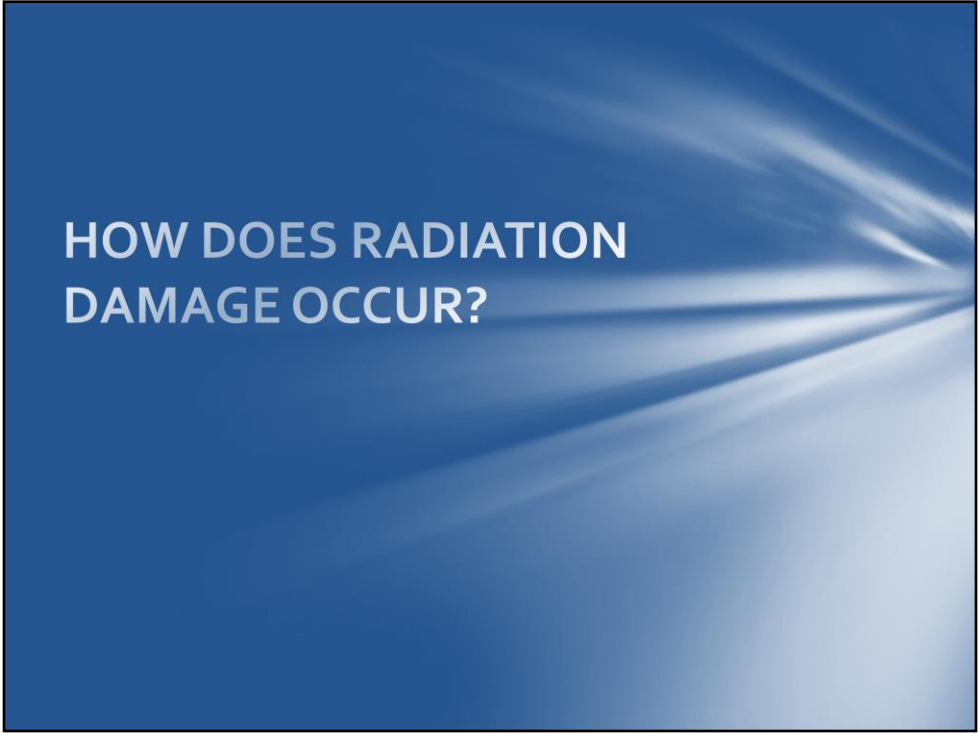


THE BIOLOGICAL EFFECTS OF IONIZING RADIATION

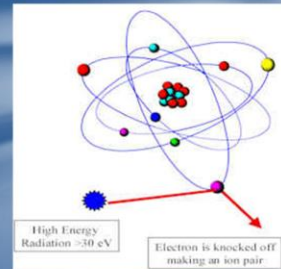
*University of Florida
Environmental Health and Safety
Radiation Control and Radiological Services*

A blue rectangular area with a gradient and light rays emanating from the right side.

HOW DOES RADIATION DAMAGE OCCUR?

IONIZATION

- Ionizing Radiation can remove tightly bound electrons from their atomic orbits
- This causes the atom to become charged or ionized
- The atom can then react with neighboring atoms, forming new chemical bonds



INTERACTIONS WITH CELL MATERIALS

- Biological damage occurs due to chemical changes caused by ionization at the cellular level
- Charged particles can ionize directly
- X-rays must first undergo interactions to produce free electrons, which can then ionize

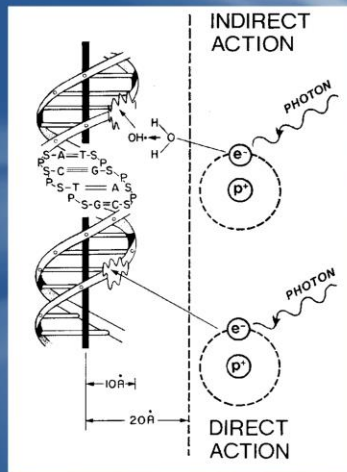


A blue gradient background with light rays emanating from the right side, creating a sense of depth and focus.

**DNA IS THE PRIMARY TARGET FOR
BIOLOGICAL DAMAGE**

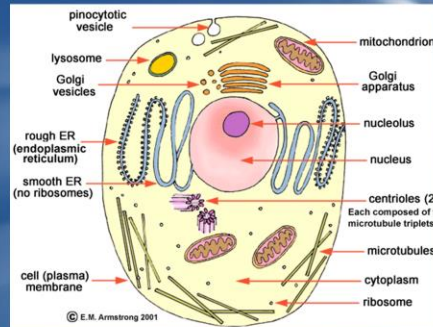
RADIATION DAMAGE MECHANISMS

- Direct Action: Direct ionization of the DNA molecule, which may result in genetic damage.
- Indirect Action: Radiation ionizes water, which causes free radicals to form. Free radicals attack targets such as DNA. Much more common.



POSSIBLE EFFECTS TO CELLS

- Radiation may pass through cell without doing any damage.
- Damage may occur but be repaired.
- The damaged cell may reproduce in its damaged form.
- The cell may die.

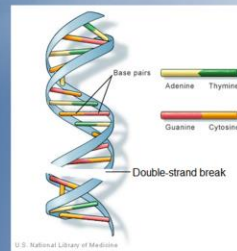
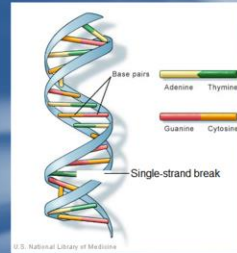


Four things can happen when radiation enters a cell:

1. The radiation may pass through without any damage occurring;
2. The radiation may damage the cell, but the cell repairs the damage;
3. The radiation may damage the cell...the damage is not repaired...and the cell replicates itself in the damaged form;
4. The cell dies.

DAMAGE AND RECOVERY

- Single-strand breaks
 - Most DNA damage is repaired, with no long-term effects
- Double-strand breaks
 - Not as easily repaired, more potential for long-term damage
 - Comparatively rare (about 1 DSB to 25 SSB)



DETERMINANTS OF BIOLOGICAL EFFECTS

- Rate of Absorption
- Area exposed
- Variations in Species and Individual Sensitivity
- Variations in Cell Sensitivity

CELL SENSITIVITY

- The degree of cell sensitivity is directly related to the reproductive capacity of cells and tissues, thus stem cells (germ cells) are more radiosensitive than mature differentiated cells
- **Law of Bergonie and Tribondeau**
- Radiosensitivity is:
 - directly proportional to growth rate
 - indirectly proportional to degree of specialization

CELL SENSITIVITY

Most Sensitive

Hematopoietic Cells

White Blood Cells (Lymphocytes)

Red Blood Cells

Epithelial Cells (Intestinal tract, Skin)

Muscle Cells

Least Sensitive

Nerve Cells

DAMAGE FROM RADIATION EXPOSURE

Acute

- High dose in short time
- Local: burns, hair loss, desquamation, blistering, damage to blood vessels, sterility, cataracts
- Whole-body: reduction in blood cell counts, nausea, radiation sickness

Chronic

- Low dose over long period of time
- Cancer, anemia, cataracts

APPEARANCE OF BIOLOGICAL EFFECTS

Prompt/Acute effect – effects seen immediately after large doses of radiation are delivered over a short period of time

- Examples: radiation sickness and burns
- threshold of 50 rad

Delayed effects- may appear months or years after a radiation exposure

- Examples: cataract formation and cancer induction
- threshold depends on effect (may be no threshold)

ACUTE RADIATION SYNDROME

Response to an acute, total body, large radiation exposure

STAGES IN ACUTE RADIATION SYNDROME

- Prodrome – initial sickness
- Latent Stage – temporary recovery (feel better)
- Manifest Illness Stage – symptoms depend on dose
- Recovery or Death

WHOLE BODY EXPOSURES

The LD_{50/30} concept

- Lethal Dose
- 50% of population
- 30 days
- used for animal species

LD_{50/60} for humans

- about 300-400 rad if no treatment is given

DOSE / RADIATION SYNDROME RELATIONSHIP

Dose < 1000 rad – white blood cells

- Hematopoietic form

Dose > 1000 rad - epithelial cells

- Gastrointestinal form

Dose > 10,000 rads - nerve cells

- Cerebrovascular form

HEMATOPOIETIC SYNDROME

- **Prodromal Stage:** Mild symptoms appear within a few hours and last for several days
- **Latent Period:** May last up to 4 weeks
- **Manifest Illness:** Vomiting, diarrhea, fatigue and fever – Decline in blood cells – Recovery in 2 to 4 weeks...May last up to 6 months
- **Possible death** due to infection, dehydration or hemorrhage

Hematologic Syndrome

Prodromal Stage: Mild symptoms appear within a few hours and last for several days

Latent Period: May last up to 4 weeks

Manifest Illness: Vomiting, diarrhea, fatigue and fever – Decline in blood cells – Recovery in 2 to 4 weeks...May last up to 6 months

Possible death due to infection, dehydration or hemorrhage

GASTROINTESTINAL SYNDROME

- **Prodromal Stage:** Vomiting and diarrhea occur within hours and last up to one day
- **Latent Period:** Lasts 3-5 days
- **Manifest Illness:** Nausea, vomiting and diarrhea – Worsens to bloody stools
- **Death** within 4 to 10 days after exposure primarily due to intestinal cell damage – Also damage to blood-forming tissue results in hemorrhaging and dehydration.

Gastrointestinal Syndrome

Prodromal Stage: Vomiting and diarrhea occur within hours and last up to one day

Latent Period: Lasts 3-5 days

Manifest Illness: Nausea, vomiting and diarrhea – Worsens to bloody stools

Death within 4 to 10 days after exposure primarily due to intestinal cell damage – Also damage to blood-forming tissue results in hemorrhaging and dehydration.

CENTRAL NERVOUS SYSTEM SYNDROME

- **Prodromal Stage:** Severe nausea and vomiting within a few minutes – Nervousness, confusion, burning skin, vision loss, possible loss of consciousness
- **Latent Period:** May last up to 12 hours, or not at all
- **Manifest Illness:** Disorientation, loss of muscle control, breathing problems, seizures, coma
- **Death** within a few days of exposure – due to increased fluid in brain (pressure) – Death occurs before hematologic and gastrointestinal symptoms appear

Central Nervous System Syndrome

Prodromal Stage: Severe nausea and vomiting within a few minutes – Nervousness, confusion, burning skin, vision loss...possible loss of consciousness

Latent Period: May last up to 12 hours, or not at all

Manifest Illness: Disorientation, loss of muscle control, breathing problems, seizures, coma

Death always within a few days of exposure – due to increased fluid in brain (pressure) – Death occurs before hematologic and gastrointestinal symptoms appear

ACUTE LOCALIZED EFFECTS

- Injury can also be caused when only localized areas of the body are exposed
- Most common effects are skin-related:
- 200 rad: mild erythema (reddening)
- 300 rad: temporary hair loss
- 600 rad: more severe erythema 10-14 days after exposure
- 700 rad: permanent hair loss
- 1000 rad: desquamation (shedding of skin) and tissue necrosis

LONG TERM EFFECTS

- Delayed effects due to previous acute high dose exposures or from chronic low dose exposure over many years.
- Carcinogenic
- Embryological
- Cataractogenic
- Life span shortening

GENETIC EFFECTS

- Genetic effects = heritable mutations to DNA
- Seen in mammals but no convincing evidence in humans
- Very difficult to measure due to subtle effects, long lifespans, uncertainties in background rate, and confounding factors
- Japanese bomb survivors
 - 77,000 births with no substantial evidence of genetic effects

HUMAN EVIDENCE OF RADIATION CARCINOGENESIS

- Radium dial painters
- Radiologists and dentists
- Uranium miners
- Atomic bomb survivors
- Patients receiving medical procedures

ANNUAL DOSE LIMITS

STATE ANNUAL LIMITS

Occupationally Exposed Workers

- 5 rem/yr whole body, gonads
- 15 rem/yr lens
- 50 rem/yr other organs, hands

Non-occupationally exposed worker (and the general public)

- 0.1 rem /yr (100 mrem)

UF GUIDELINES

Badged radiation workers will be contacted by a Radiation Control physicist when dose is:

- Over 40 mrem/month for employees working with irradiator or in research labs
- Over 300 mrem/month for employees working with x-ray units in medical or veterinary settings
- Unusual for you or your work area

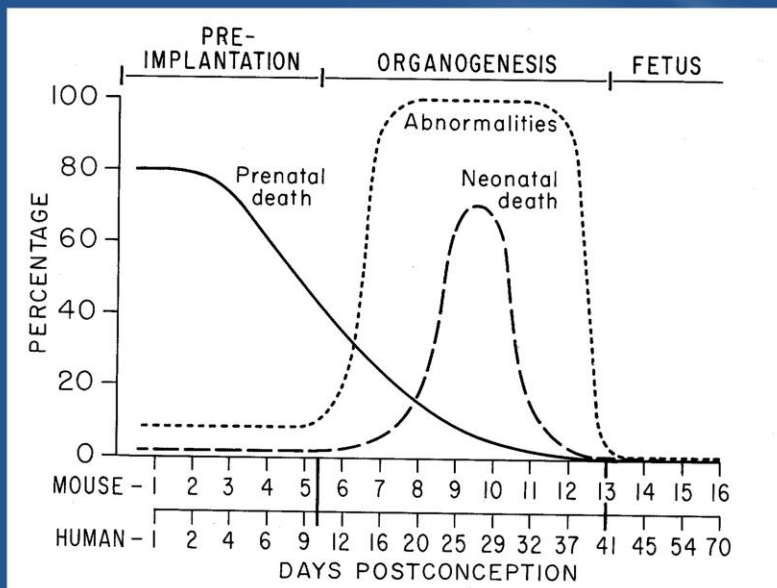
PREGNANT WORKERS

EFFECTS ON EMBRYO AND FETUS

Embryonic/fetal cells are rapidly dividing!

- High sensitivity
- Higher probability that damage will be reproduced over a large number of cells

Effects depend on stage of gestation



REGULATIONS FOR PREGNANT WORKERS

- Limit embryo/fetus dose equivalent to 500 mrem (0.5 rem) total.
- Once a pregnancy becomes known limit embryo fetus dose equivalent to 50 mrem per month, excluding medical exposure
- Wear two personnel monitors. Fetal monitor under apron at waist. Maternal, outside apron at collar.

FEDERAL GUIDELINES FEDERAL REGISTER 1/27/87

"The health protection objectives...for the unborn should be achieved in accordance with the provisions of Title VII of the Civil Rights Act of 1964...with respect to discrimination in employment practices."

-VOLUNTARY declaration of pregnancy to employer as soon as soon as possible.

FEDERAL GUIDELINES

FEDERAL REGISTER 1/27/87

Protection of the unborn is a joint responsibility of the employer and the worker.

Protection through:

Use of protective equipment, worker self selection, and temporary job rotation.