

Studies of impact of ionizing radiation on the human body - Hiroshima -

US-Japanese teams medical tests, autopsies, human organ analysis, on-site radioactivity measurements ...

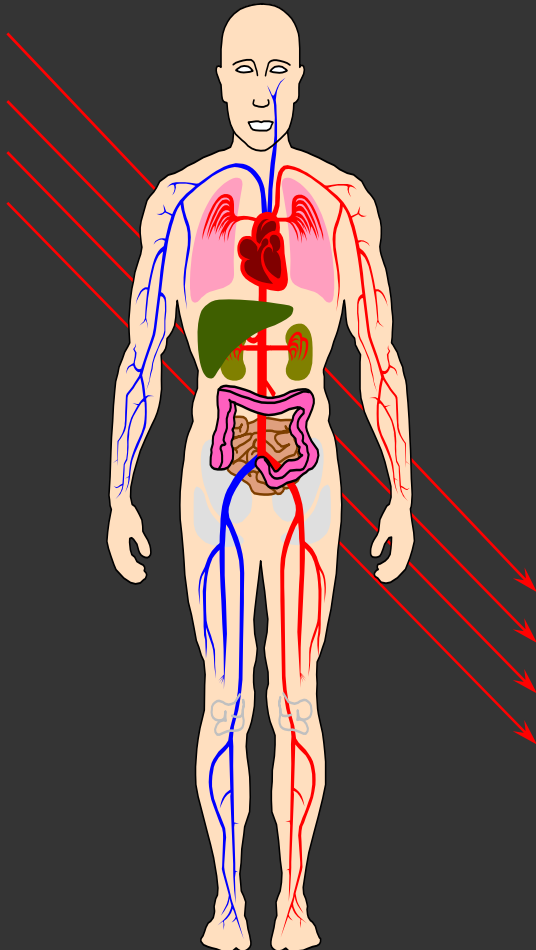


autopsy

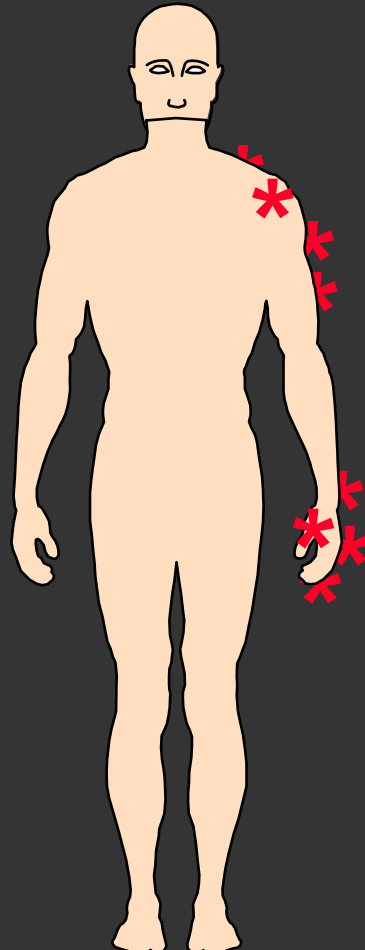


Radiation Exposure Types

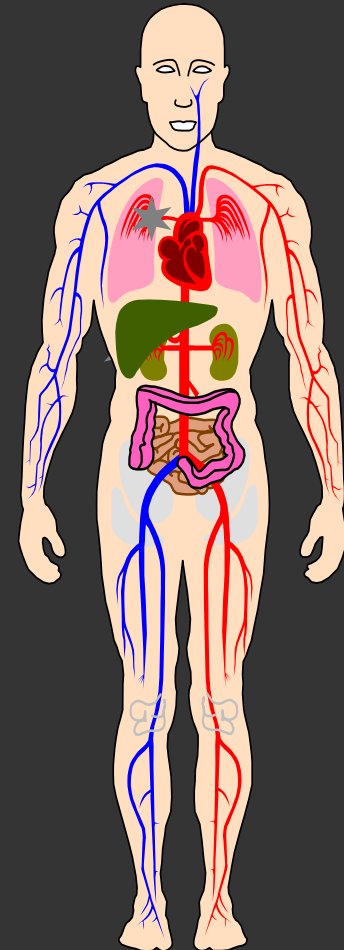
Irradiation



External Contamination

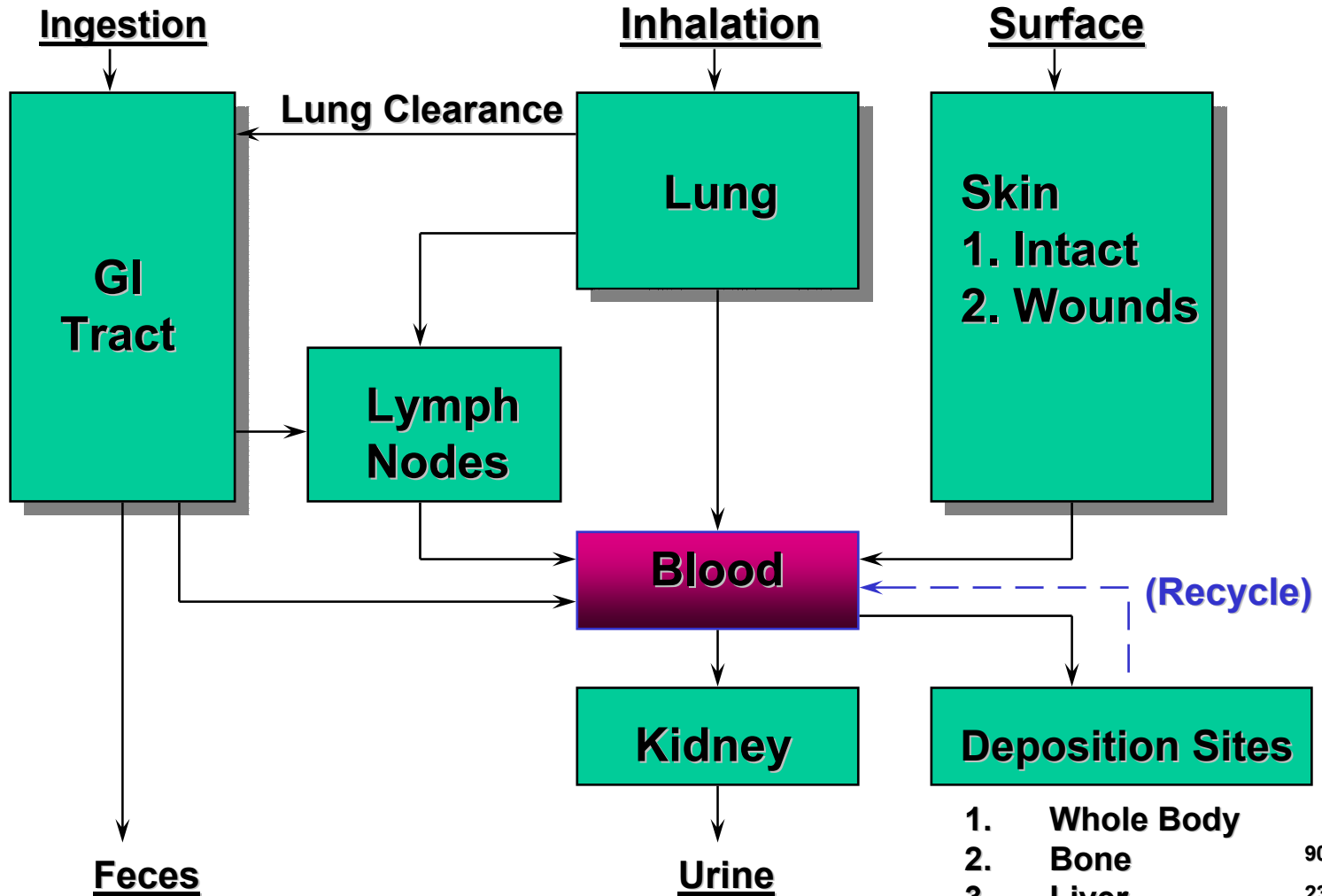


Internal Contamination



Schematic Model of Radionuclide Uptake

Intake:

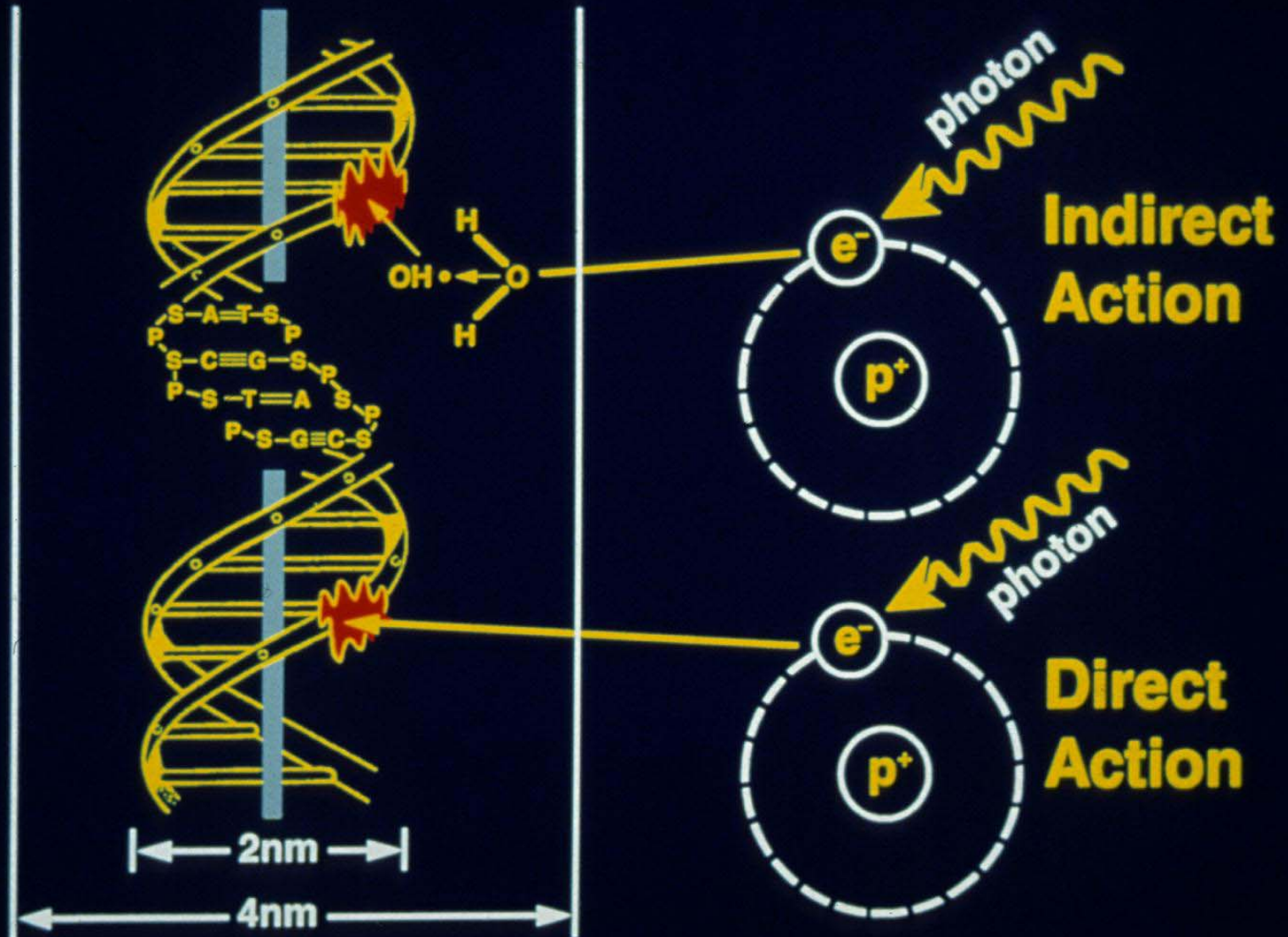


Uptake:

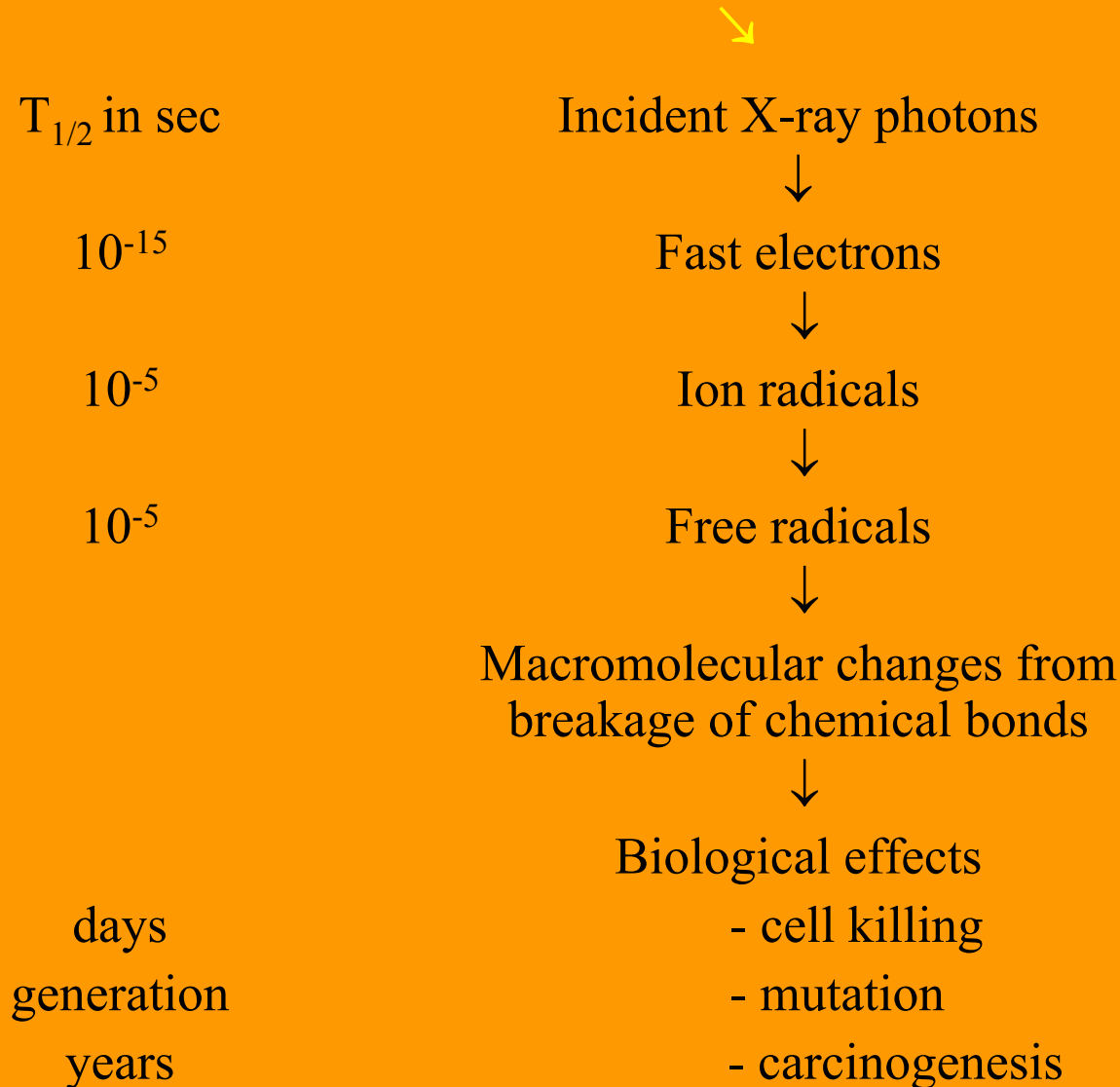
Excretion:

^{90}Sr
 ^{232}Th
 ^{137}Cs
 ^{131}I

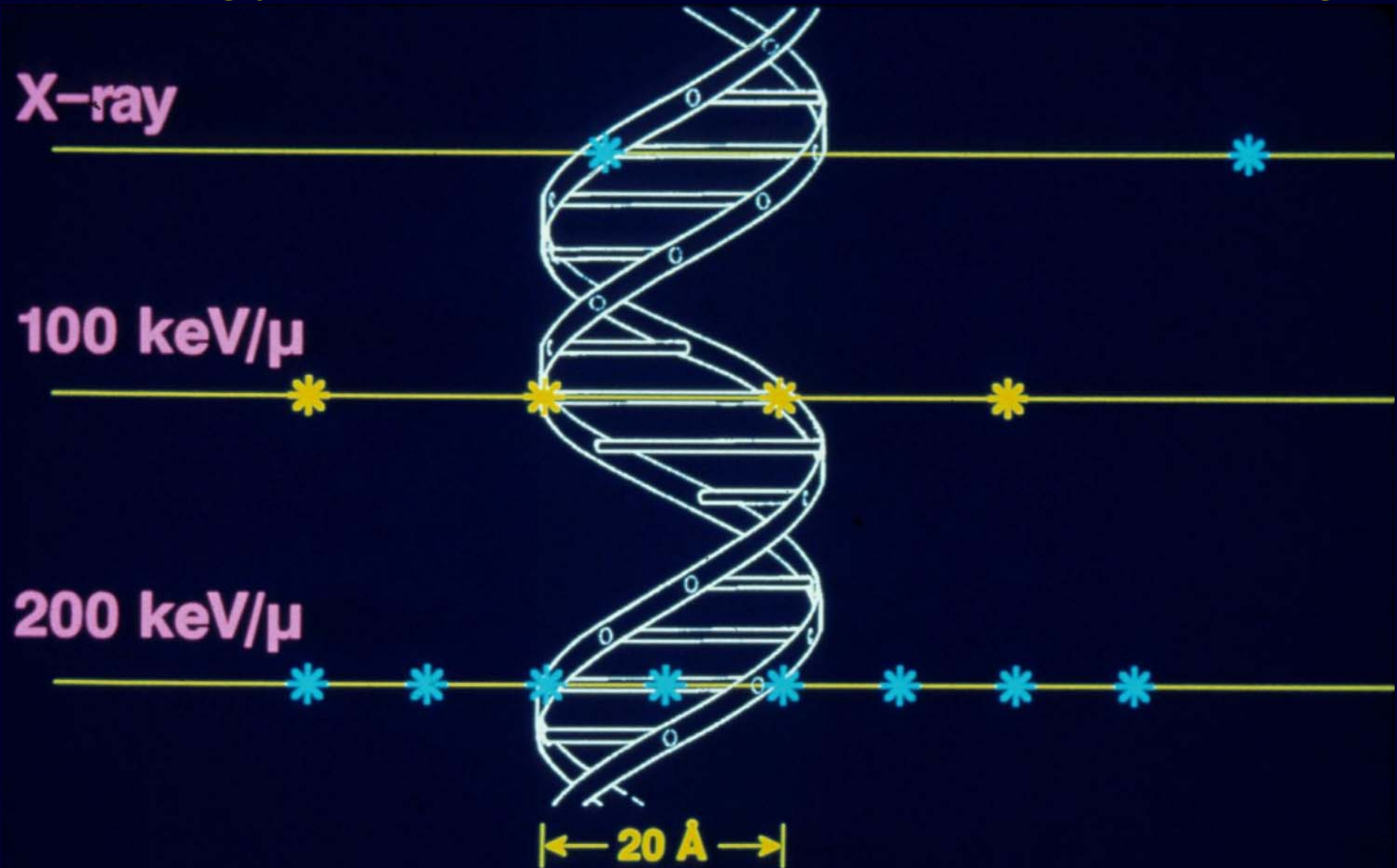
Radiation interacting with cell molecules



Sequence of Events in Indirect Action



Energy dependence of radiation damage



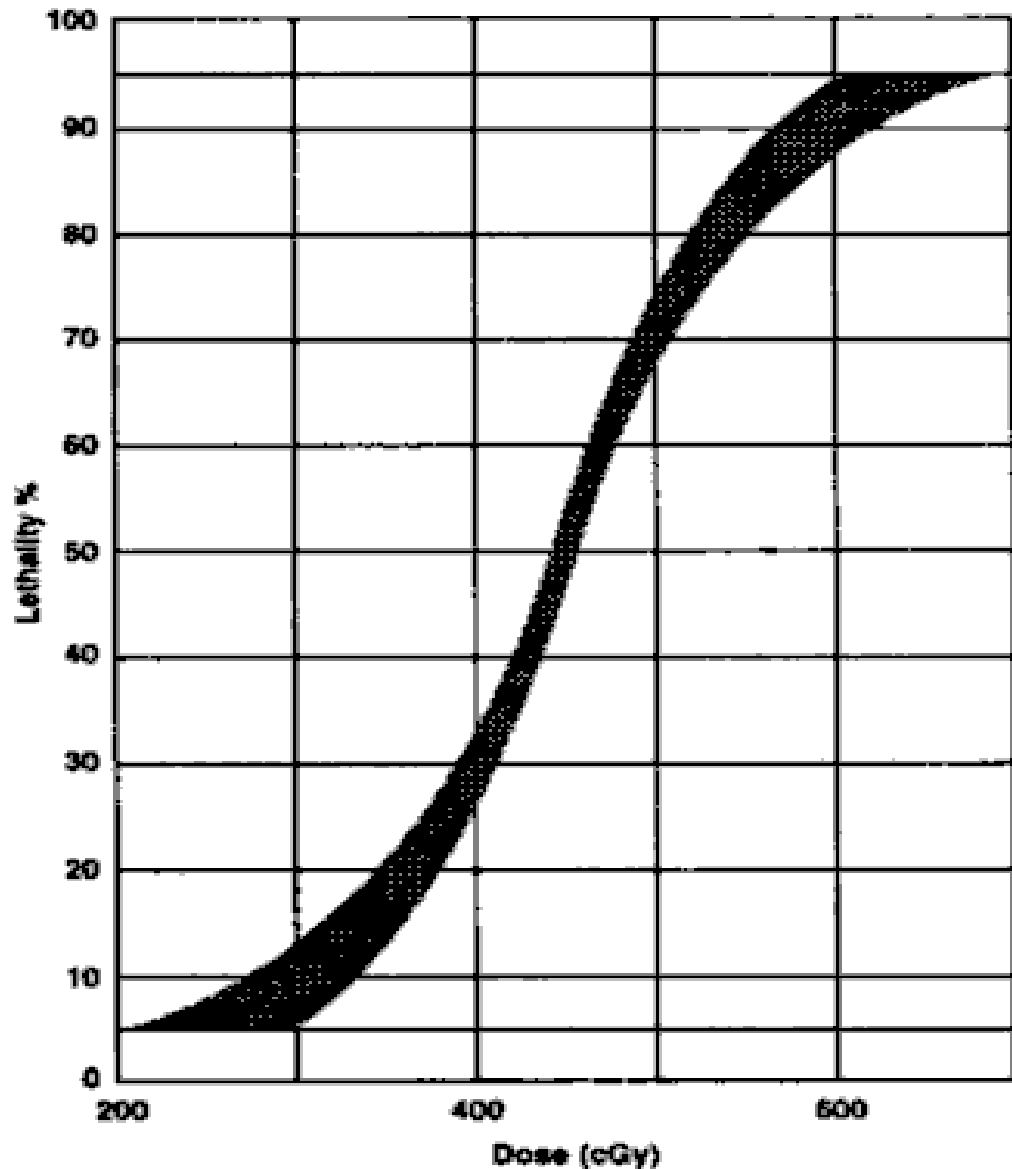
Linear energy transfer (LET): amount of energy deposited per unit track length

Acute Radiation Syndrome

- Signs and symptoms experienced by individuals exposed to acute whole body irradiation.
- Data collected largely through Japanese atomic bomb survivors at Hiroshima and Nagasaki.
- Limited number of accidents at nuclear installations.
- Clinical radiotherapy.
- Well-characterized animal data base.
- LD₅₀ dose of human is ~4.5 Gy.
- Lethal Dose is ≥ 8 Gy

Human lethality as function of Dose

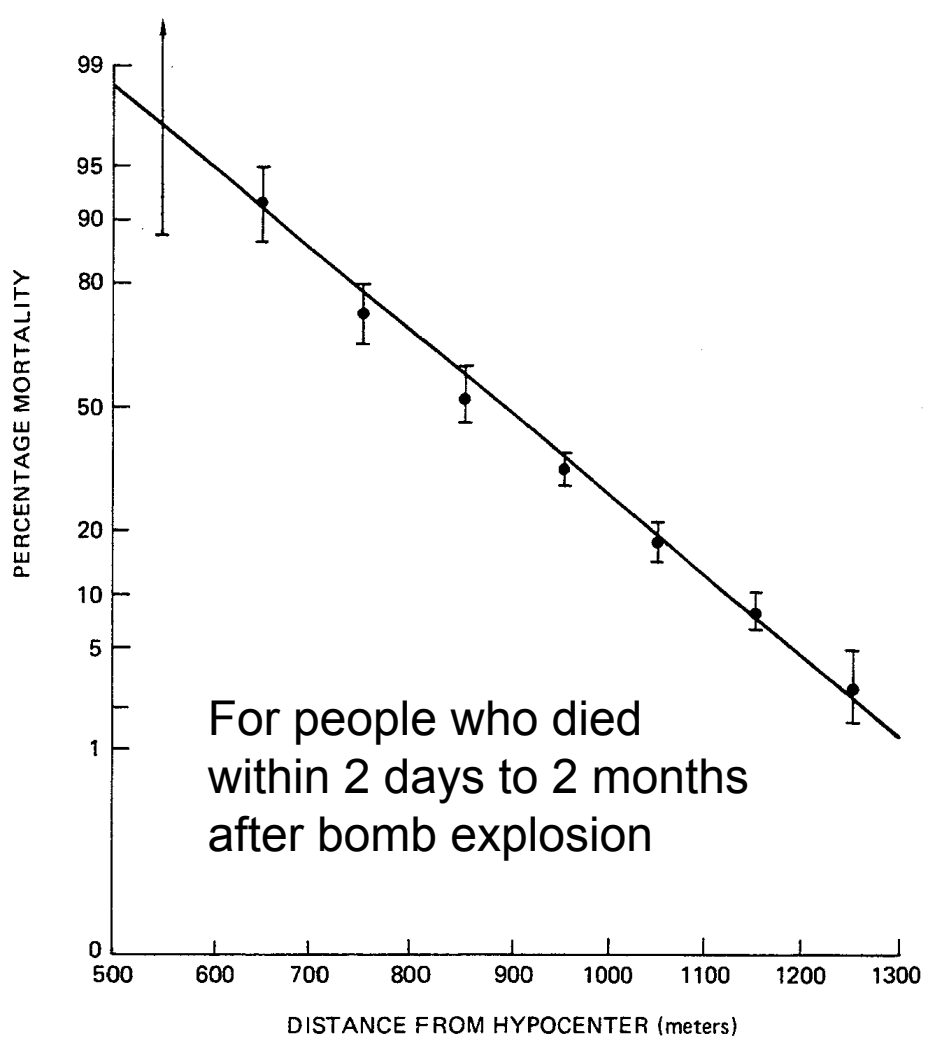
A 50% lethality is reached at an accumulated dose of 450 cGy = 450 rad = 4.5 Gy. A 100 rad dose is survivable. A 800 rad dose is lethal.



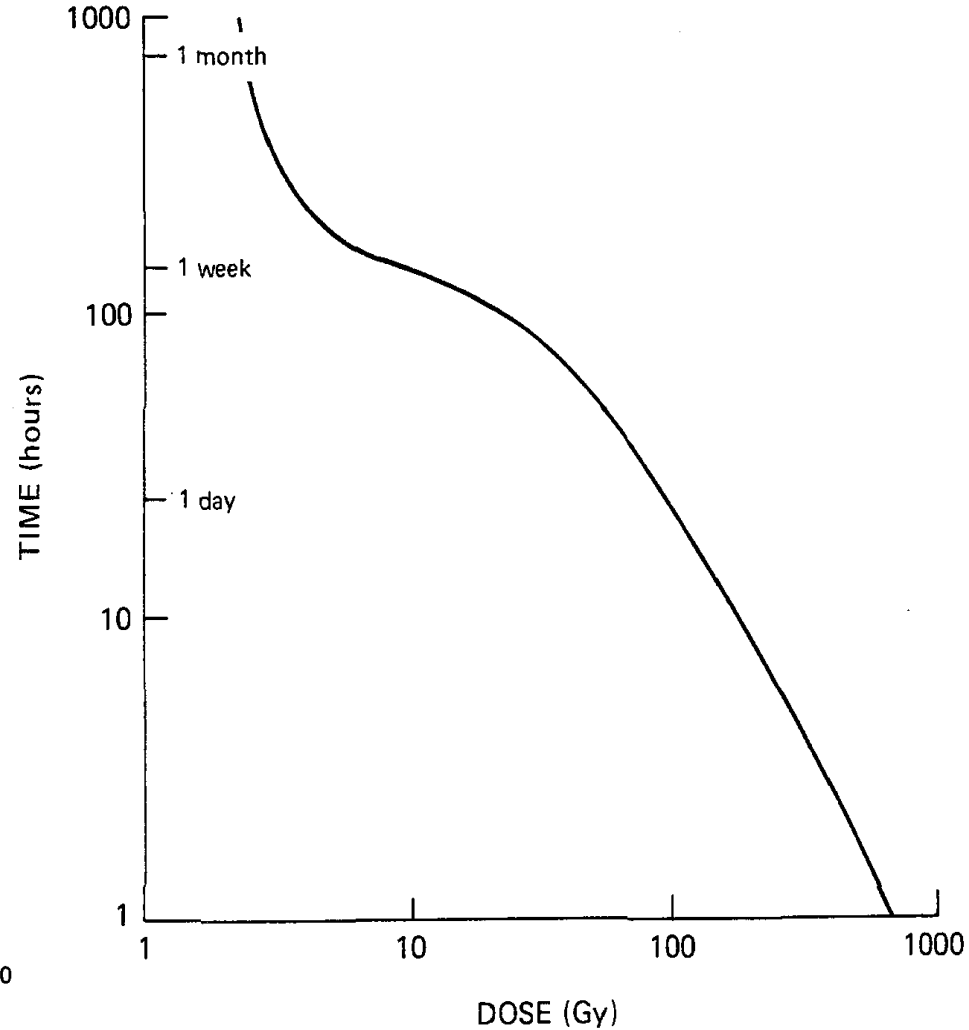
Prodromal Radiation Syndrome

- Early symptoms that appear after exposure to whole body radiation:
 - gastrointestinal: nausea, vomiting, diarrhea, anorexia
 - neuromuscular: easy fatigability
- Effect is dose dependent:
 - Varies in time of onset
 - Severity
 - Duration

Survival Chance

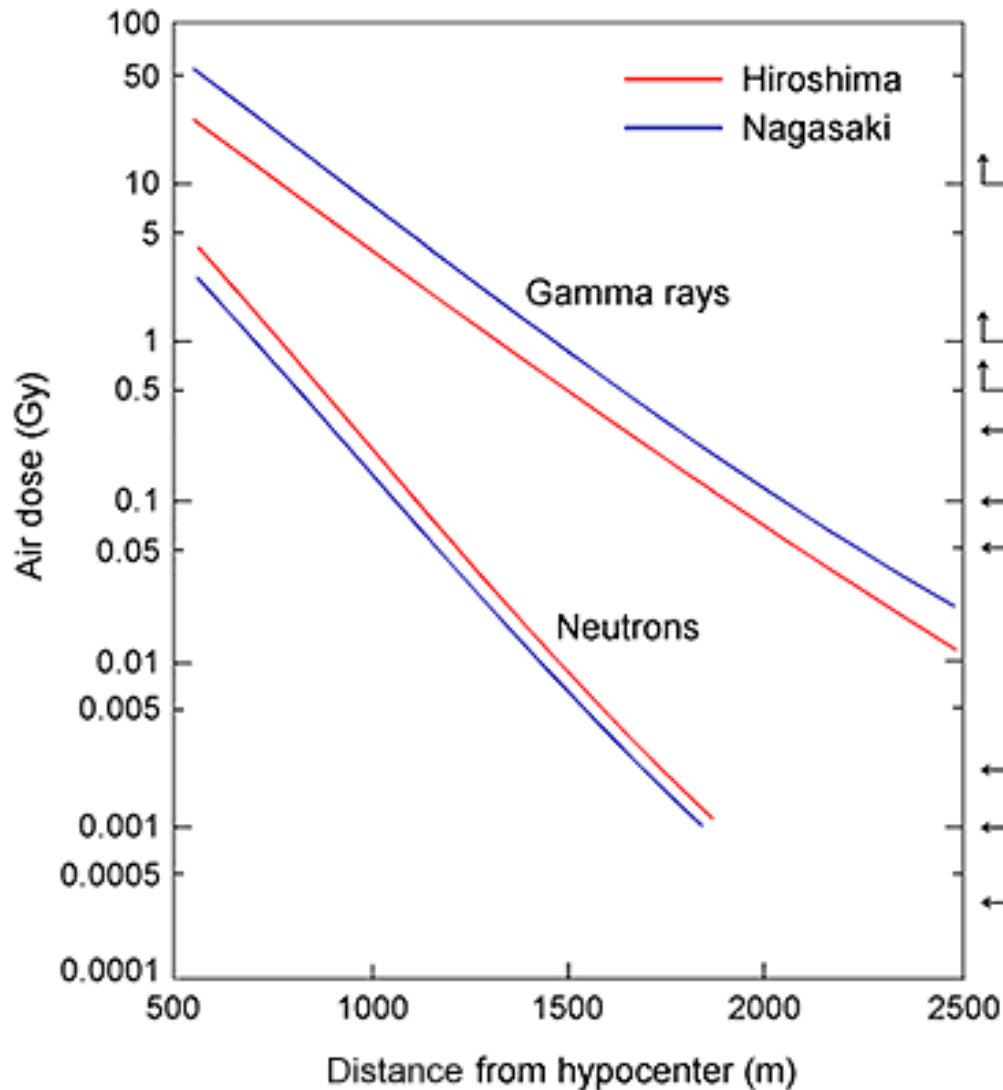


Probability of death as a function of distance from the hypocenter.



Time of occurrence of death from acute radiation effects.

Radiation Side Effects



radiation sickness

↑ 100% death within several days to weeks with modern medical interventions

↑ Vomiting, nausea

↑ Decrease of lymphocyte counts

↑ Cumulative dose of residual radiation beyond the first day

← Gastric fluoroscopy (skin dose)

← Annual background dose

← Chest X-ray photograph

Early Lethal Effects

Hematopoietic syndrome:

- Cause of death at doses <8 Gy.
- Peak incidence of death occurs at about 30 days post-irradiation, and continues for up to 60 days.
- Suppresses normal bone marrow and spleen functions.
- Symptoms associated with hematopoietic syndrome are: chill, fatigue, hemorrhages, ulceration, infection and anemia. Death usually result unless receive bone marrow transplant.

Early Lethal Effects

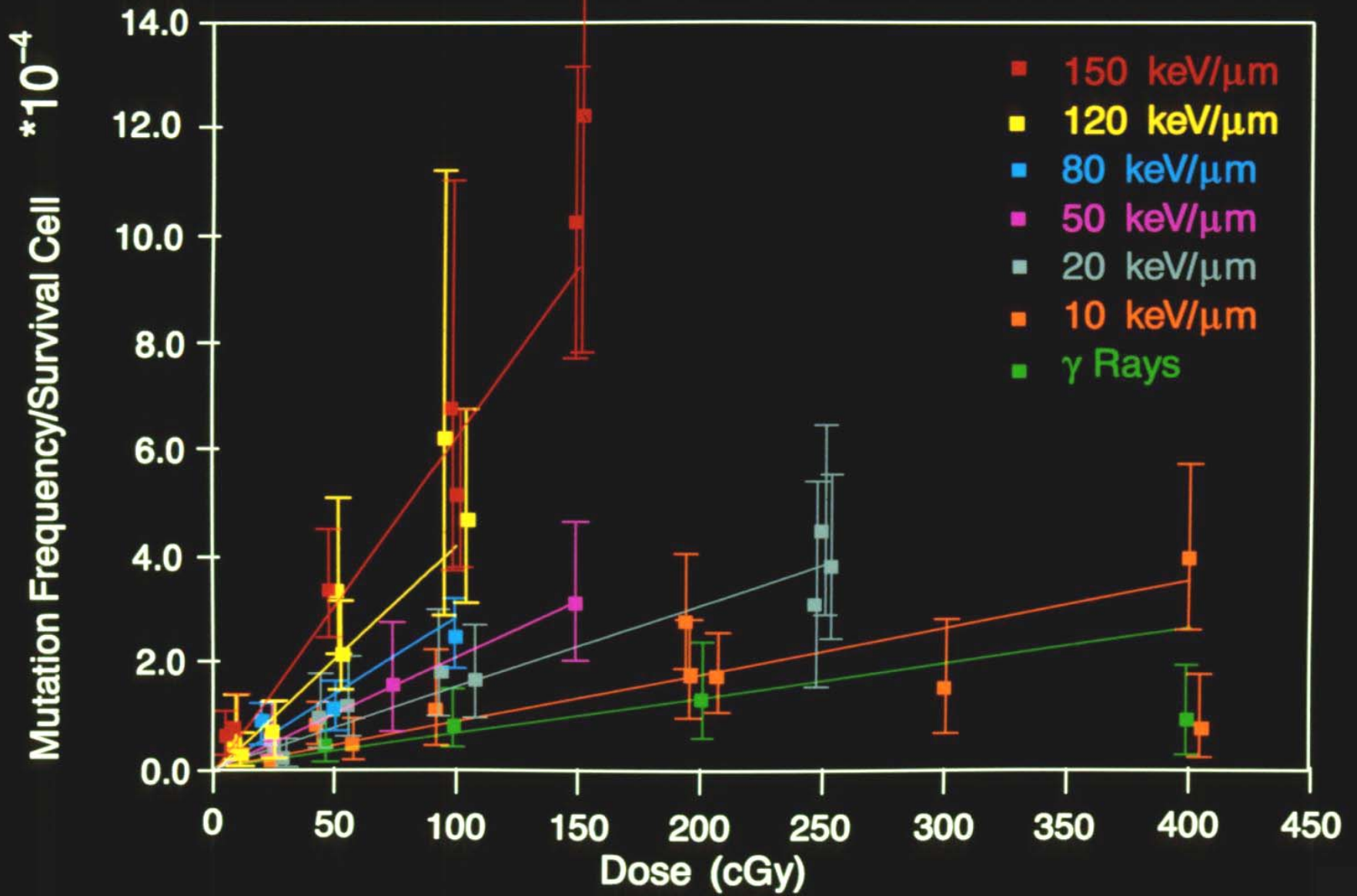
Gastrointestinal syndrome:

- Occurs at dose >10 Gy of gamma-rays or its equivalence.
- Death usually occurs within 3 to 10 days.
- Symptoms due largely to depopulation of the epithelial lining of the GI tract by radiation.
- No human has survived radiation dose >10 Gy.
- Clinical symptoms include nausea, vomiting, and prolonged diarrhea, dehydration, loss of weight, complete exhaustion, and eventually death.

Early Lethal Effects

Cerebrovascular syndrome:

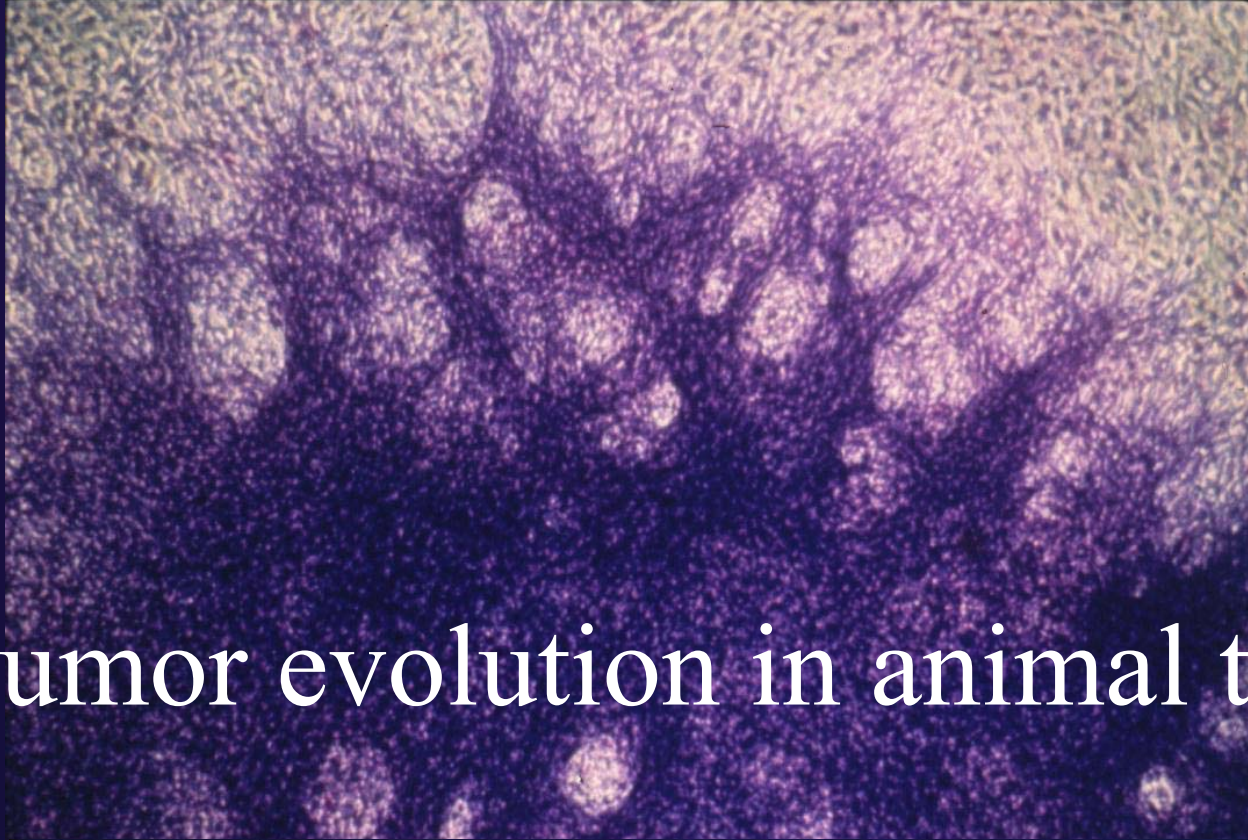
- Identified at doses >100 Gy of gamma-rays.
- Death occurs within hours from cardiovascular and neuromuscular complications.
- Clinical manifestations include severe nausea, vomiting within minutes of exposure, disorientation, loss of muscular co-ordination, respiratory distress, seizures, coma and death.



Radiation-induced Mutagenesis

- Radiation *DOES NOT* produce new, unique mutations, but increases the incidence of the same mutations that occur spontaneously.
- Mutation incidence in humans is *DOSE* and *DOSE-RATE* dependent.
- A dose of 1 rem (10 mSv) per generation increases background mutation rate by 1%.
- Information on the genetic effects of radiation comes almost entirely from animal and *IN VITRO* studies.
- Children of A-bomb survivors from Hiroshima and Nagasaki fail to show any significant genetic effects of radiation.

Tumor evolution in animal tests



Radiation Carcinogenesis

- A stochastic late effect.
- No threshold, an all or none effect.
- Severity is not dose related.
- Probability of carcinogenesis is dose dependent.
- Leukemia has the shortest latency period of ~5 years.
Solid tumors have a latency period of ~20 to 30 years.
- Total cancer risk for whole body irradiation is one death per 10^4 individuals exposed to 1 rem.

Nagasaki Effects

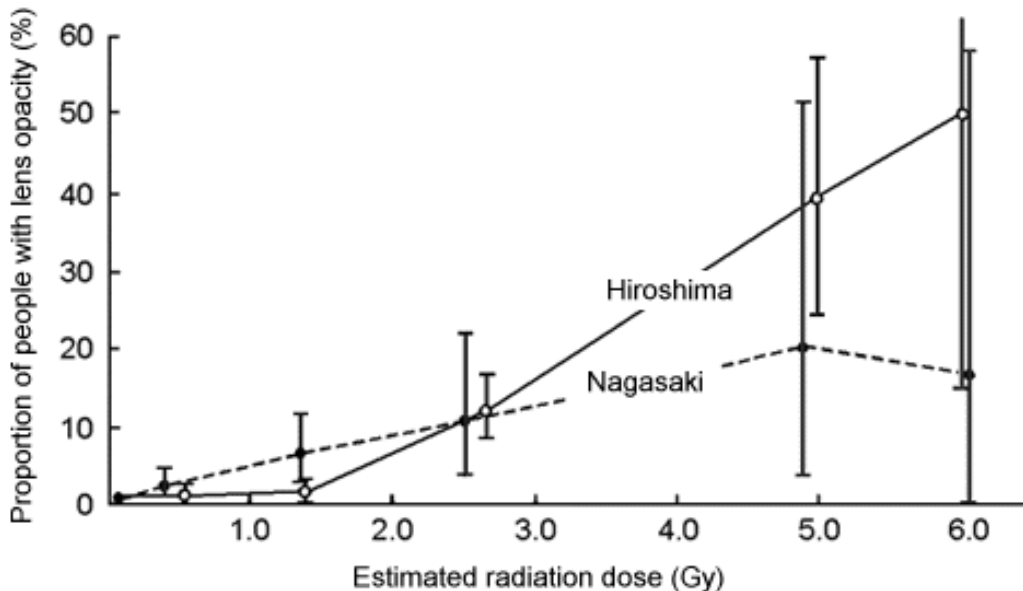
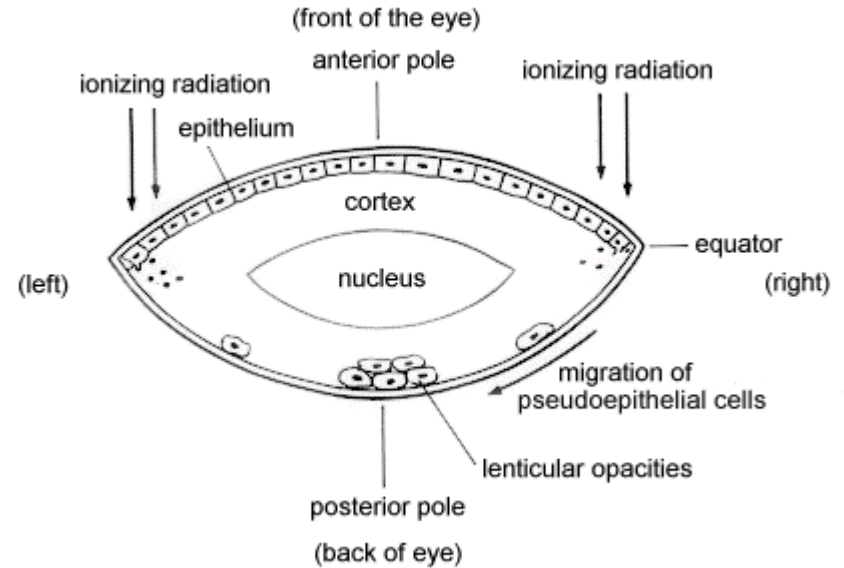
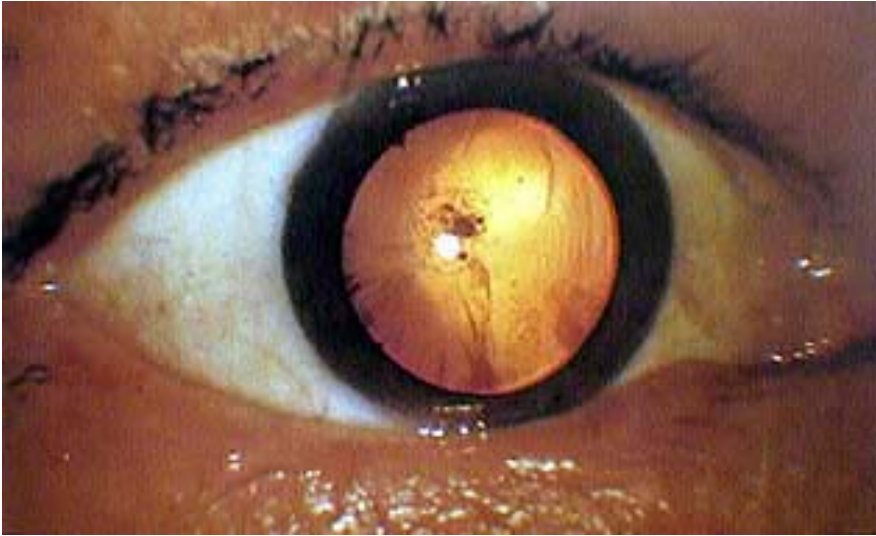


Purpura, Vomiting, ...



Purpura, or bleeding under the skin, is one of the symptoms of acute radiation sickness. The heavily exposed survivors experienced fever, nausea, vomiting, lack of appetite, bloody diarrhea, epilation, purpura, sores in their throat or mouth (nasopharyngeal ulcers), and decay and ulceration of the gums about the teeth (necrotic gingivitis). The time of onset of these symptoms depends on the exposure level.

Long term effects - blindness



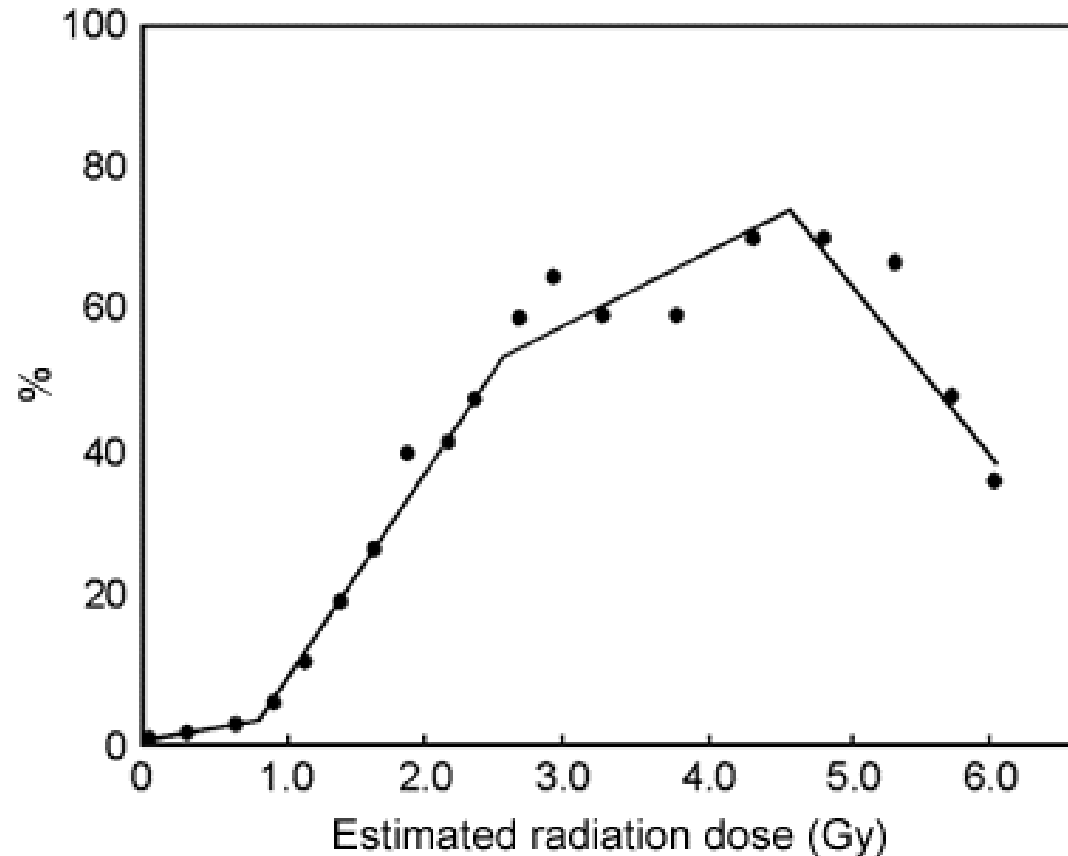
Radiation damage to epithelial cells. Damaged cells move to the back of the eye and cause lens opacity by blocking light. Occurs with 50% chance for people with dose of ~500 rad.

Epilation – severe loss of hair

Hair loss is a common sign of radiation exposure & sickness. Severe epilation (2/3 hair loss) occurs at doses of >200 rad.

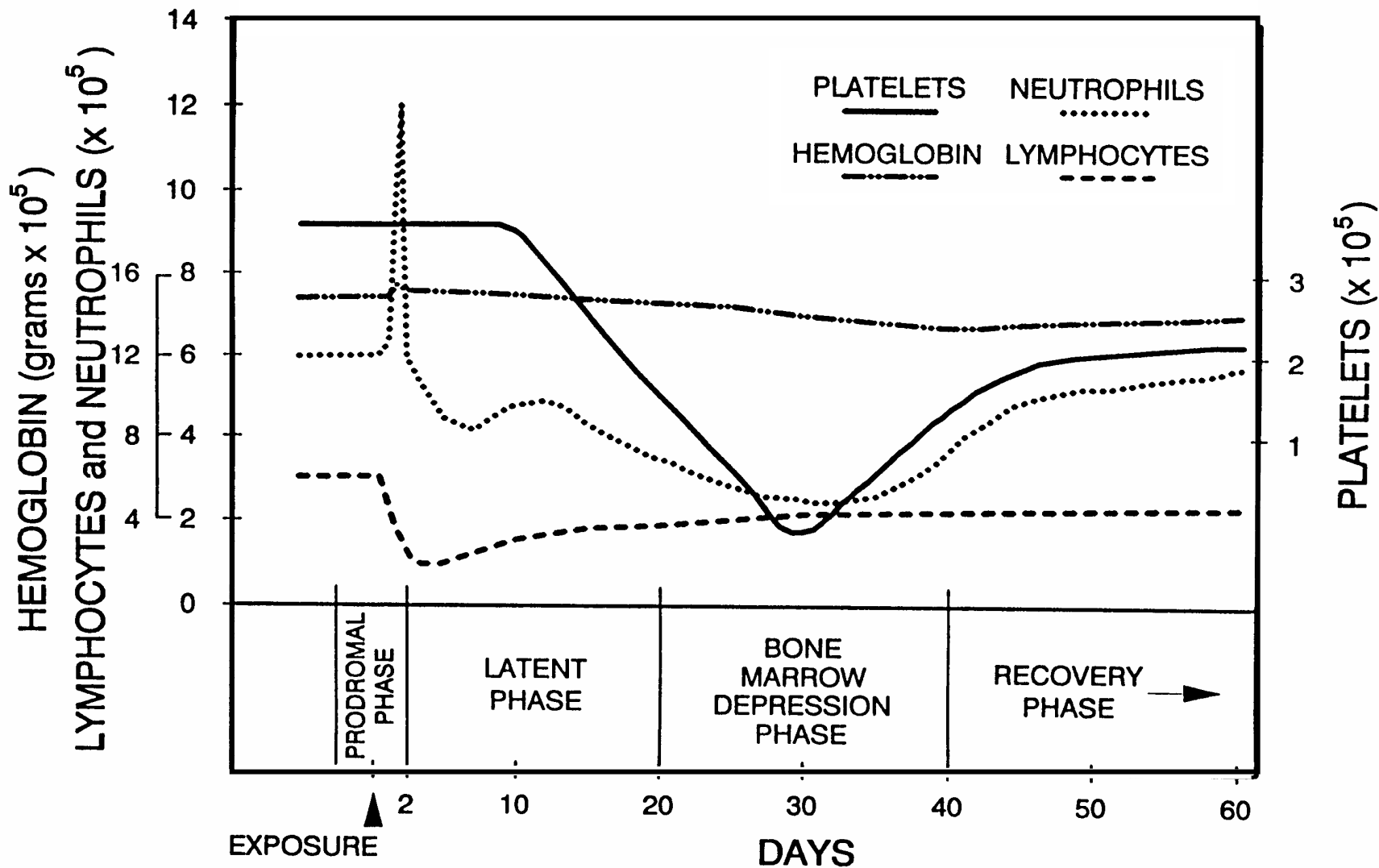


2km from hypocenter



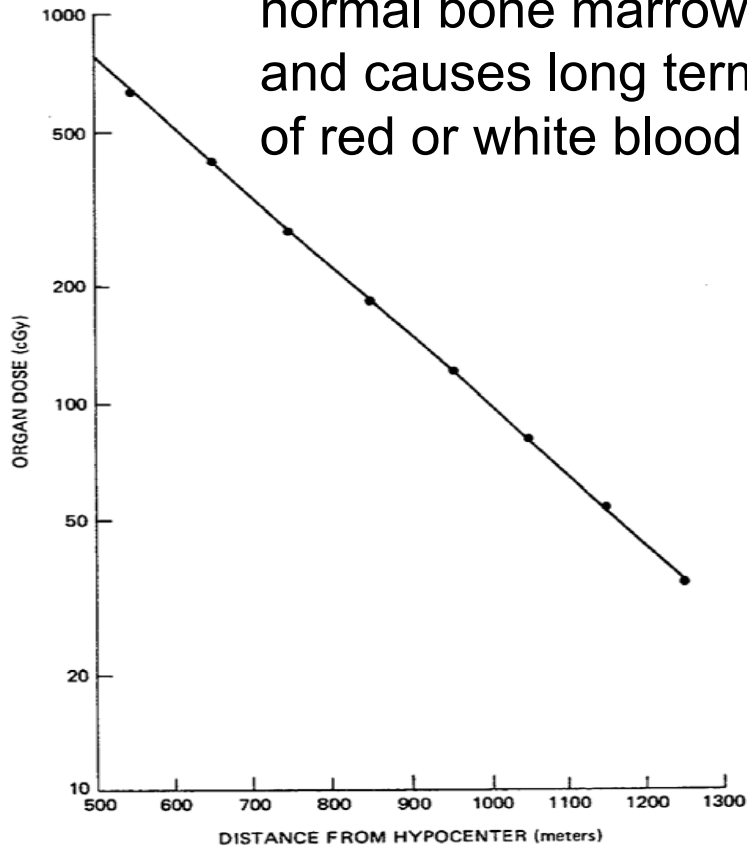
Hemogram

blood impact of 300 rad exposure

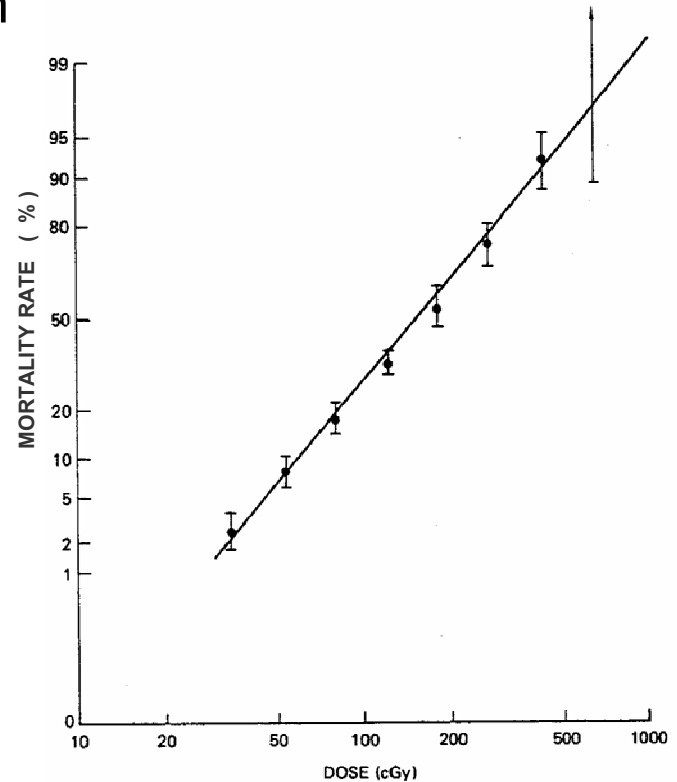
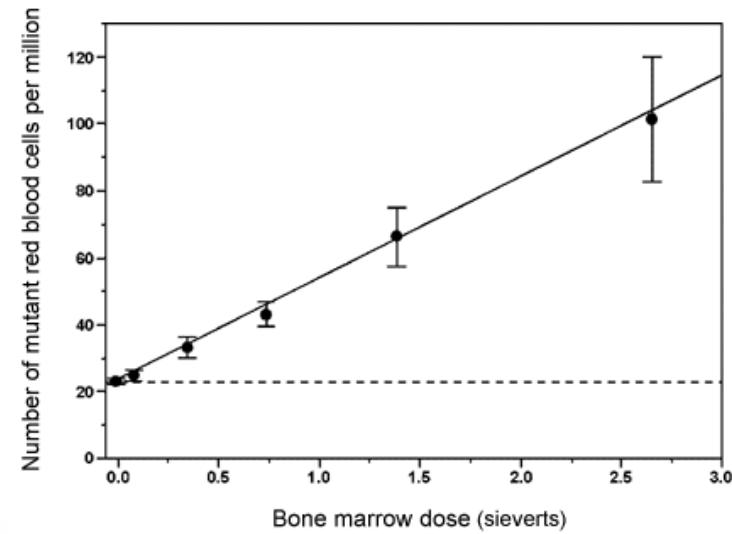


Radiation impact on bone marrow

100 rad = 1 Gy \approx 1 Sv
 Radiation >2 Gy suppresses normal bone marrow functions and causes long term mutation of red or white blood cells



Bone marrow dose versus distance from hypocenter in the Hiroshima survey group.

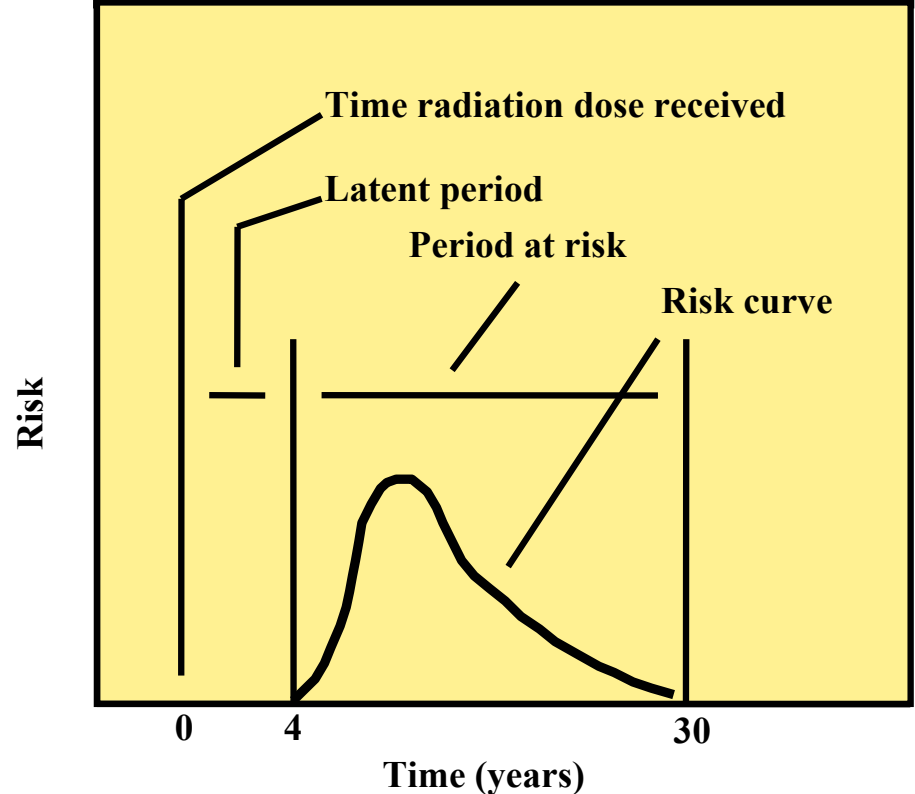
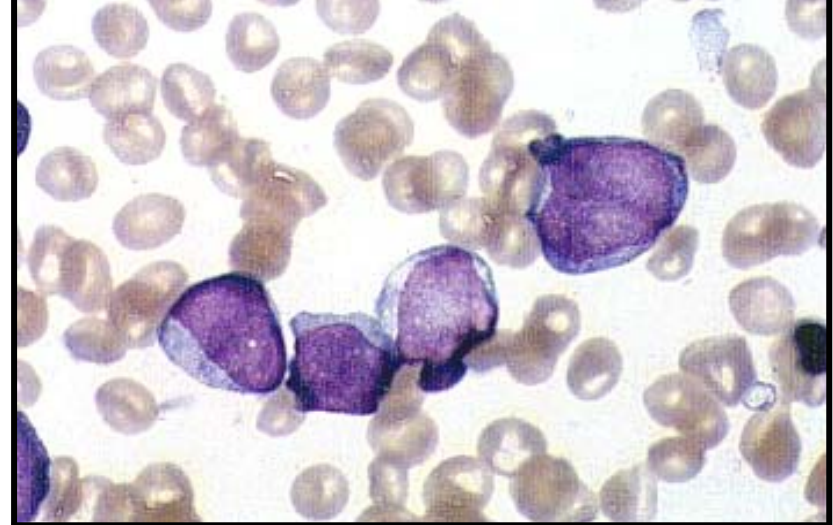


Percent mortality versus bone marrow dose in the Hiroshima survey

Leukemia

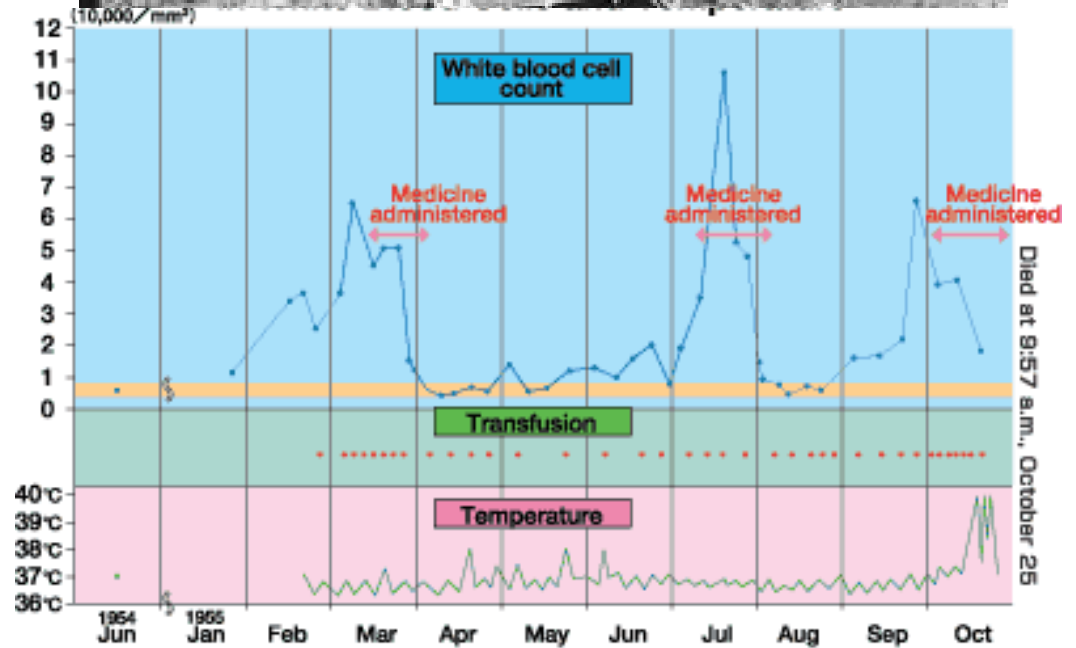
When leukemia develops, the body produces large numbers of abnormal blood cells. In most types of leukemia, the abnormal cells are white blood cells.

An increase in the number of leukemia cases was first noted in the late 1940s. As of 1990, there were 176 leukemia deaths among 50,113 survivors with significant exposures ($>0.5\text{Gy}$). It is estimated that about 90 of these deaths are associated with radiation exposure.



Leukemia Latency and Time at Risk Periods

Leukemia – case of Sadako

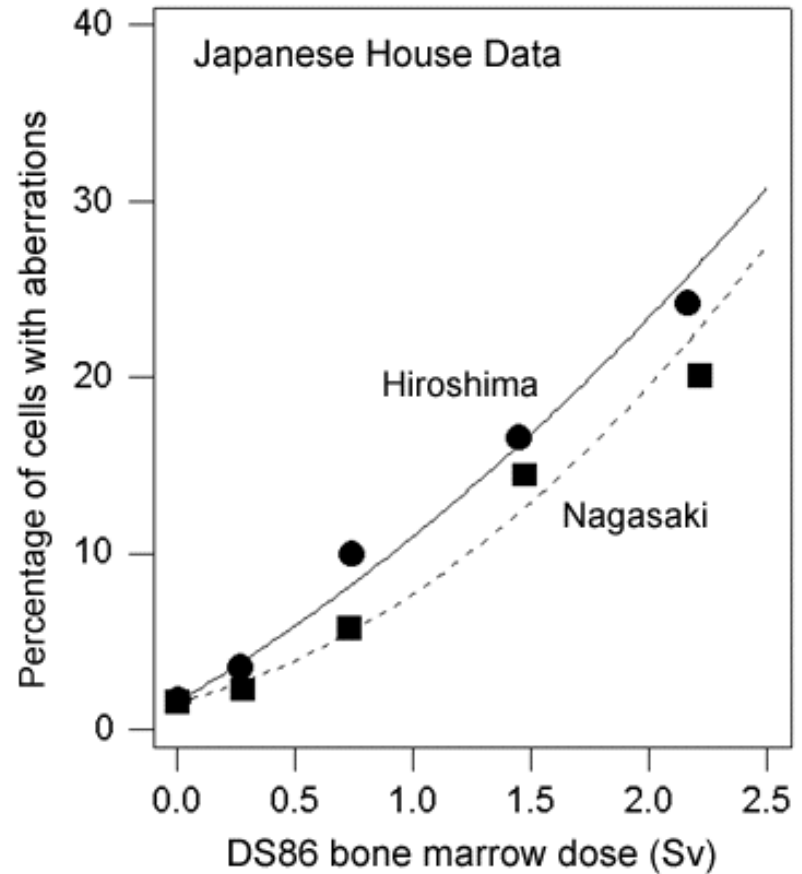
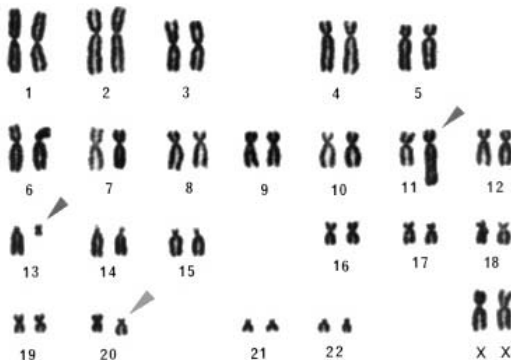


Note) Standard white blood count 4,000 to 8,000 / mm³
June is the results of Sadako's blood test during a physical exam.

Long range genetic effects



Chromosomes observed during cell division. Abnormal ones are marked by grey arrow.



Observed increase with dose indicates long term genetic effects