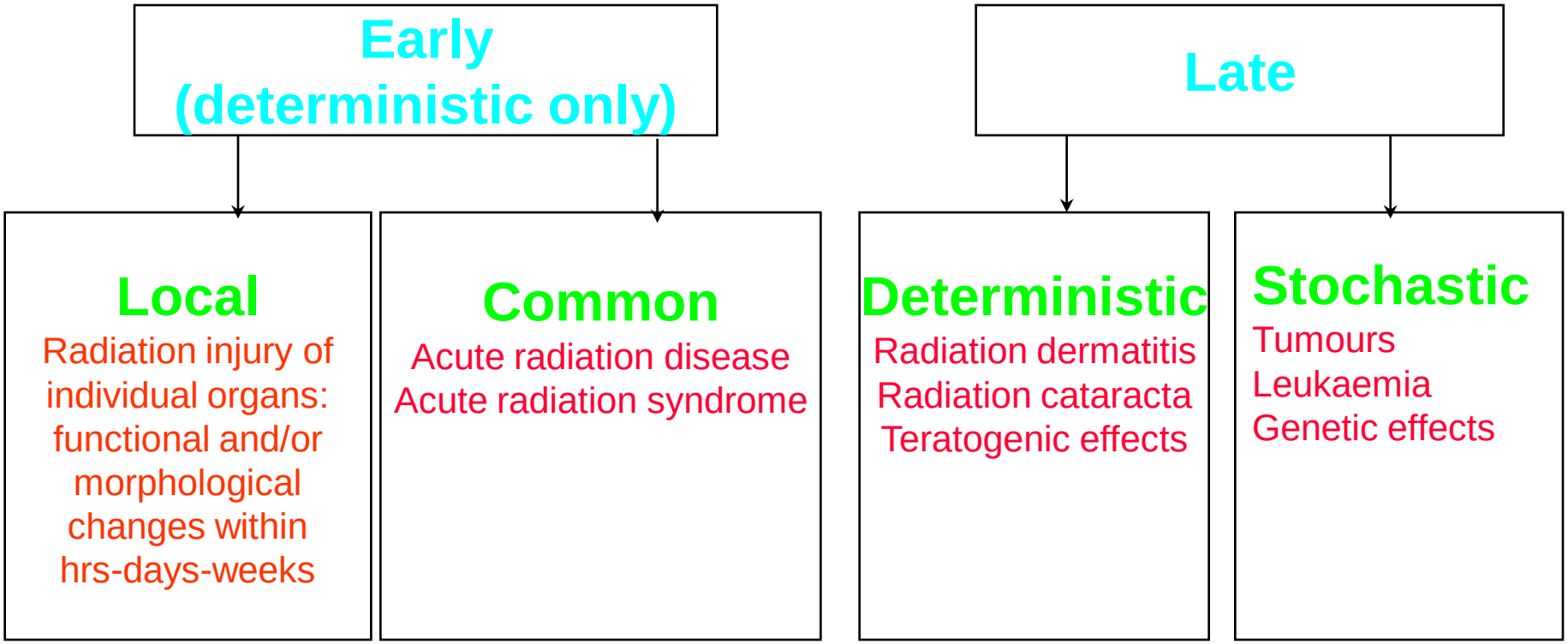
BIOLOGICAL EFFECTS OF RADIATION IN TIME PERSPECTIVE



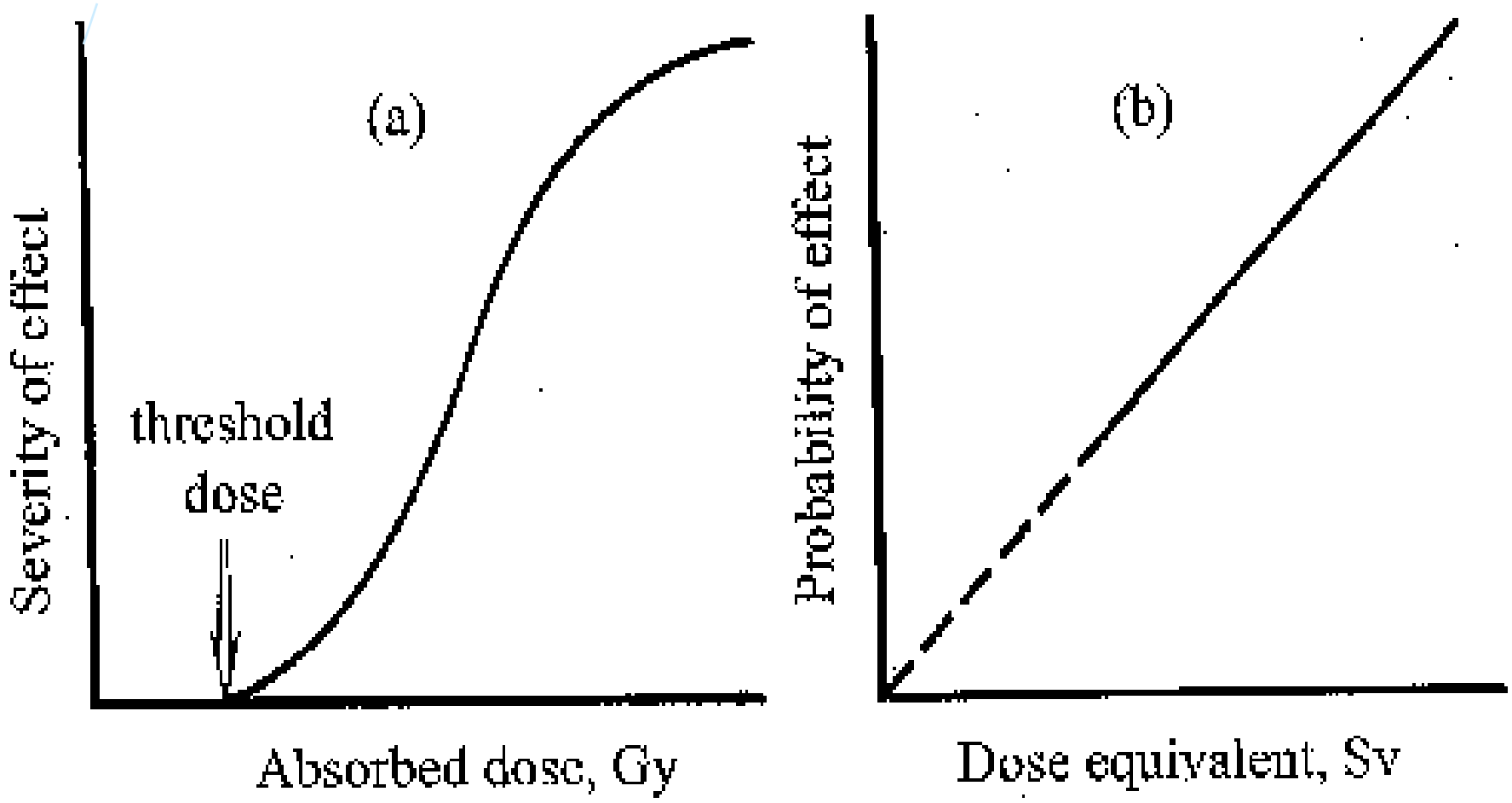
Classification of radiobiological effects



Radiation effects



Deterministic (a) and stochastic (b) effects of radiation

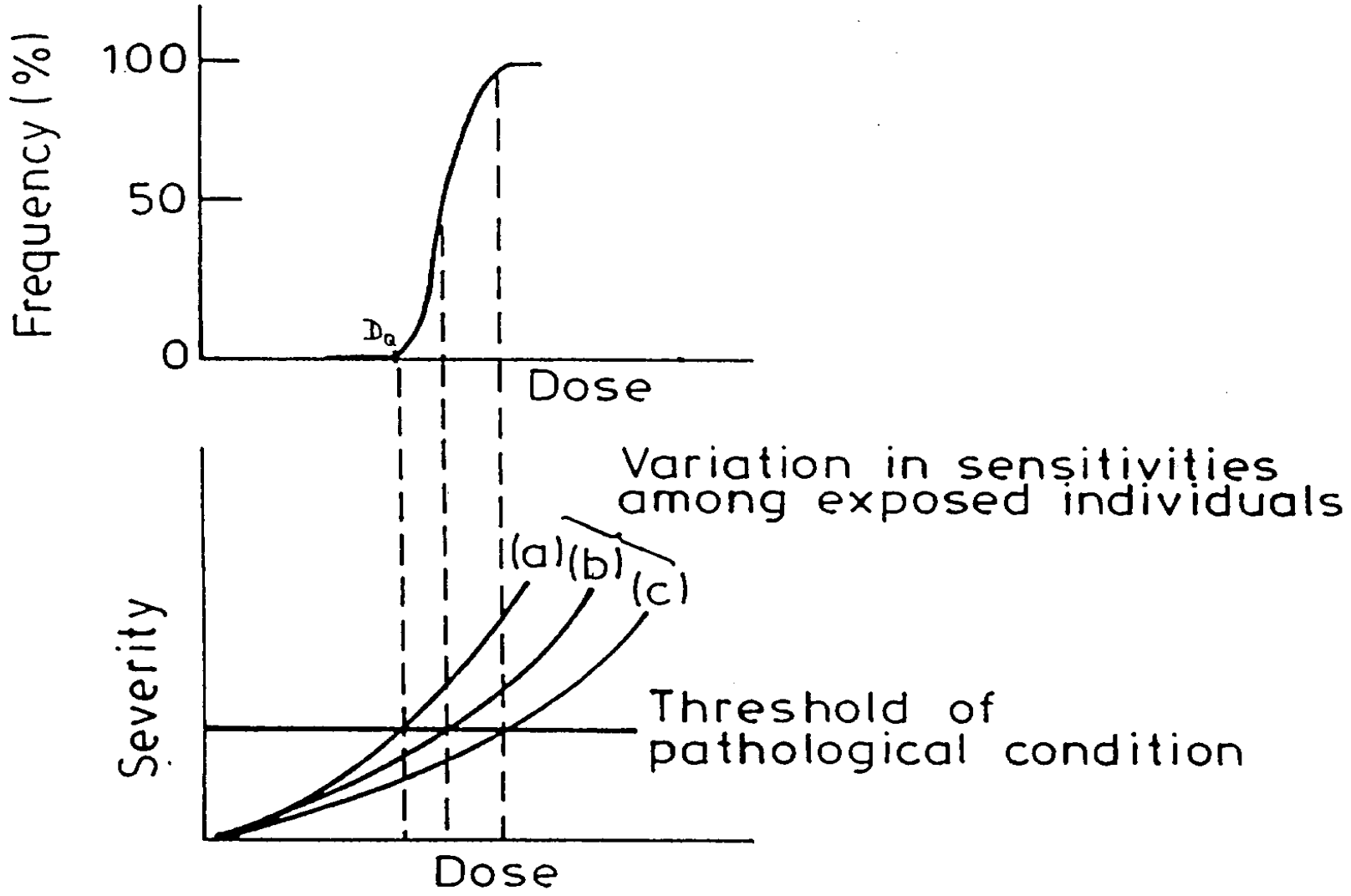


Deterministic and stochastic effects

- **Deterministic effects develop due to cell killing by high dose radiation, appear above a given threshold dose, which is considerably higher than doses from natural radiation or from occupational exposure at normal operation, the severity of the effect depends on the dose, at a given high dose the effect is observed in severe form in all exposed cells, at higher doses the effect cannot increase.**

- **Stochastic effects develop due to mutation effect of low dose radiation, the threshold dose is not known accurately; it is observed that cancer of different location appears above different dose ranges, the severity of the effect does not depend on the dose, but the frequency of the appearance of the (probabilistic) effect in the exposed population group is dose dependent, (in most cases) linearly increasing with the dose.**

Typical dose-effect relationships for deterministic effects in population



Threshold doses for some deterministic effects

in case of acute total radiation exposure

- **0,2 Gy** – increase of number of the chromosomal aberration in bone marrow and lymphocytes
- **0,3 Gy** – temporary sterility for man
- **0,5 Gy** – depression of haematopoiesis
- **1,0 Gy** – acute radiation syndrome
- **2,0 Gy** – detectible opacities
- **5,0 Gy** – visual impairment
- **2,5 – 6,0 Gy** – sterility for woman
- **3,5 – 6,0 Gy** – permanent sterility for man
- **3,0 – 10,0 Gy** – skin injury

Threshold doses for some deterministic effects
in case of radiation exposure for many years

- **0,1 Gy** – detectible opacities
- **0,2 Gy** – sterility for woman
- **0,4 Gy** – visual impairment
- **0,4 Gy** – temporary sterility for man
- **0,4 Gy** – depression of haematopoiesis
- **1,0 Gy** – chronic radiation syndrome
- **2,0 Gy** – permanent sterility for man

Time of onset of clinical signs of skin injury depending on dose received

Symptoms	Dose range (Gy)	Time of onset (day)
Erythema	3-10	14-21
Epilation	>3	14-18
Dry desquamation	8-12	25-30
Moist desquamation	15-20	20-28
Blister formation	15-25	15-25
Ulceration	>20	14-21
Necrosis	>25	>21

Ref.: IAEA-WHO: Diagnosis and Treatment of Radiation Injuries. IAEA Safety Reports Series, No. 2, Vienna, 1998

Acute radiation syndrome *(ARS)*

- ARS is the most notable ***deterministic effect*** of ionizing radiation
- Signs and symptoms are ***not specific*** for radiation injury but ***collectively highly characteristic*** of ARS
- ***Combination of symptoms*** appears in phases during hours to weeks after exposure
  - prodromal phase
  - latent phase
  - manifest illness
  - recovery (or death)
- ***Extent and severity*** of symptoms determined by
  - total radiation dose received
  - how rapidly dose delivered (dose rate)
  - how dose distributed in body (whole or partial body irradiation)

Critical organs or tissues after acute whole body radiation exposure

Whole body dose, Gy	Critical organ or tissue	Mortality, per cent	Time of death, days
1 – 2	Bone marrow	–	–
2 – 4		5	40 – 60
4 – 6		50	30 – 40
6 – 10		95	10 – 20
10 – 30	Gastrointestinal tract	100	7 – 14
> 30	Neurovascular system	100	1 – 5

Teratogenic effects of radiation as special deterministic effects

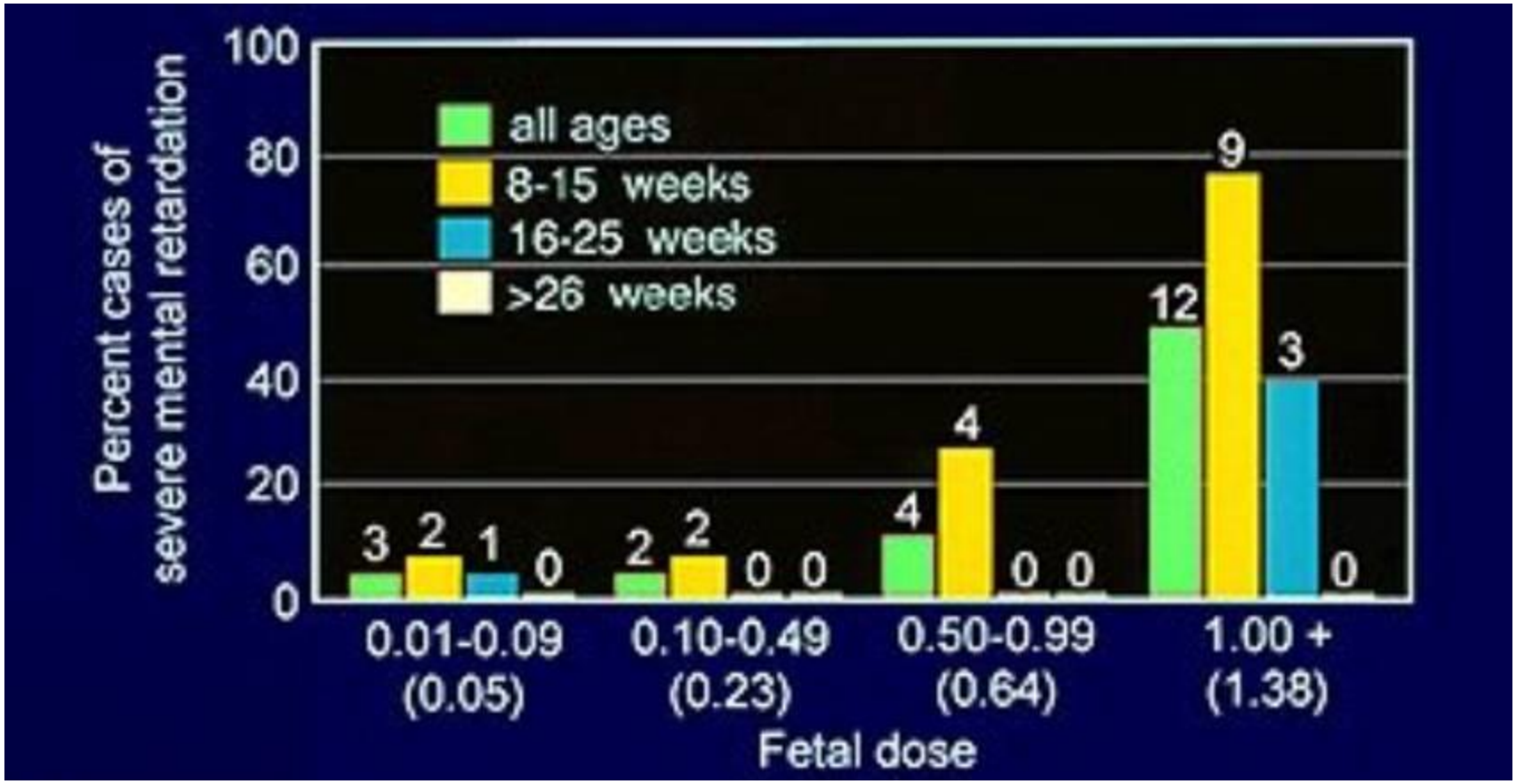
The foetus

Typical effects of radiation on embryon:

Effects of radiation according to gestational stage

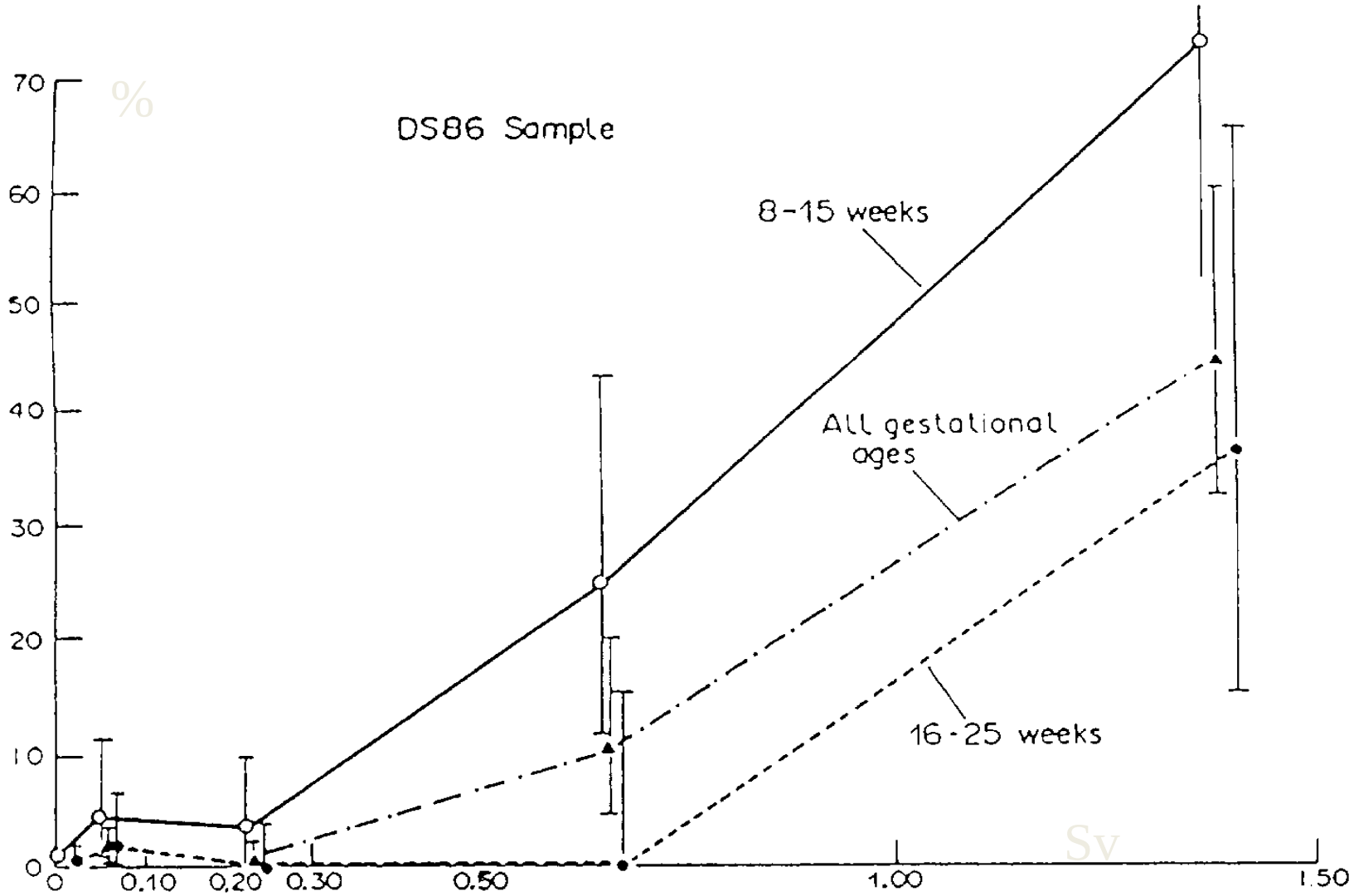
Gestational age	Stage	Radiogenic effects
0 - 9 days	Preimplantation	All or none
10 days - 6 weeks	Organogenesis	Congenital anomalies, growth retardation
6 weeks - 40 weeks	Foetal	Growth retardation, microcephly, mental retardation

Specific radiation effects on foetus: mental retardation, microcephaly

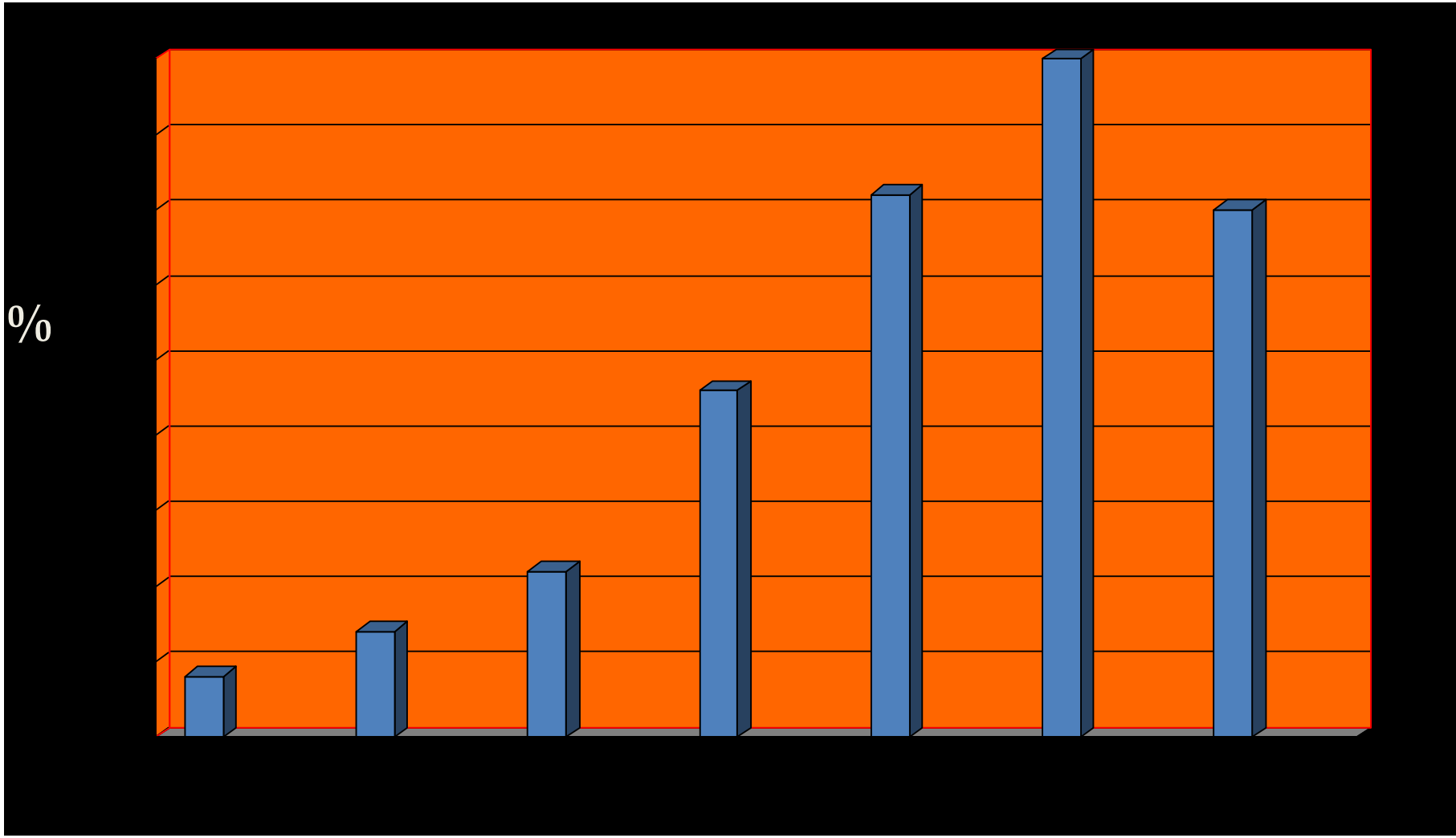


Cases of mental retardation caused by radiation exposure in Hiroshima and Nagasaki

Frequency of severe mental retardation in prenatally exposed survivors of A-bombing in Hiroshima and Nagasaki



Microcephaly: Hiroshima data



Considerations for pregnancy termination

-
- Normal rate of preclinical loss > 30 %;

  at 0,1 Gy – increase of 0,1–1 %
- The foetal absorbed dose > 0,5 Gy at 7–13 weeks: substantial risk of IUGR and CNS damage
- 0,25–0,5 Gy at 7–13 weeks: parental decision with physician's guidance

Cancer induction
and genetic effects
as examples of stochastic effects
of radiation exposure

Stochastic effects of radiation exposure

- Frequency proportional to dose
- No threshold dose
- No method for identification of appearance of effect of ionizing radiation in individuals
- Increase in occurrence of stochastic effects provable only by epidemiological method

Stochastic effects of radiation exposure

(continued)

- Stochastic effects observed in animal experiments
- Dose-effect relationship for humans can be studied only in human population groups
- Dose-effect relationship in low dose range (below 100 mSv) not yet verified
- Extrapolation down to zero excess dose accepted only for radiation protection and safety

Carcinogenic effects

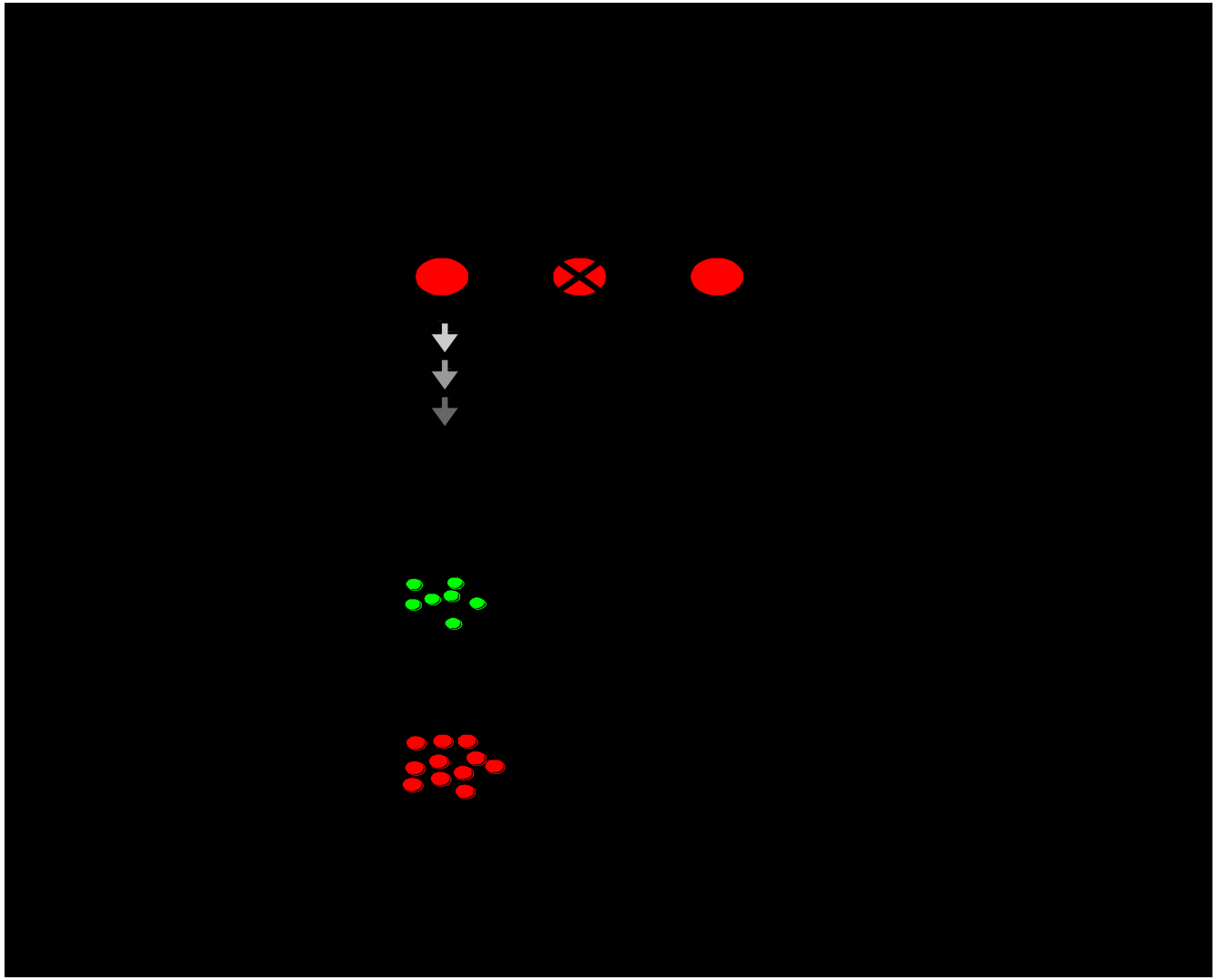
- ***Carcinogenic effects*** **have been known practically since the discovery of radioactivity and since the first case of radiation-induced cancer was described in 1902.**

- **The epidemiological assessment was made from over 575 cancers and leukaemias for the 80,000 survivors irradiated at Hiroshima and Nagasaki, and about 2,000 cancers of the thyroid in children in the Chernobyl region.**

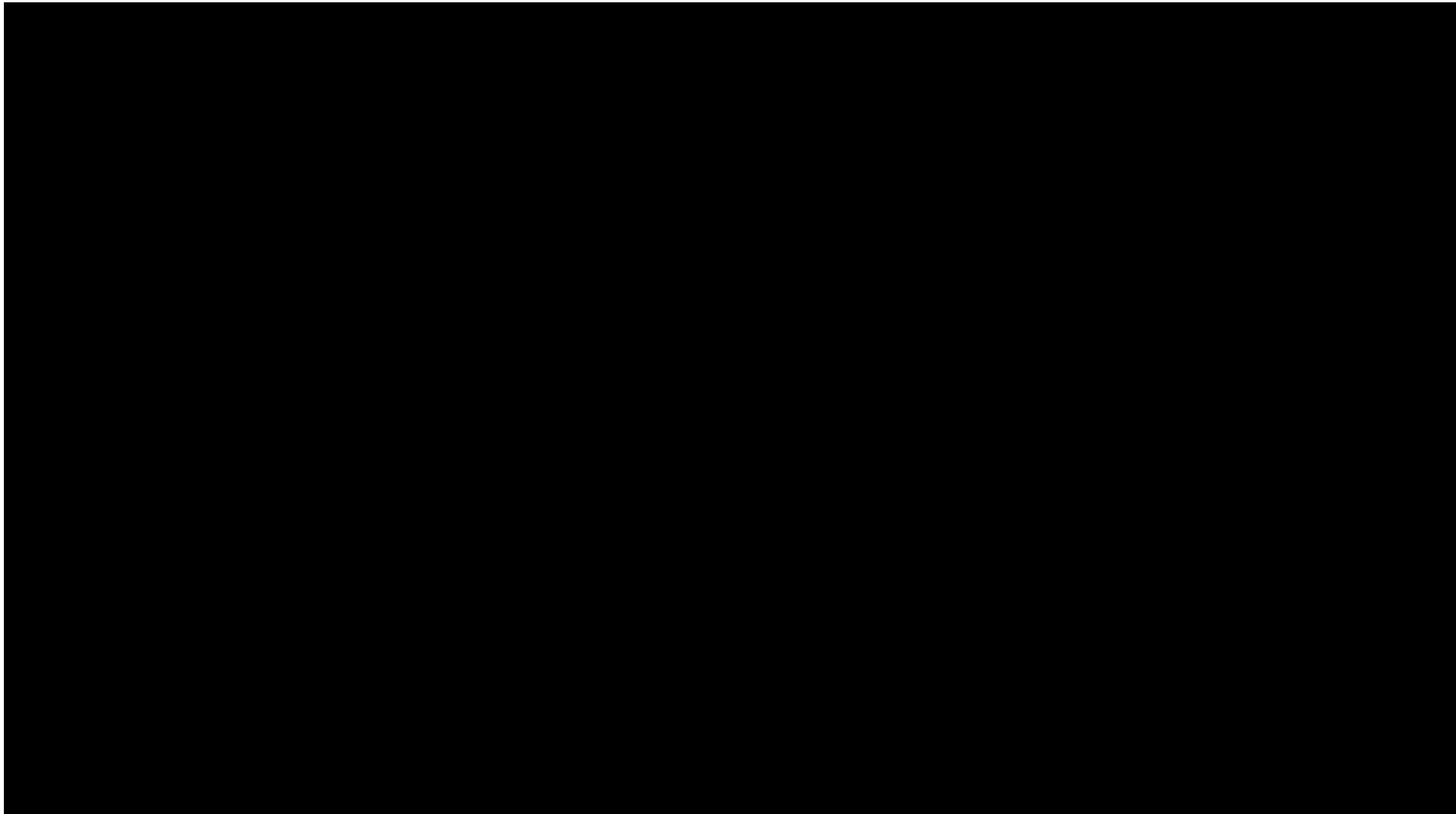
- **The actual data does not enable us to show a risk of cancer at greater than 0,1 Gy by acute irradiation.**

  Nevertheless, it is considered that risk of cancer and the relationship dose/risk remains linear for doses below 0,1 Gy.

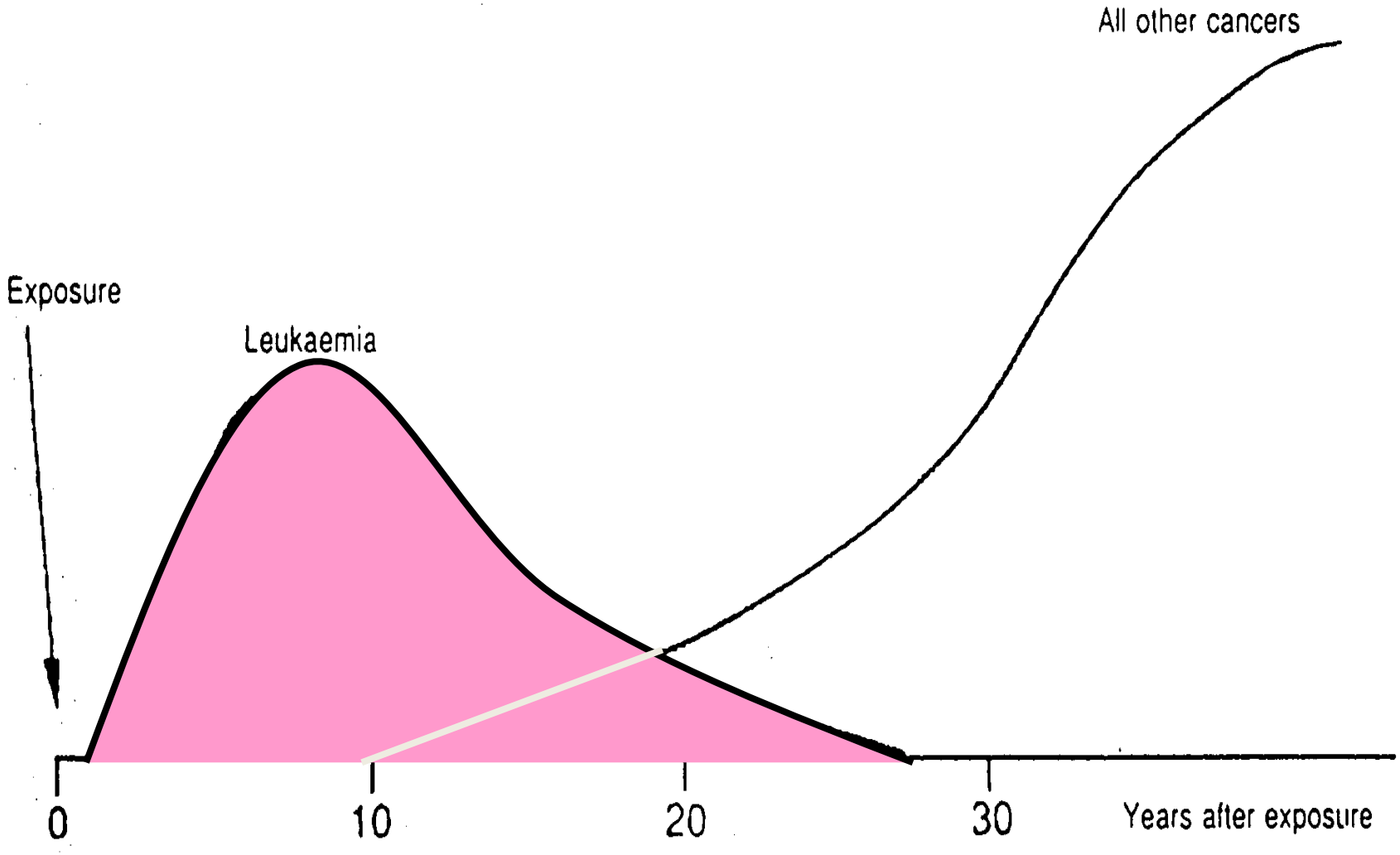
Phases of cancer induction and manifestation



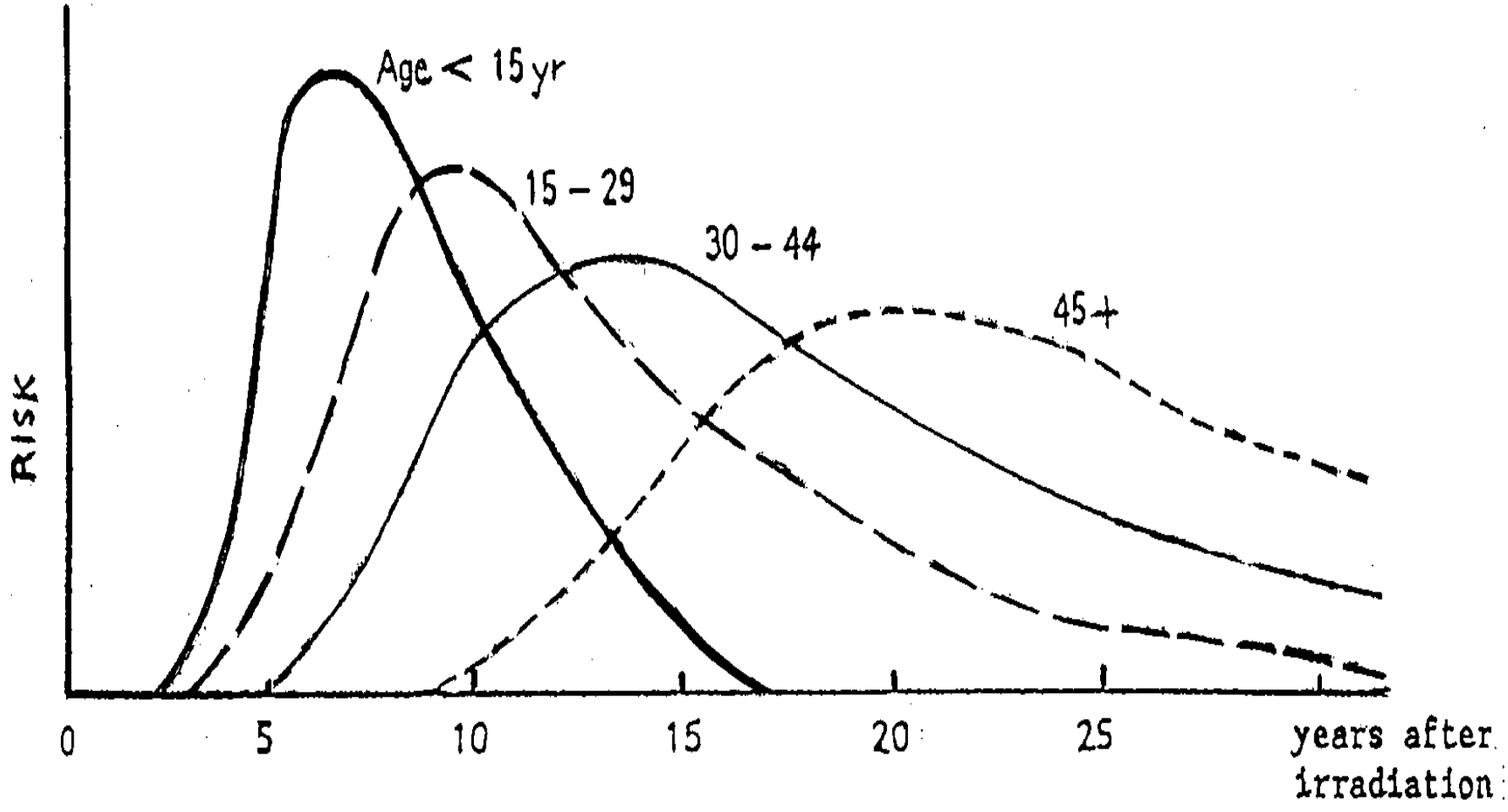
Human data on radiation cancerogenesis



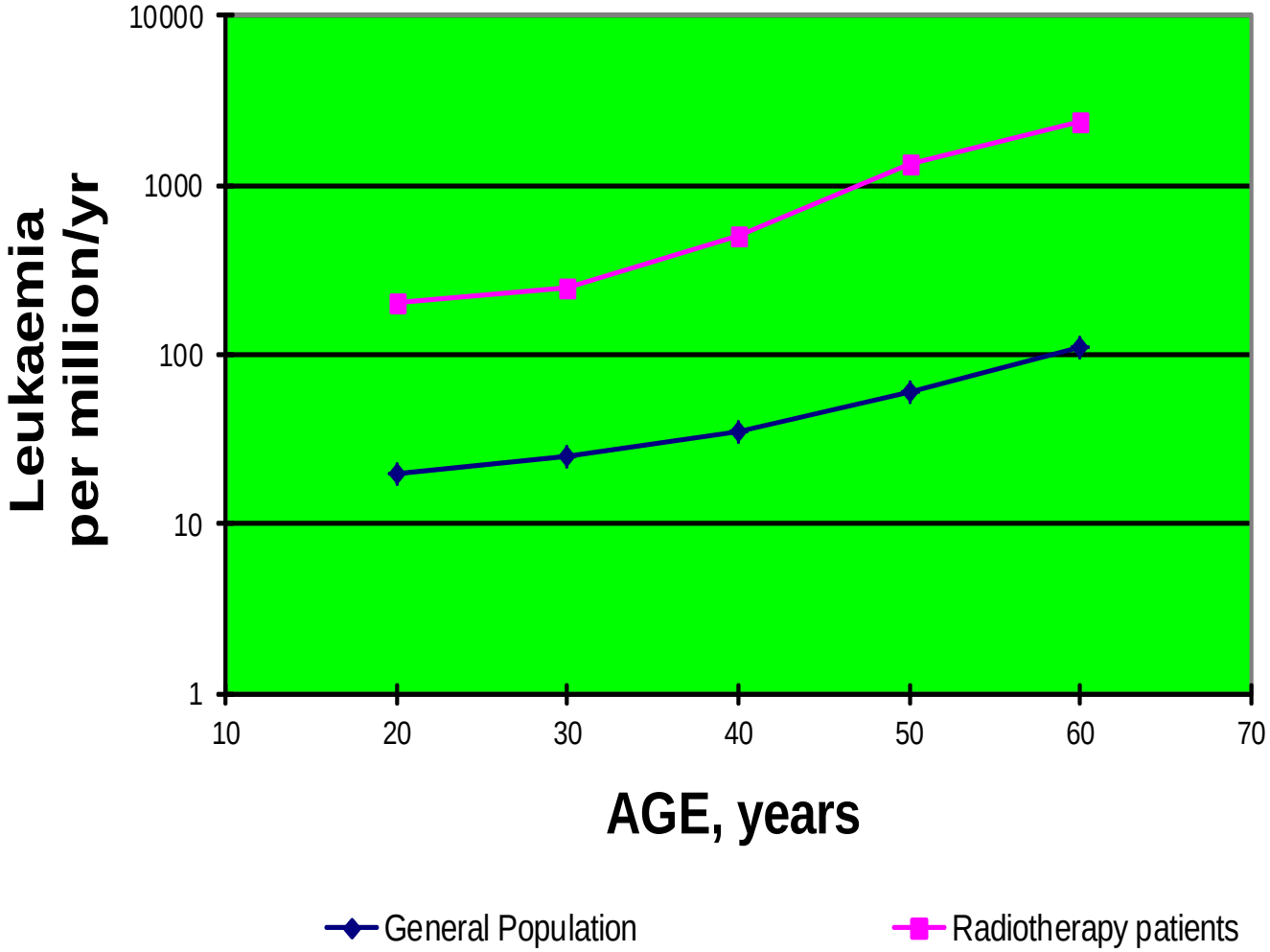
Latency periods for radiation-induced cancer



Risk of leukaemia depending on age at exposure to A-bomb



Age dependency of incidence of leukaemia in British population and radiotherapy patients



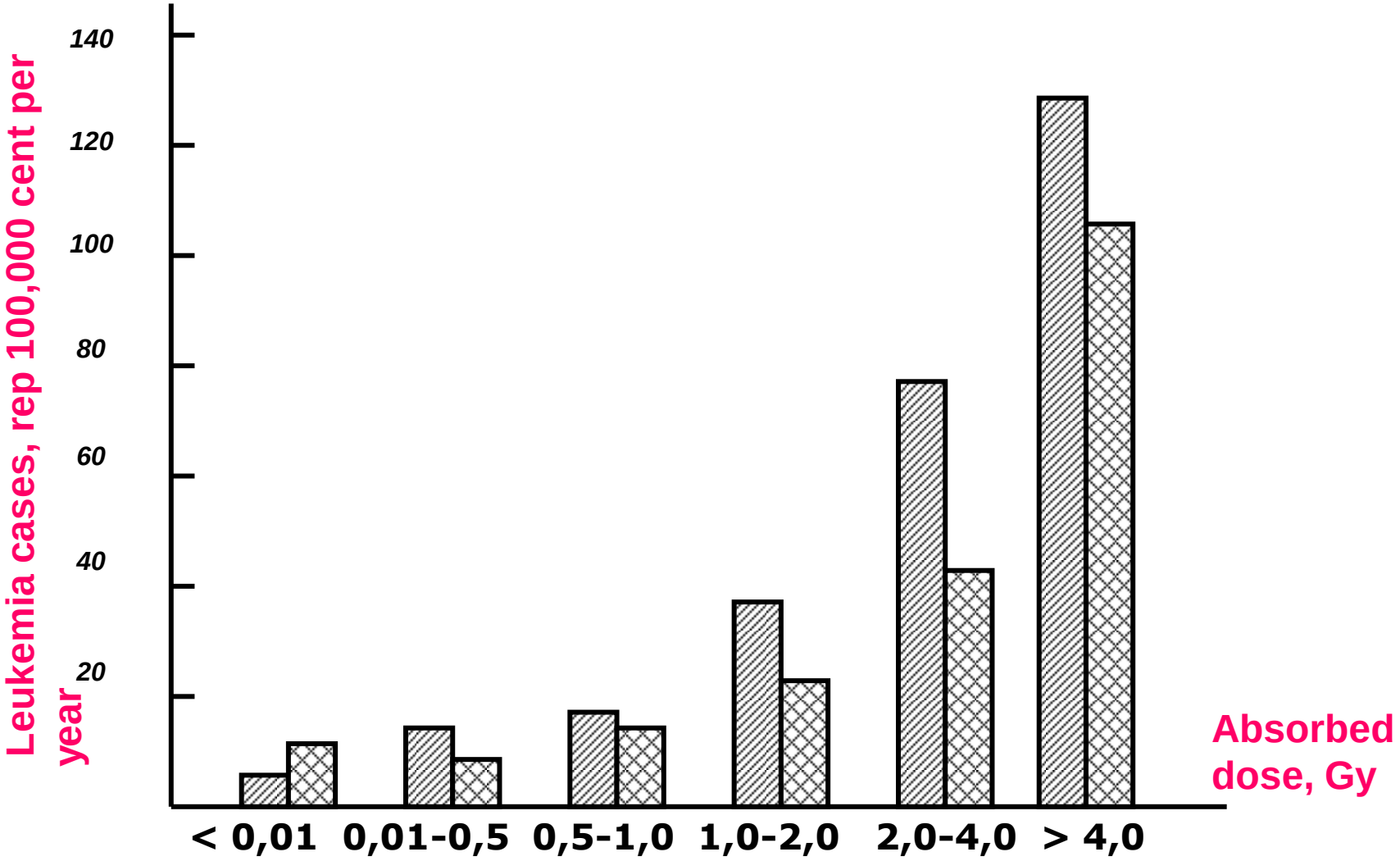
Cancer deaths attributable to A-bomb

In 86 572 survivors of Hiroshima and Nagasaki, 7827 persons died of cancer in 1950-90

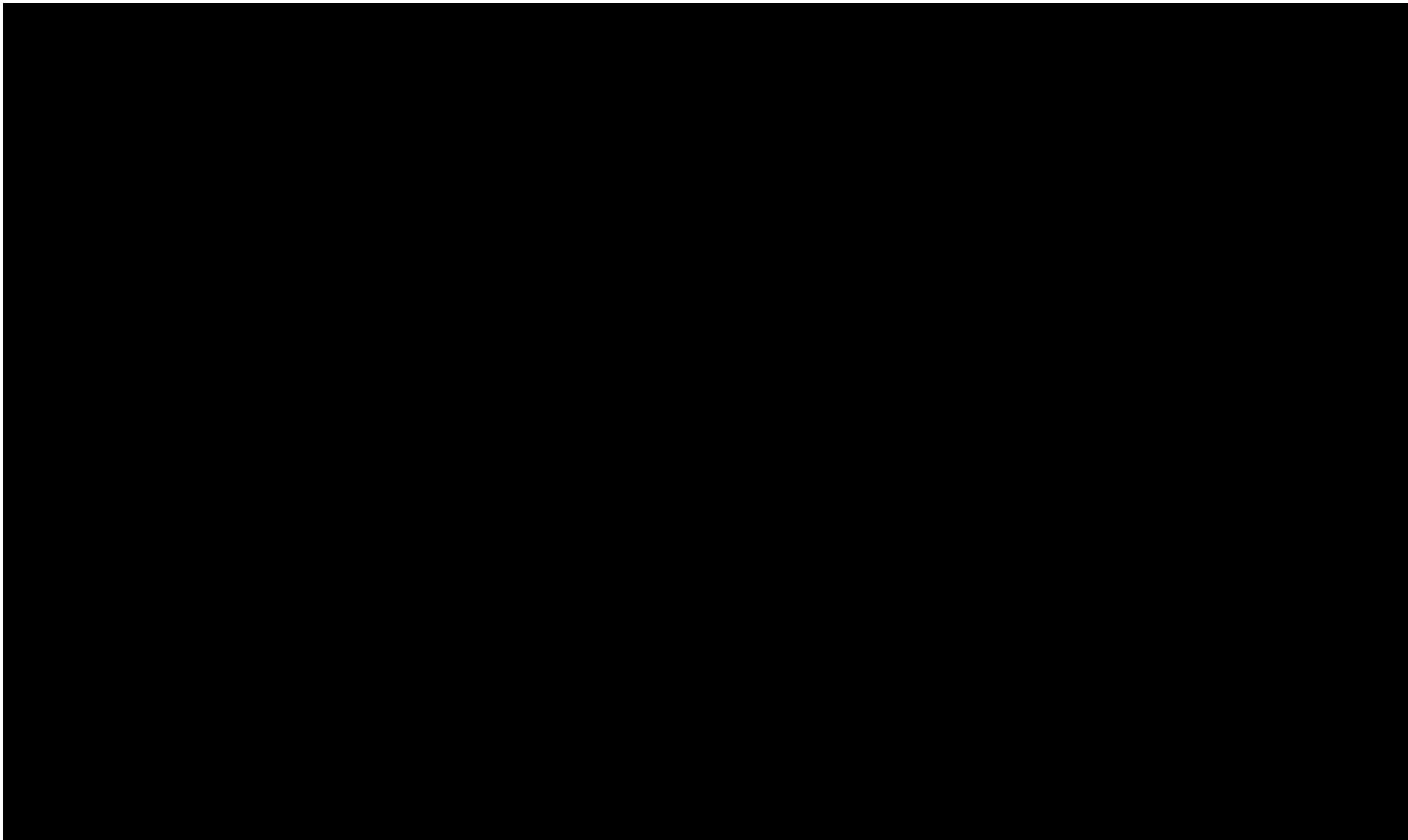
	Observed	Expected	Excess	(%)
All tumours	7578	7244	334	(4.4)
Leukaemia	249	162	87	(35.0)
All cancers	7827	7406	421	(5.4)

Ref: Pierce et al, Rad.Res. 146: 1-27, 1996

Dose dependence of leukemia in A-bomb survivors



Cancer mortality of nuclear industry workers

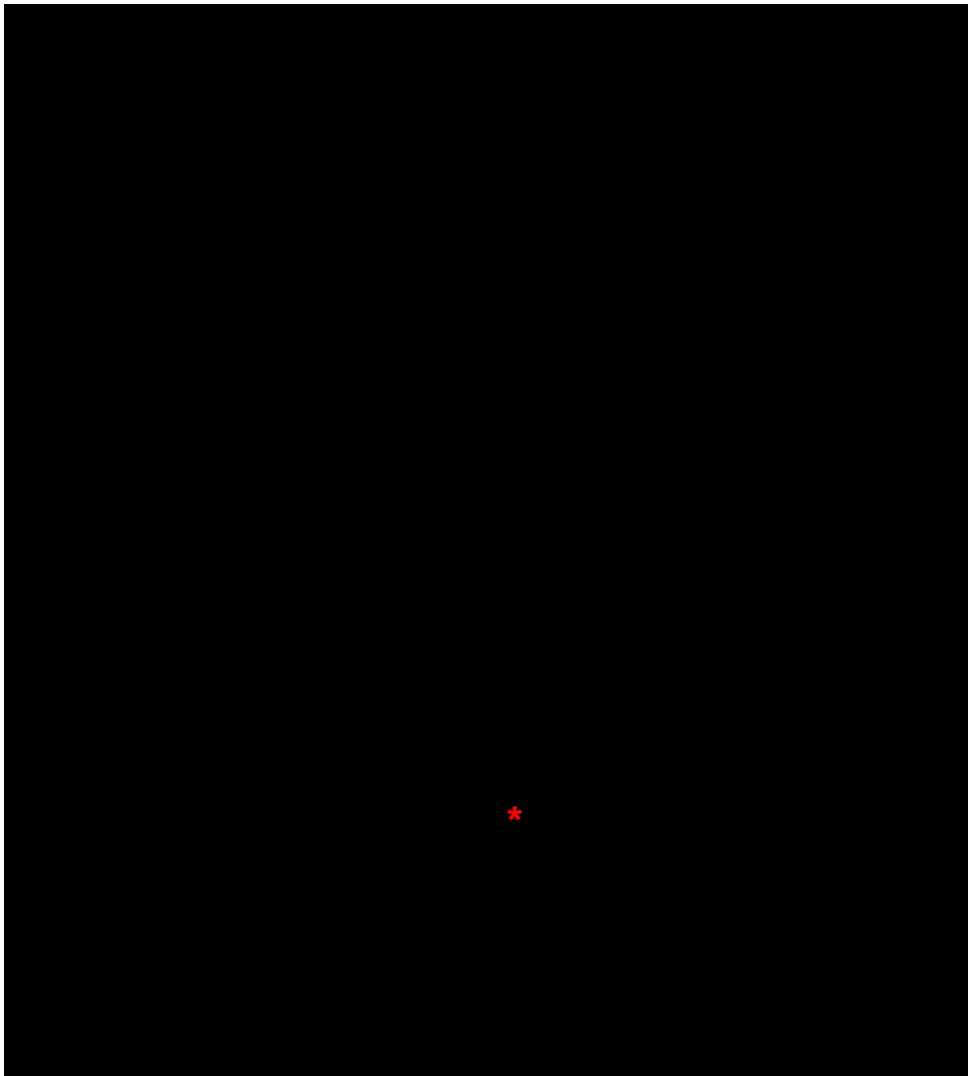


Childhood leukaemia around UK nuclear facilities

- STUDY GROUP: 46 000 children (followed till the age of 25 yrs) born to parents working in nuclear industry
- FINDINGS: 111 cases of acute leukaemia observed, i.e. fewer than expected in a group of this size and age
- Study found 3 cases of leukaemia in children of male workers who had received a pre-conceptional exposure of 100 mSv or more
- Two of these three cases had already been identified in the 1990 Gardner report (proposed theory that paternal pre-conception radiation leads to increased risk of leukaemia in offspring)
- Conclusions
  - No substantial evidence found to support Gardner's theory
  - Study did not confirm theory

Ref. ICRF, LSHTM & LRF: Nuclear Industry Family Study (NIFS). BMJ, 28-05-1999

Lifetime mortality in population of all ages from cancer after exposure to low doses

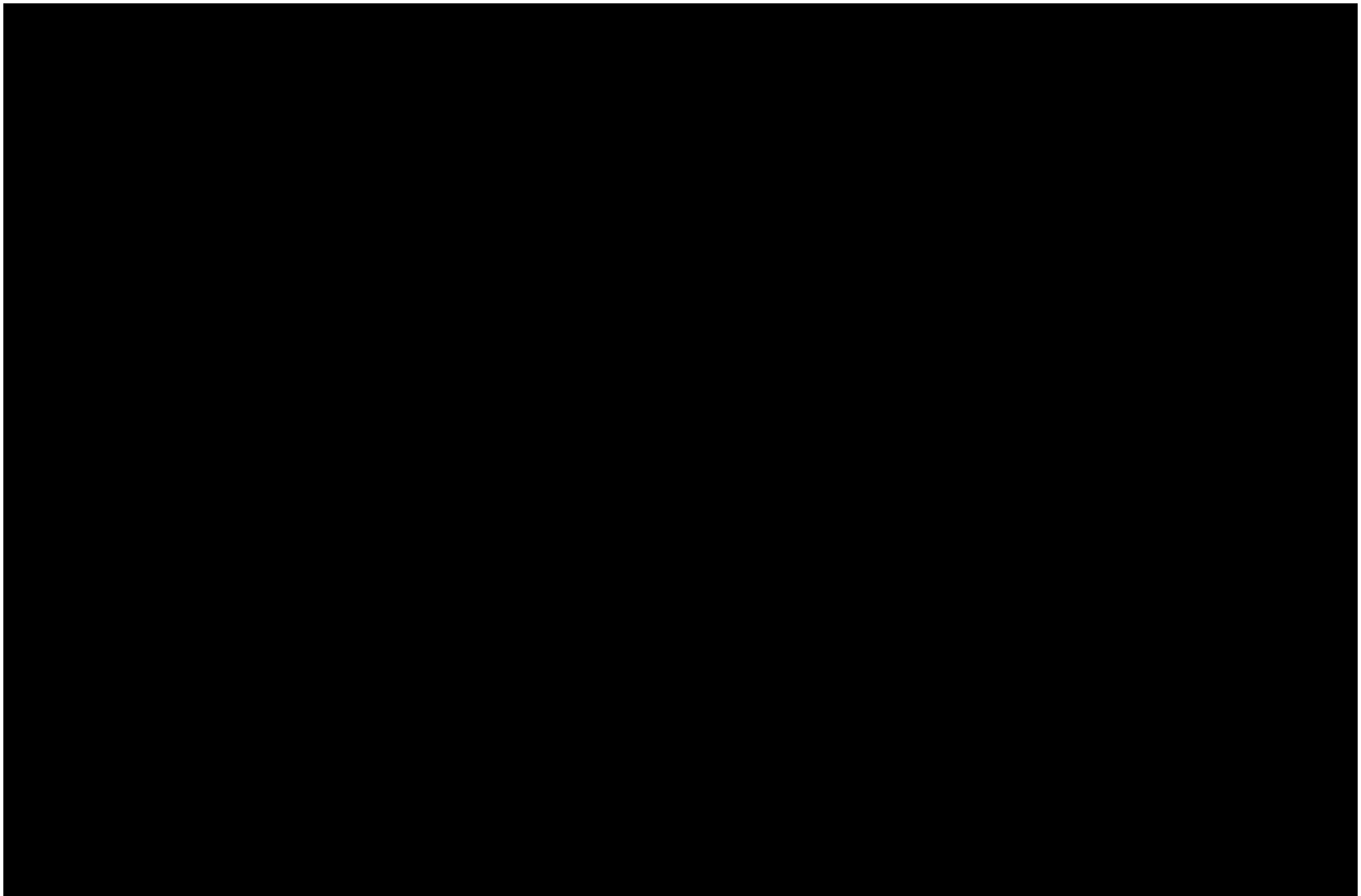


* For general public (all age groups) only

Summary factor of cancer risk for working population taken to be 400×10^{-4} Sv^{-1}

Reference ICRP, Publ. 60, 1991

Nominal probability coefficients for stochastic radiation effects



Genetic effects

- **Genetic effects might result in lesions of chromosomes in the germinal lineage (ovule and spermatozoid), prone to lead to anomalies in close or distant descendants of the irradiated individual.**

- **The mutagenic action of radiation was discovered by Nadson and Philipov (1925) and then in the fly was demonstrated by Muller from 1927 onwards.**

- **As it has not been possible to find any study showing a genetic effect in man, the risk is evaluated from the data obtained from animals.**

Genetic radiation damage

- **Increase of chromosome aberrations in human spermatogonia following radiation exposure of testes has been detected**

- **Inheritance of radiation damage in human population (including A-bomb survivors) not yet detected**

Summary

- **Deterministic effects develop due to cell killing by high dose radiation, appear above a given threshold dose, which is considerably higher than doses from natural radiation or from occupational exposure at normal operation, the severity of the effect depends on the dose, at a given high dose the effect is observed in severe form in all exposed cells, at higher doses the effect cannot increase.**

- **Stochastic effects develop due to mutation effect of low dose radiation, the threshold dose is not known accurately; it is observed that cancer of different location appears above different dose ranges, the severity of the effect does not depend on the dose, but the frequency of the appearance of the (probabilistic) effect in the exposed population group is dose dependent, (in most cases) linearly increasing with the dose.**

Summary

- **Teratogenic effects of radiation: severe mental retardation, microcephaly**

- **Latency periods of radiation induced cancers occur from 2 to 10 years, risk of cancer depending on age at exposure (reverse dependence), cancer deaths attributable to A-bombs – 5.4 % in 40-yr follow up, cancer mortality studies of nuclear industry workers and offspring – leukaemia probable in workers**

- **Genetic effects of radiation – not proved in human population**

THANKS FOR ATTENTION