RADIOACTIVTY AND ITS APPLICATIONS

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Presentation outlines

- Introduction to radioactivity
- Sources of radionuclides
- Background radiation
- Applications of radioactivity
- Conclusion

Japanese Fukushima nuclear disaster (2011),

- Japanese Fukushima nuclear disaster (2011)
- shut down the nation's 54 nuclear power plants.
- 2013 repots - highly radioactive, with some 160,000 evacuees still living in temporary housing.
- Some land will be unfarmable for centuries.
- The difficult cleanup job will take 40 or more years
- Cost tens of billions of dollars

- **Fukushima Daichi, March 11, 2011**
  An 8.9 magnitude earthquake and subsequent tsunami overwhelmed the cooling systems of an aging reactor along Japan's northeast coastline. The accident triggered explosions at several reactors at the complex, forcing a widespread evacuation in the area around the plant.

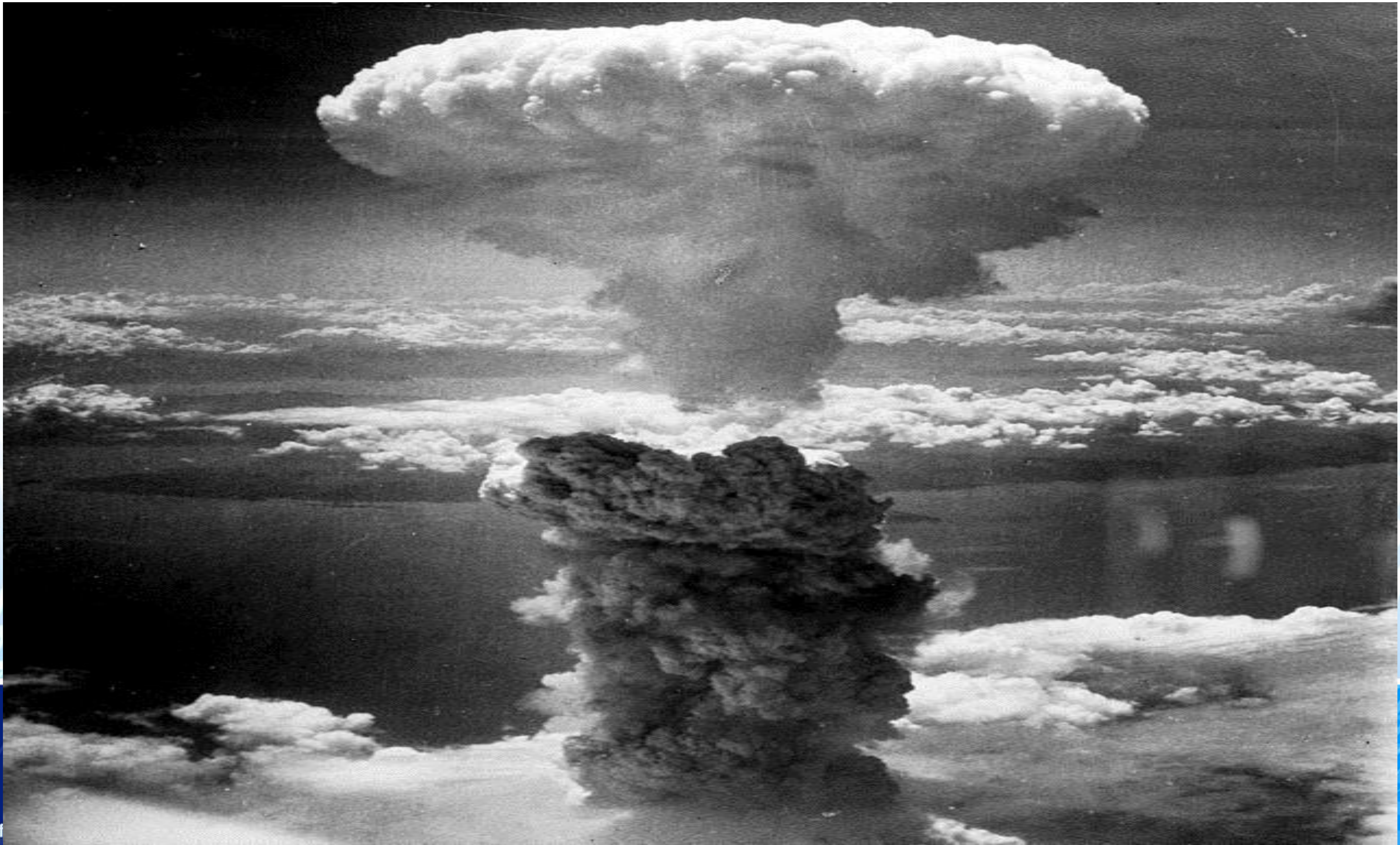
August 10. 1985, Russia, the Echo II class submarine suffered an explosion, sending a radioactive cloud of gas into the air. Ten sailors were killed in the incident and 49 people were observed to have radiation injuries.

The abandoned city of Prypiat, Ukraine, Chernobyl disaster, Russia (1986).

- One of the worst nuclear accidents till date.
- The accident killed 30 people directly and damaged approximately $7 billion of property.
- A study published in 2005 estimates that there will eventually be up to 4,000 additional cancer deaths related to the accident among those exposed to significant radiation levels.
- Radioactive fallout from the accident was concentrated in areas of Belarus, Ukraine and Russia. Approximately 350,000 people were forcibly resettled away from these areas soon after the accident.

- **Chernobyl, April 26, 1986**
  The Chernobyl disaster is considered to be the worst nuclear power plant disaster in history. On the morning of April 26, 1986, reactor number four at the Chernobyl plant exploded. More explosions ensued, and the fires that resulted sent radioactive fallout into the atmosphere. Four hundred times more fallout was released than had been by the atomic bombing of Hiroshima.

Mushroom cloud from the atomic explosion over Nagasaki, Japan rising 60,000 feet into the air on the morning of August 9, 1945.

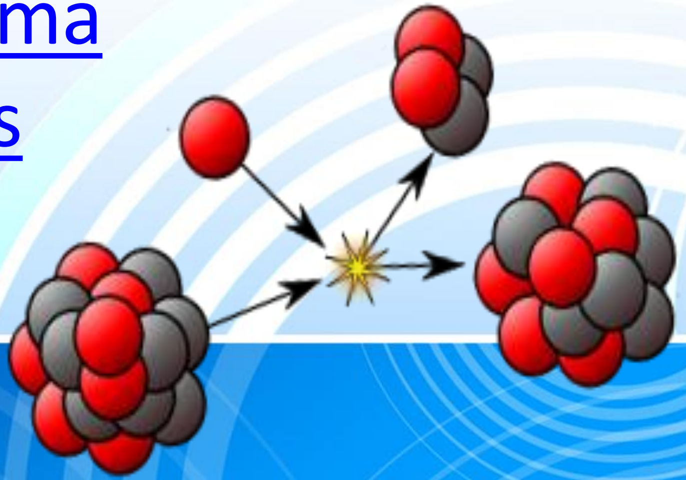


- On August 6, 1945, the uranium-type nuclear weapon, code named "Little Boy" was detonated over Hiroshima with an energy of about 15 kilotons of TNT
- Destroying nearly 50,000 buildings and killing approximately 70,000 people.
- On August 9, a plutonium-type nuclear weapon code named "Fat Man" was used against the Japanese city of Nagasaki with the explosion equivalent to about 20 kilotons of TNT.
- Approximately 35,000 people killed.

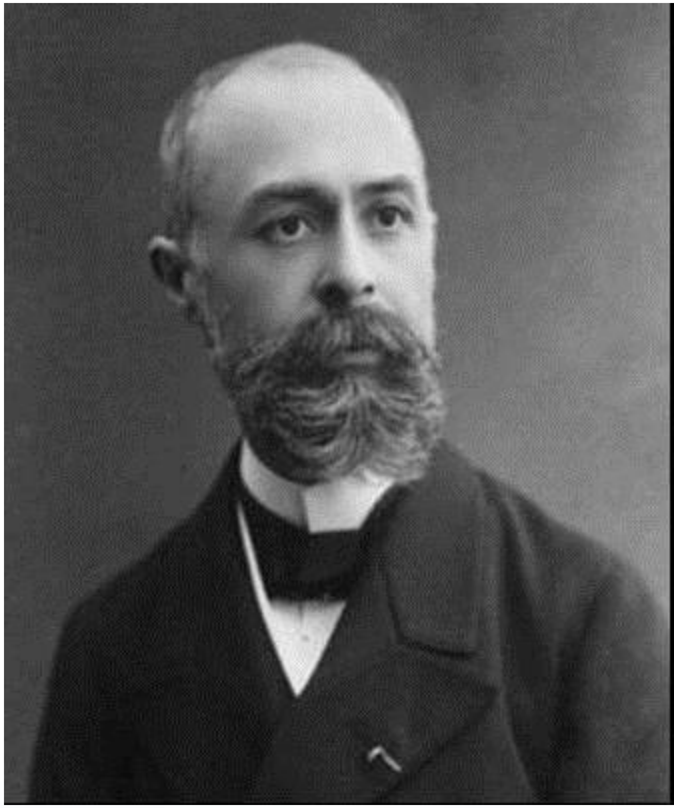
What is radioactivity?

Nuclear decay or **radioactivity**, is the process by which a nucleus of an unstable atom loses energy by emitting ionizing radiation.

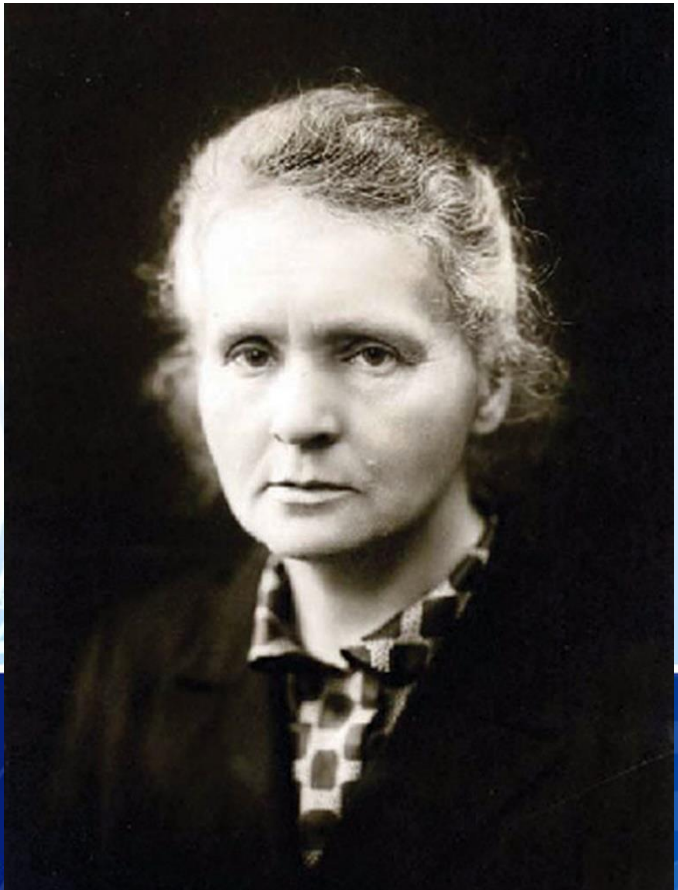
A material that spontaneously emits this kind of radiation which includes the emission of alpha particles, beta particles, gamma rays and conversion electrons



Who discovered radioactivity?



Antoine Henri Becquerel

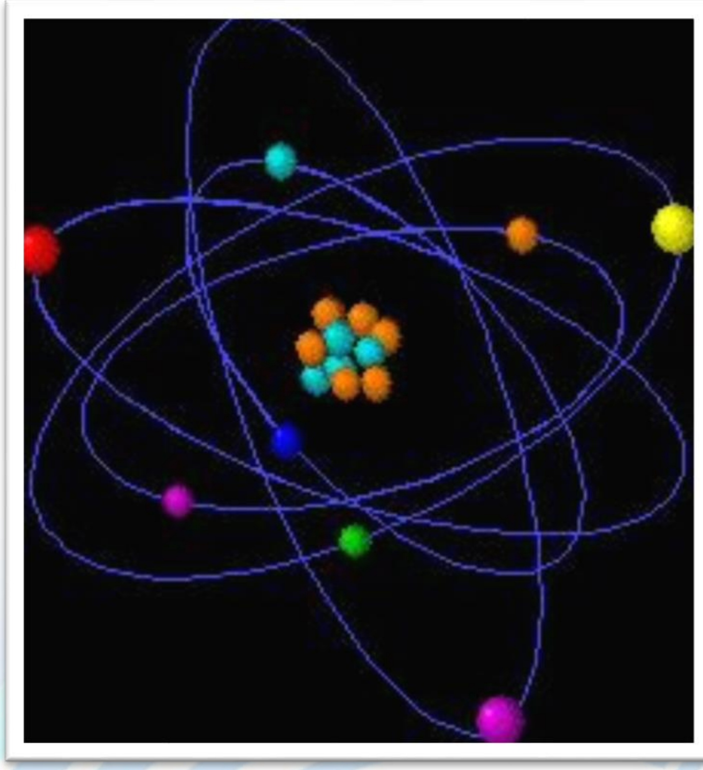


Marie Curie

Why are elements radioactive?

Unstable nucleus:

- Has excess energy.
- Wants to go to “ground state.”
- Becomes stable by emitting ionizing radiation.



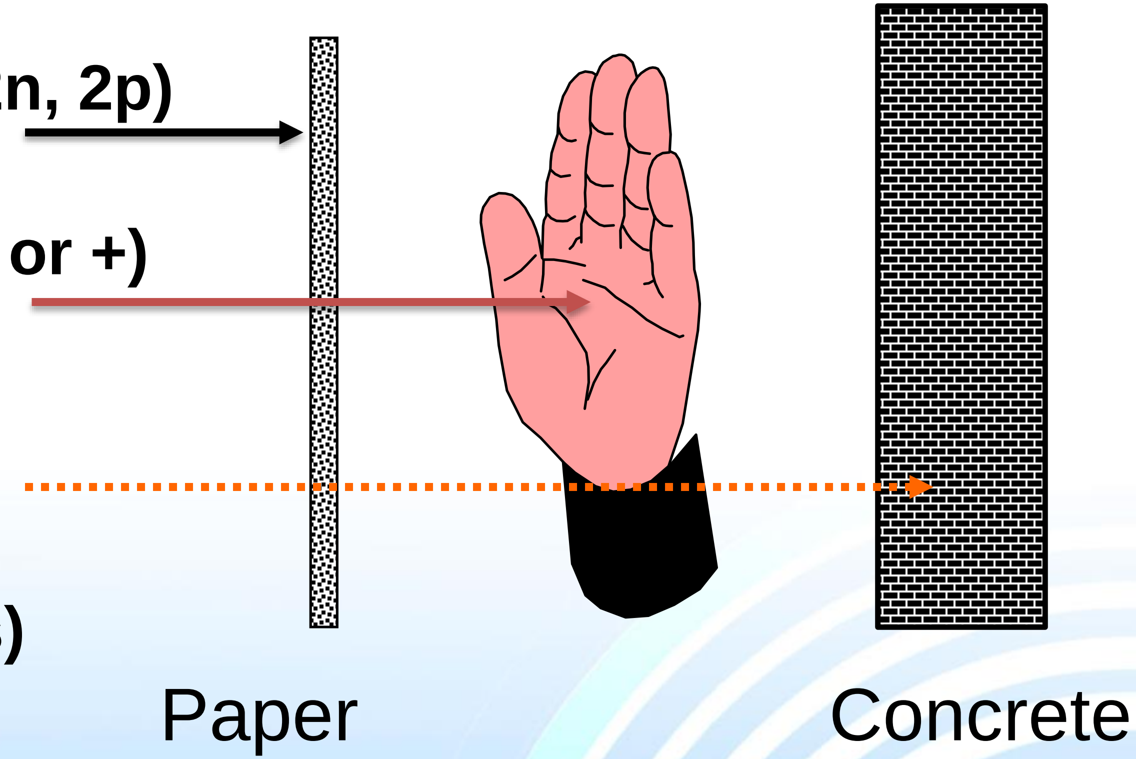
Radiation Types

Alpha Particles (2n, 2p)

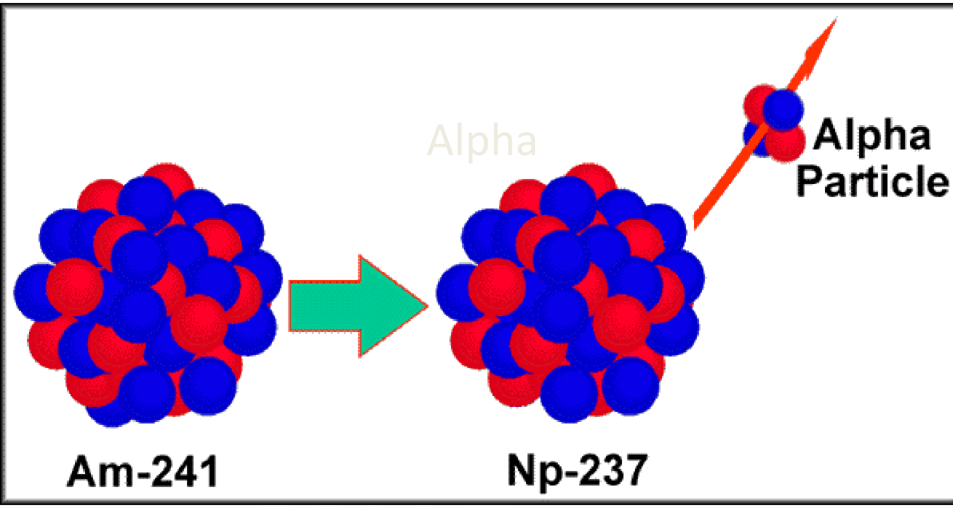
Beta Particles (e- or +)

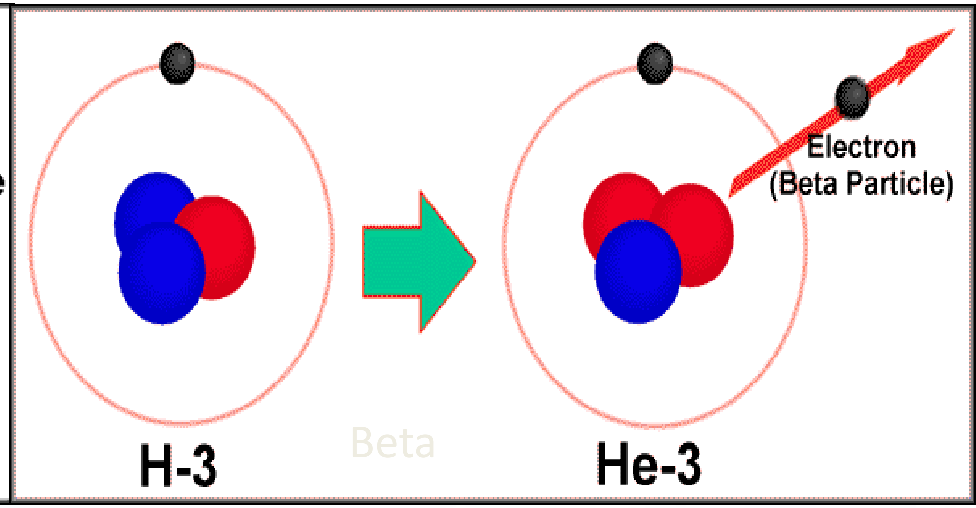
Photons (hv)

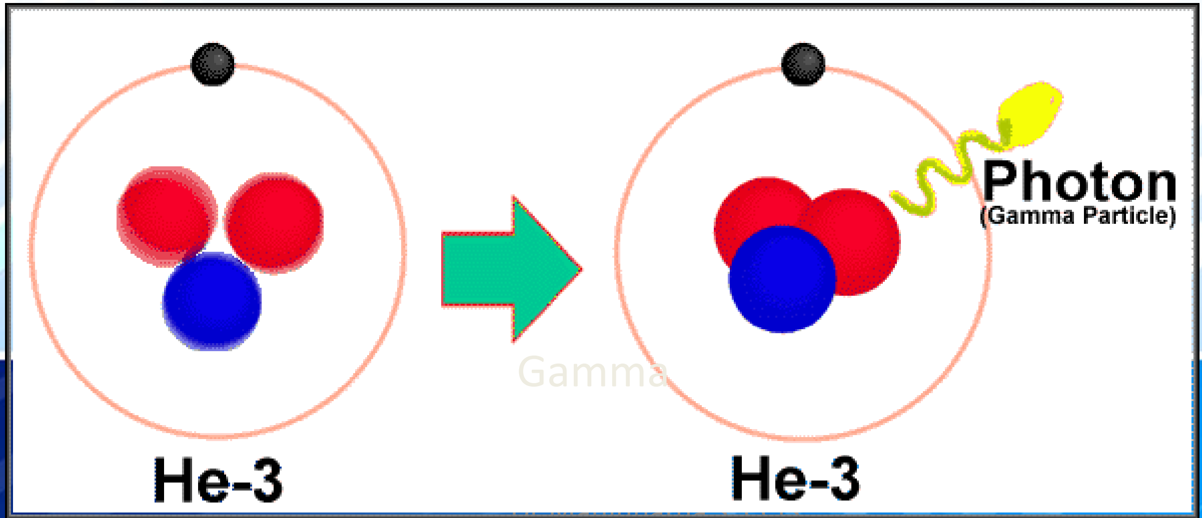
(x or gamma rays)



Three Common Types of Radioactive Emissions







The electromagnetic spectrum

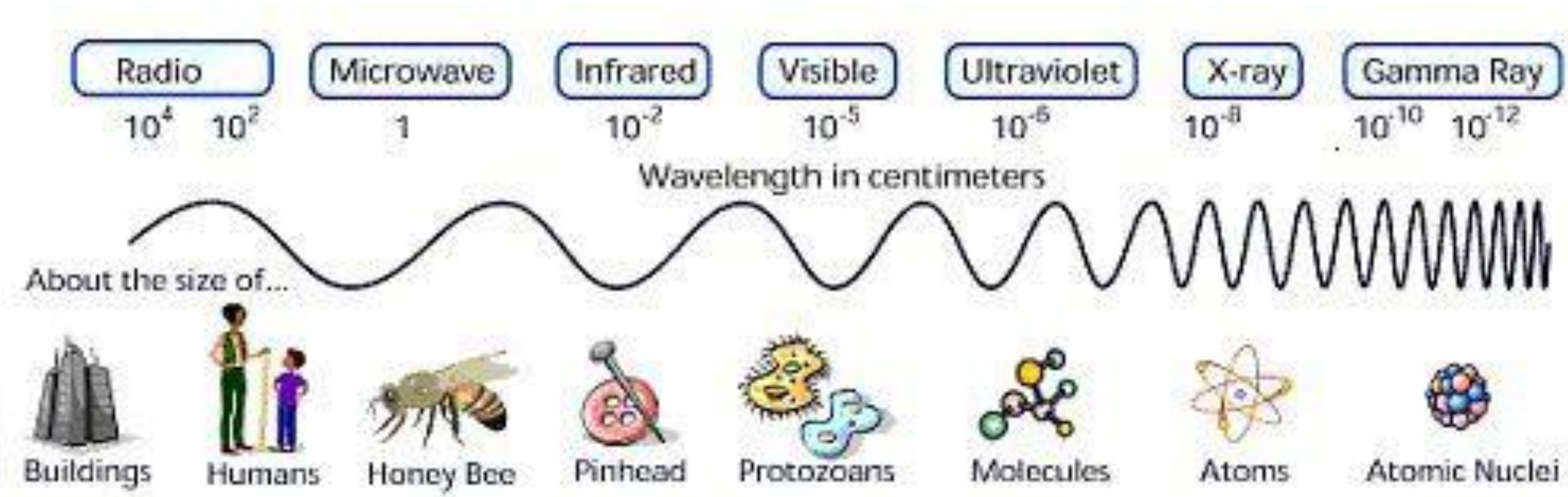
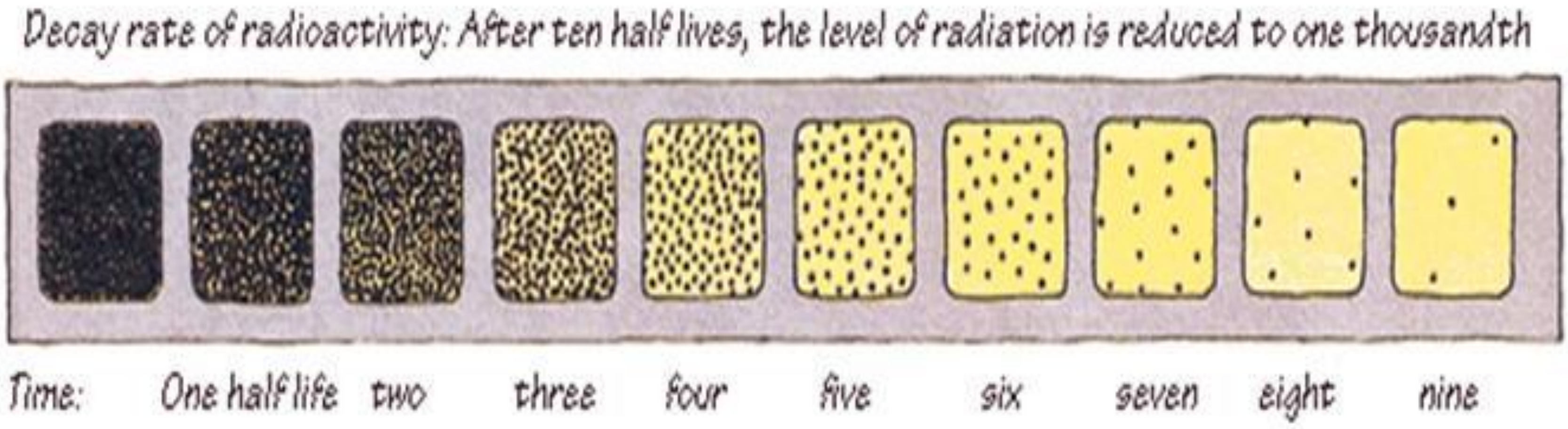


Figure courtesy of NASA/JPL-Caltech

Half life and mean life

Half-life is the time required for half of the atoms of a radioactive material to decay to another nuclear form.

Mean life is average of all half lives



Sources of radioactivity

(i) Primordial Radionuclides

That radionuclides that are present since the creation of earth and having long half-lives, e.g. ^{210}Pb, ^{226}Ra, K^{40}

(ii) Cosmogenic Radionuclides

That radionuclides that are produced in the upper atmosphere as a result of cosmic rays interaction with light particles (carbon, Nitrogen and Oxygen), e.g. C^{14}, ^{7}Be, ^{22}Na, ^{32}P, ^{32}S

(iii) Anthropogenic Radionuclides

That radionuclides that are produced as a result of man-made activities such as nuclear fuel fabrication, enrichment, nuclear power generation, nuclear accidents etc., e.g. ^{137}Cs, ^{134}Cs, ^{131}I, ^{90}Sr etc.

Units of Radioactivity

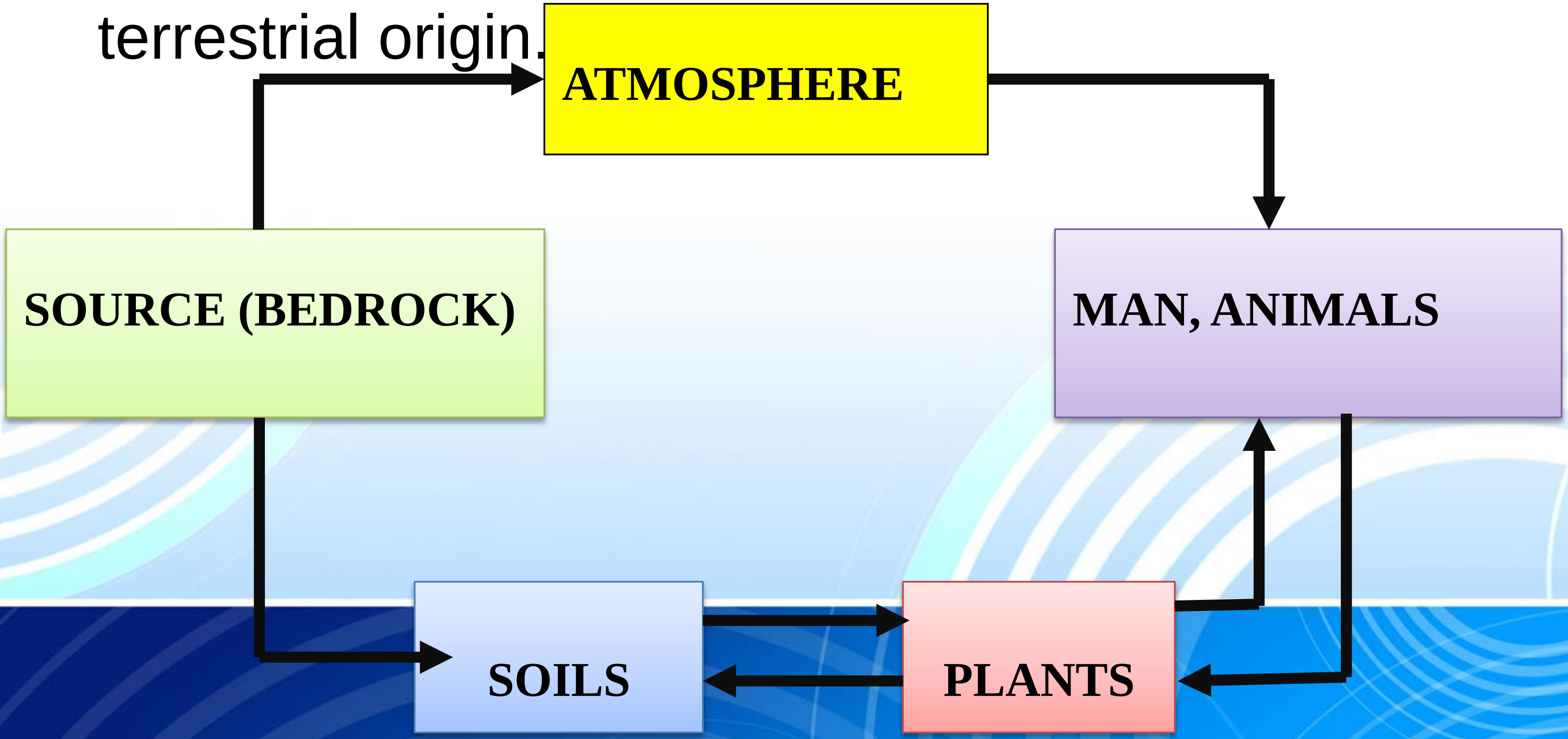
- The Becquerel (Bq): Disintegration per second, dps
- The curie (Ci)

  1 Ci = 37,000,000,000 Bq

  so 1 mCi = 37 MBq; and 1 μCi = 37 kBq
- rem: Rem is the term used to describe equivalent or effective radiation dose.
- In the International System of Units, the Sievert (Sv) describes equivalent or effective radiation dose. One Sievert is equal to 100 rem.

Natural background radiation

- The natural radiation energy between few KeV to MeV from primordial radionuclides are called background radiation.
- Background radiation is of terrestrial and extra-terrestrial origin.



1. Terrestrial radiation components

- The terrestrial component originates from primordial radionuclides in the earth's crust, present in varying amount.
- Components of three chains of natural radioactive elements viz. the uranium series, the thorium and actinium series.
- ^{238}U, ^{226}Ra, ^{232}Th, ^{228}Ra, ^{210}Pb, ^{210}Po, and ^{40}K, contribute significantly to natural background radiation.

1. Terrestrial radiation components contd…

- Among the singly occurring radionuclides tritium and carbon-14 (produced by cosmic ray interactions) and ^{40}K (terrestrial origin) are prominent.
- Radionuclides from these sources are transferred to man through food chains or inhalation.

2. Extra terrestrial radiation

- The extra terrestrial radiation originates in outer space as primary cosmic rays.
- The primary cosmic rays mainly comprise charged particles, ionised nuclei of heavy metals and intense electromagnetic radiation.

3. Artificial Radionuclides

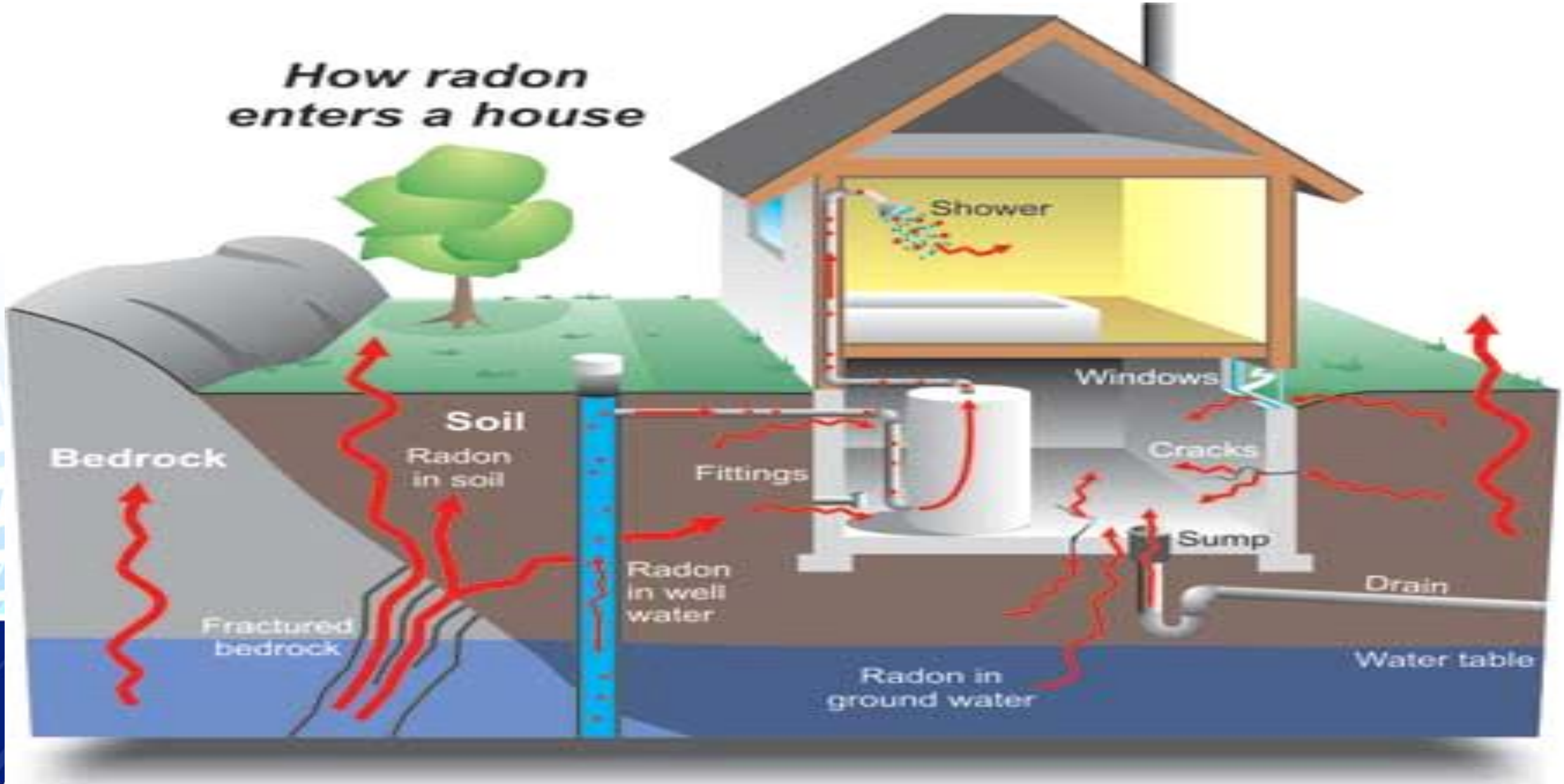
- Over the last few decades man has artificially produced hundreds of radionuclides.
- Artificial radioisotopes to the atmosphere during the course of operation of the nuclear fuel cycle, nuclear tests (mainly atmospheric) and nuclear accidents
- Most of the artificial radioisotopes decay -short half-lives. Therefore only a few of them are significant from the point of human exposure.

Radon

- Radon is a radioactive gas decay product of radium, created during the natural breakdown of uranium in rocks and soils
- It is one of the heaviest substances that remains a gas under normal conditions and is considered to be a health hazard causing cancer
- It has three isotopes, namely, ^{222}Rn (^{238}U), ^{220}Rn (^{232}Th) and ^{219}Rn (^{235}U). ^{222}Rn has longer half life (3.84 days) than the other two isotopes

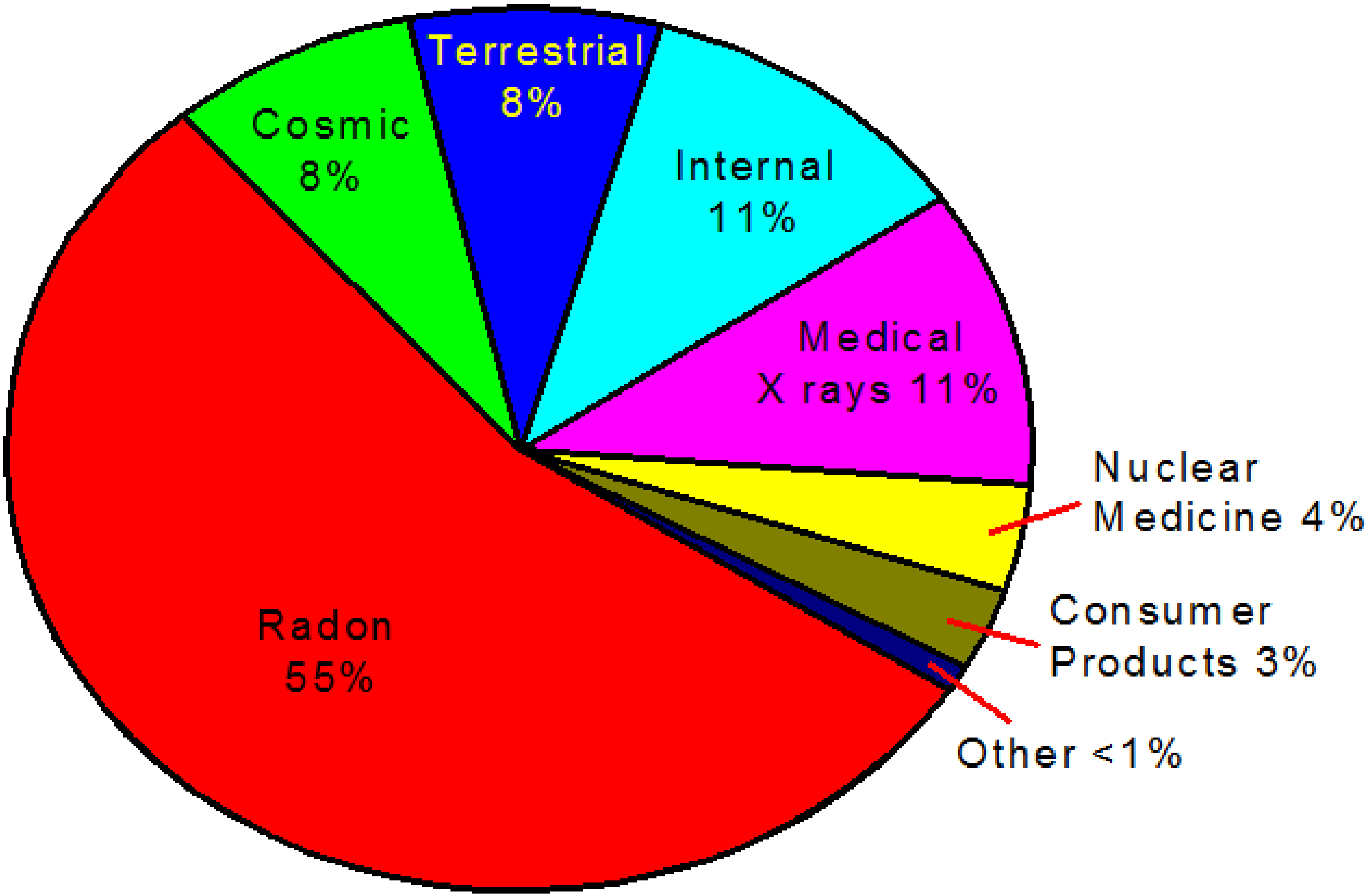
Radon in Buildings

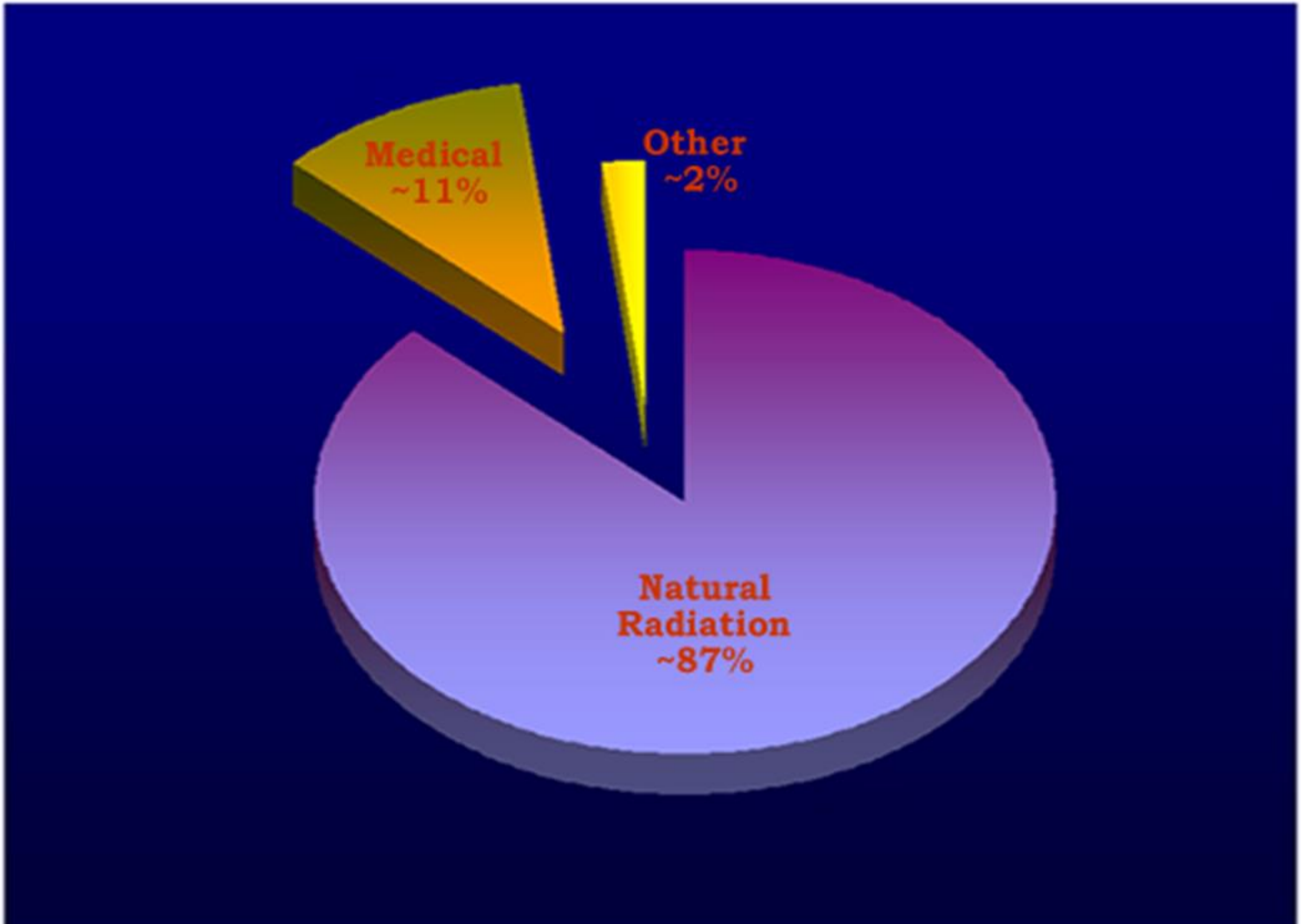
There are two main sources for the radon in home's indoor air, soil and water supply.



fppt.com

Sources of background radiation

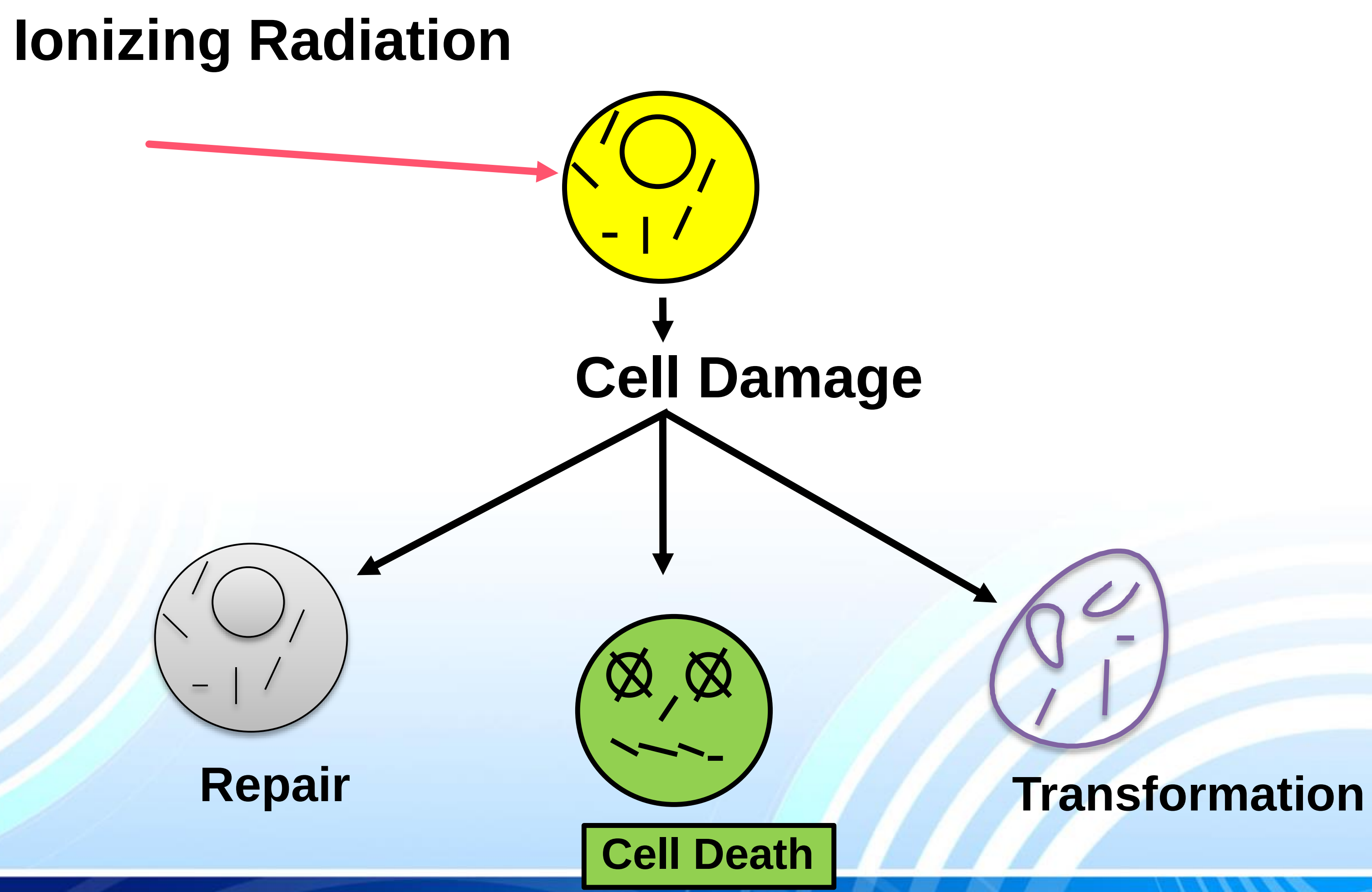



Medical
~11%
Other
~2%
Natural
Radiation
~87%

Radioactivity – is it a health problem?

- The Alpha, Beta and Gamma particles **all add energy** to the body's tissues. The effect is called the **Ionizing Energy.** It can **alter DNA.**
- Even though Alpha particles are not very penetrative if the decaying atom is already in the body (inhalation, ingestion) they can cause trouble.

Biological Effects: Mechanisms of Injury

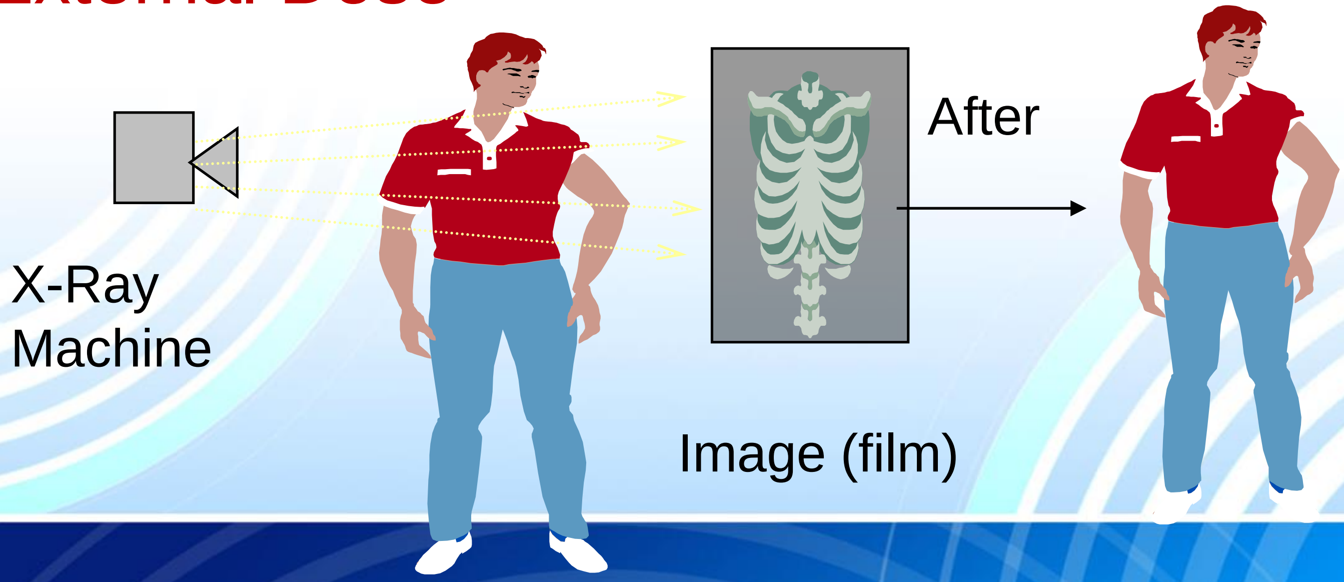


Radiation Dose

Dose or radiation dose is a generic term for a measure of radiation exposure. In radiation protection, dose is expressed in millirem.

Radiation dose (single chest x ray = 5-10 mrem).

External Dose



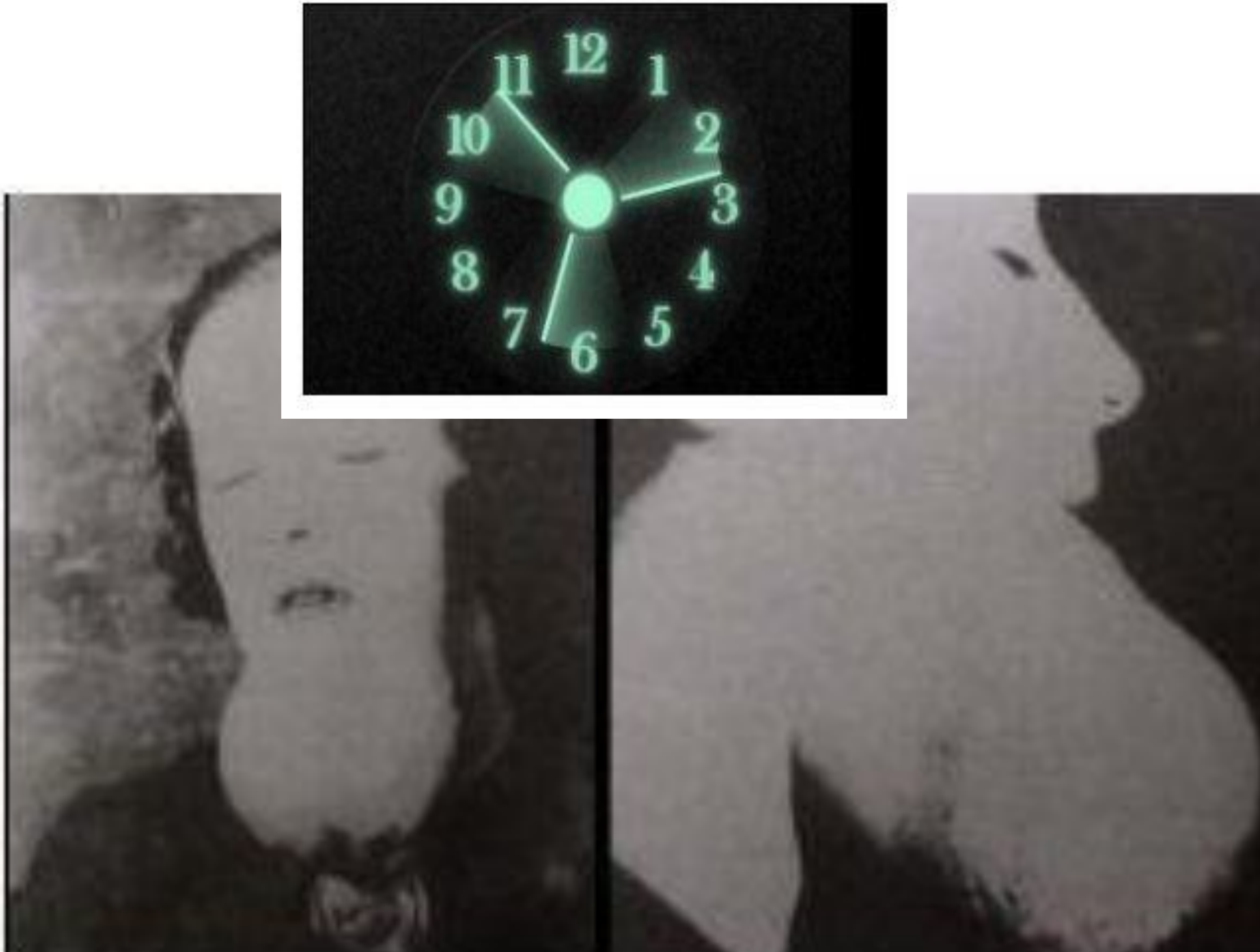
Contamination

Contamination is the presence of a radioactive material in any place where it is not desired, and especially in any place where its presence could be harmful.

The radium dial painters

- Watch-dial painters - United States Radium factory in Orange, New Jersey, around 1917 .
- The **Radium Girls** (4000) were female factory workers who contracted radiation poisoning from painting watch dials withself-luminous paint.
- They were used to tip (i.e., bring to the lips) their radium-laden brushes to achieve a fine point.
- Unfortunately this practice led to ingested radium, and many of the women died of sicknesses related to radiation poisoning.
- The paint dust also collected on the workers, causing them to "glow in the dark."
- Some also painted their fingernails and teeth with the glowing substance.

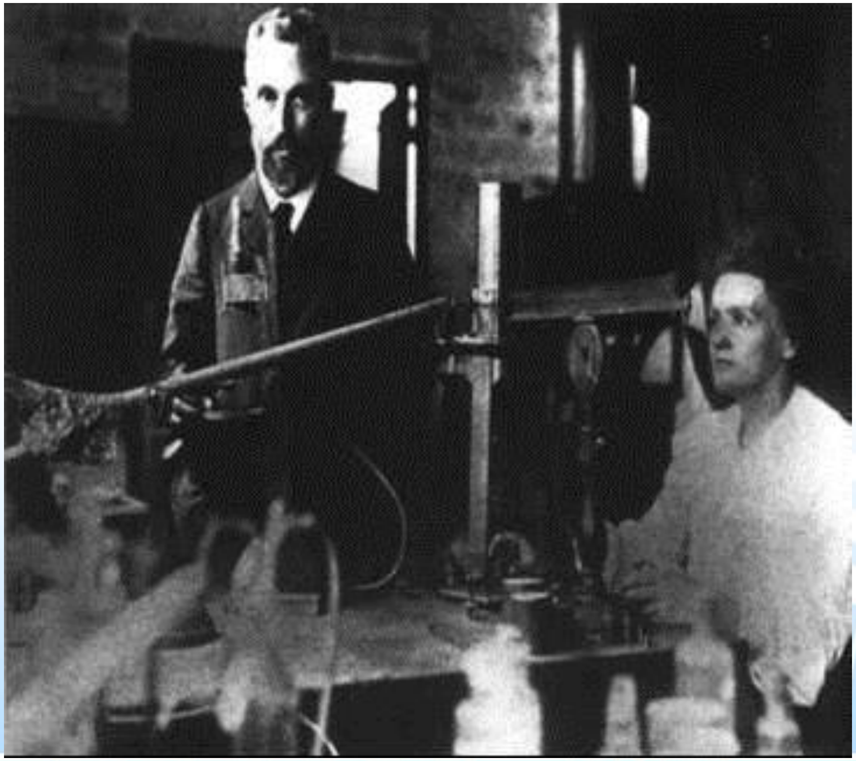

7
4
5



Who's the Famous "Madame" of Radiological Fame?

<u>Marie Curie</u>

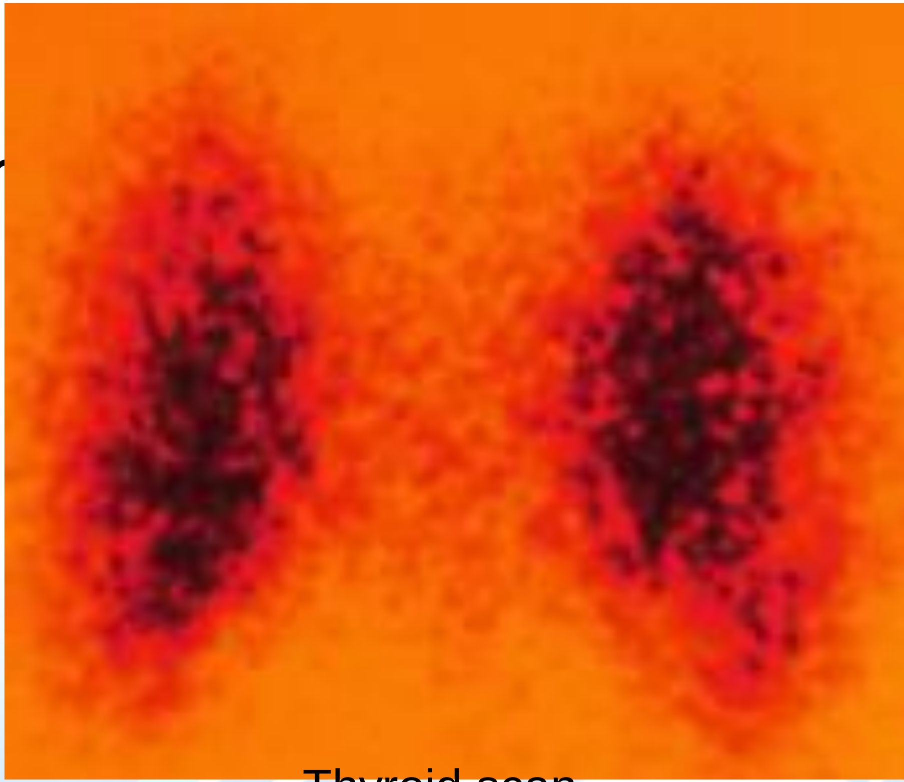
- With her husband Pierre, discovered radium and coined the term "radioactive"
- First woman to win two Nobel Prizes



Medical Applications

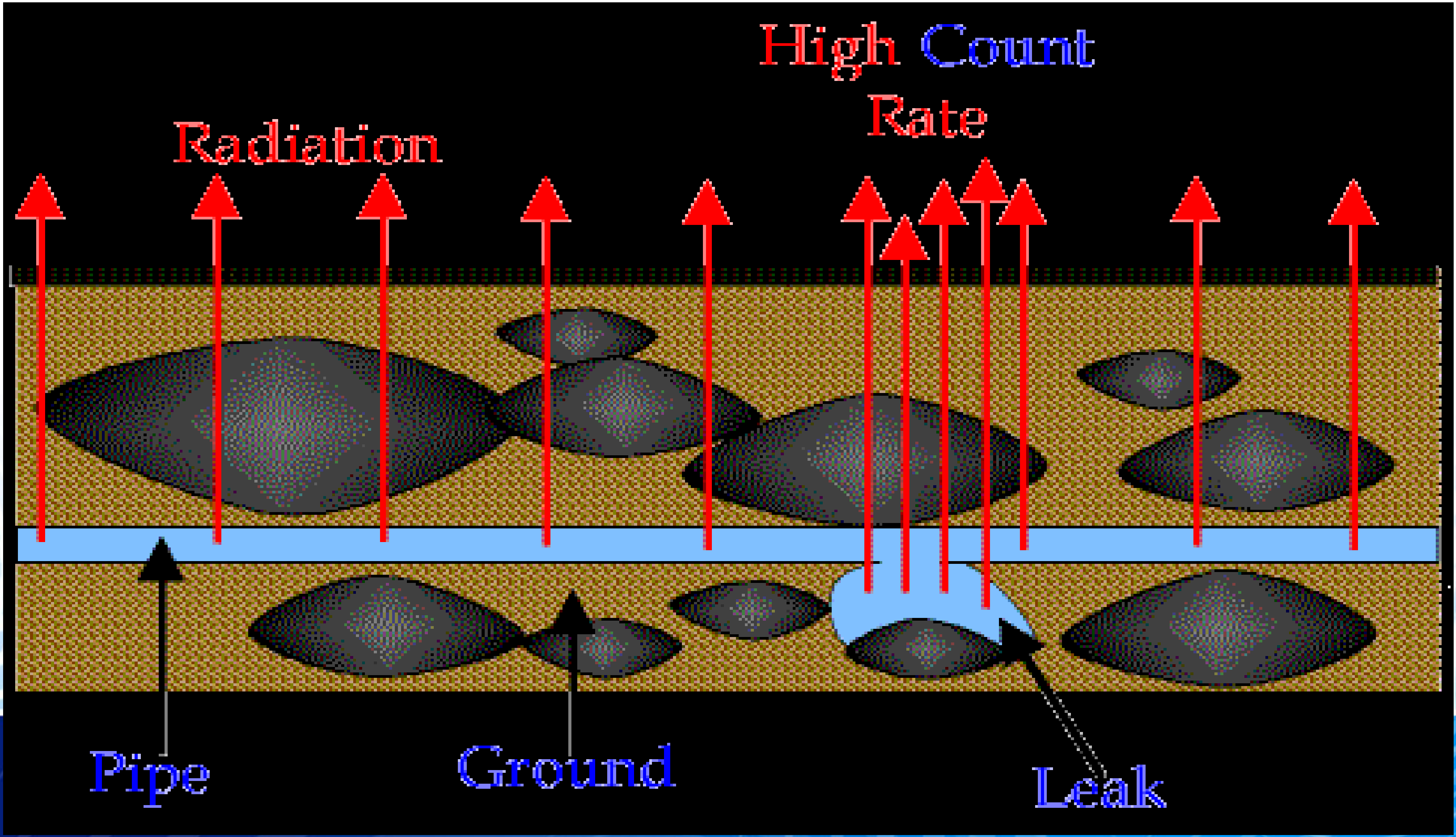
Radioisotopes with short half-lives are used in nuclear medicine because they have the same chemistry in the body as the nonradioactive atoms.

- In the organs of the body, they give off radiation that exposes a scan giving an image of an organ.



Thyroid scan

To find the location of a leak in a shallowly buried pipe without excavation

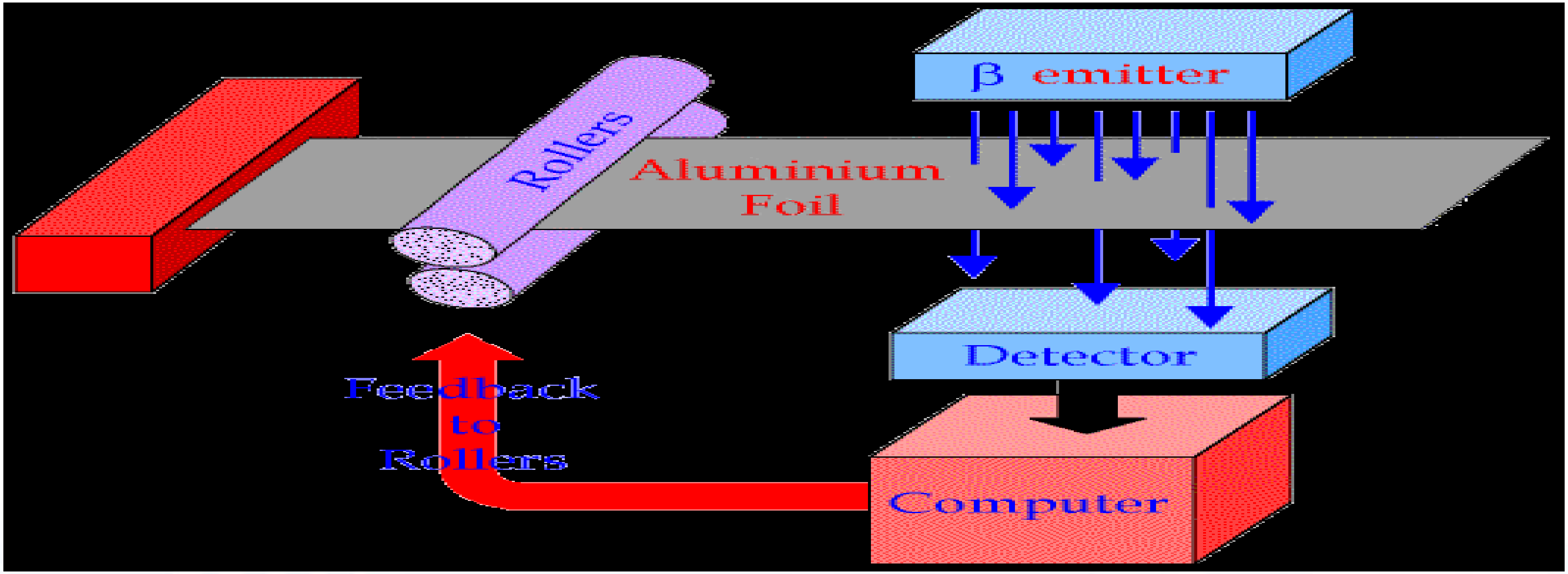


Leak Detection

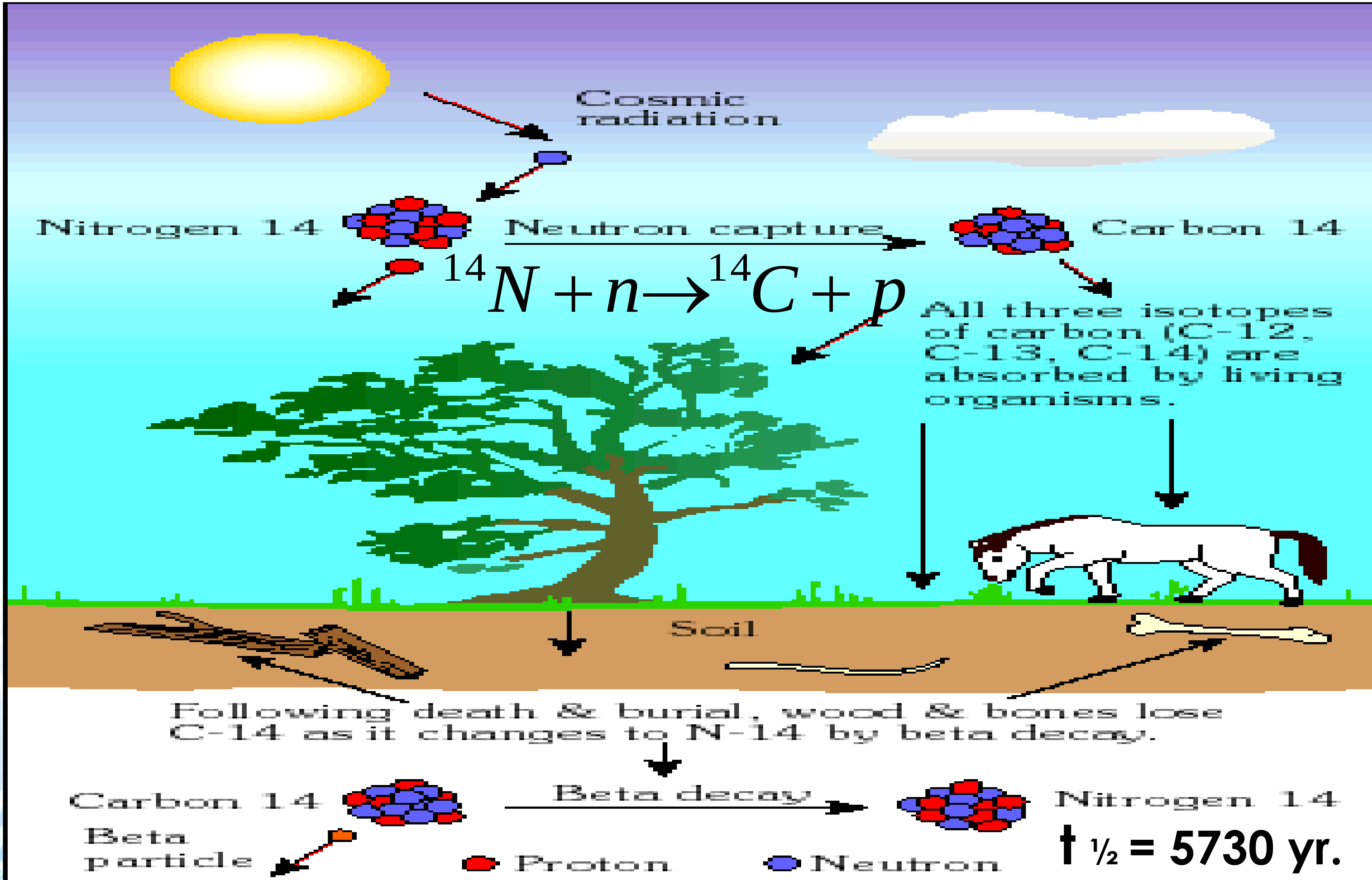
This use of radionuclide tracers to find leaks or flow paths has wide applications:

- Finding the location of leaks in oil-well casings,
- Determining the tightness of abandoned slate quarries for the temporary storage of oil,
- Locating the positions of leaks in refrigeration coils,
- Finding leaks in heat exchanger piping,
- Locating leaks in engine seals.

Thickness control



- The manufacture of aluminium foil, β emitter is placed above the foil and a detector below it.
- Some β particle will penetrate the foil and the amount of radiation is monitored by the computer.
- The computer will send a signal to the roller to make the gap smaller or bigger based on the count rate



Living Tissue $^{14}C/^{12}C$, Tissue ratio same as atmospheric ratio

Dead Tissue $^{14}C/^{12}C < {}^{14}C/^{12}C$, tissue ratio is less than atmosphere

Mummified remains found frozen in the Italian Alps

In 1991, hikers discovered the body of a prehistoric hunter that had been entombed in glacial ice until the ice recently moved and melted.

At least 5000 years old By carbon-14 dating

Space Exploration

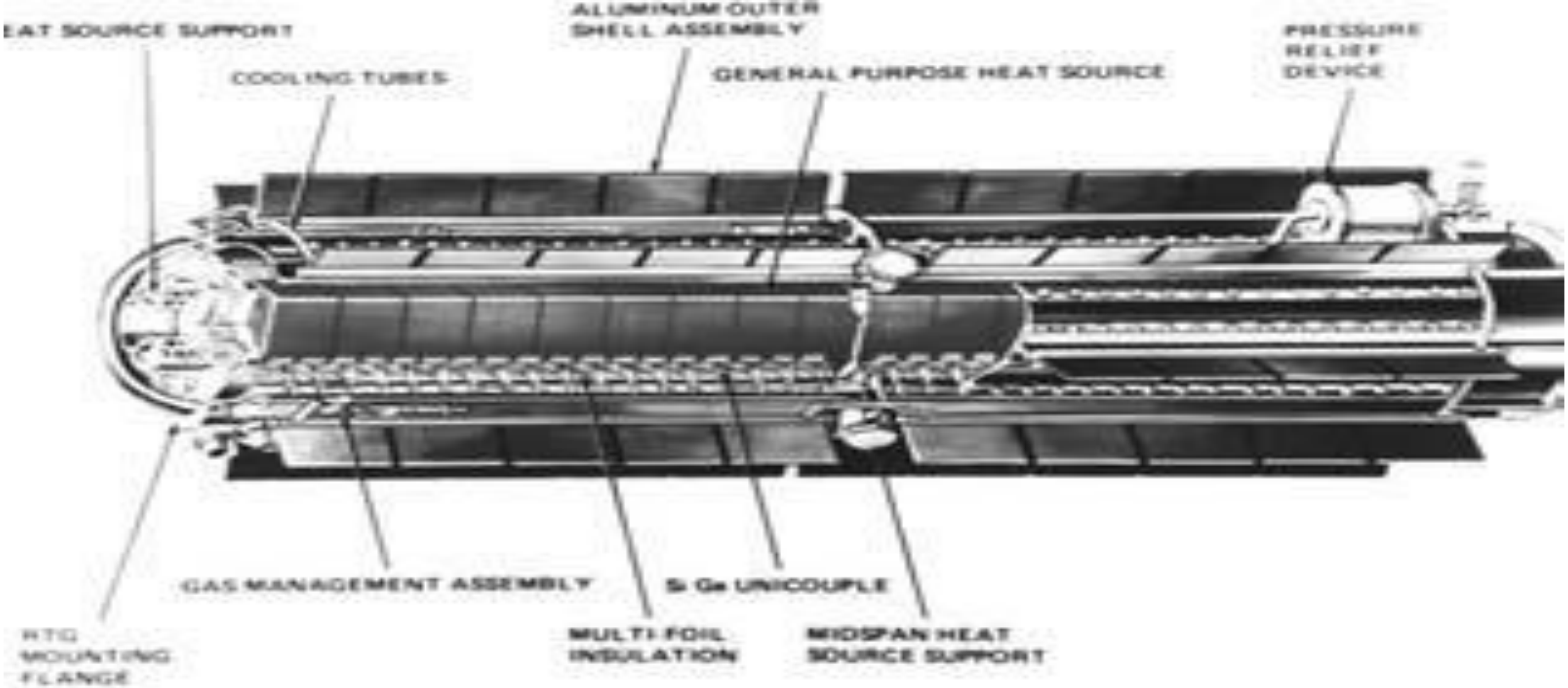
- Radioisotope Thermoelectric Generator (RTG)

- If two dissimilar metals were joined at two locations that were maintained at different temperatures, an electric current would flow in a loop.
- In an RTG, the decay of a radioisotope fuel provides heat to the “hot” junction, while the other junction uses radiation heat transfer to outer space to maintain itself as the “cold” junction.

Space Exploration

The fuel in:

- Satellites
- Jupiter Probe
- Others



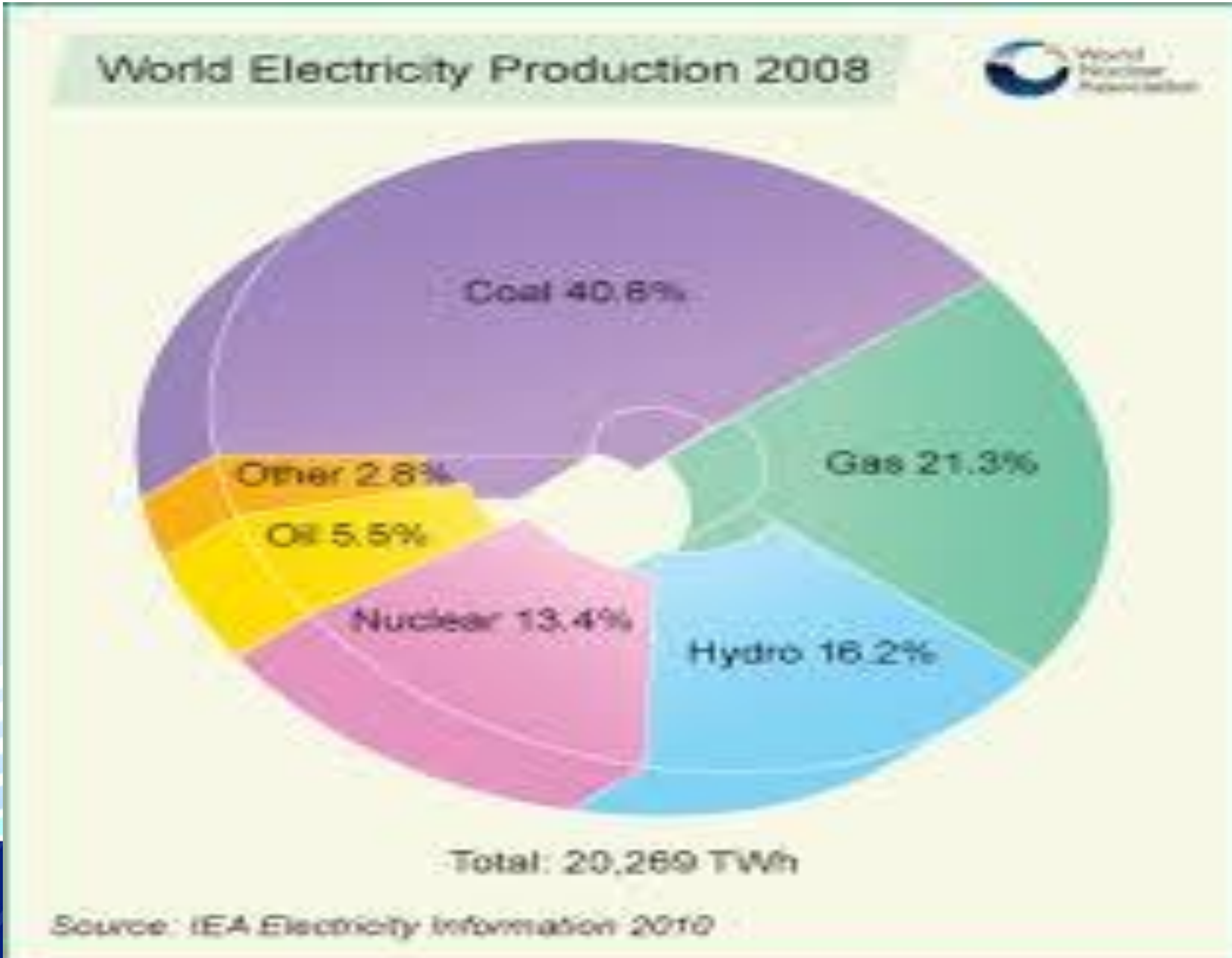
An RTG loaded with 1 kilogram of plutonium (238) dioxide fuel would generate between 21 and 29 watts of electric power for the spacecraft.

After five years of travel through space, this plutonium-fueled RTG would still have approximately 96 percent of its original thermal power level available for the generation to electric power

Power Generation

Nuclear power supplies 19.4 percent of energy in the United States.

There are 104 nuclear power plants in the United States.


World Electricity Production 2008
Coal 40.8%
Gas 21.3%
Other 2.8%
Oil 5.5%
Nuclear 13.4%
Hydro 16.2%
Total: 20,269 TWh
Source: IEA Electricity Information 2010

Rank	Country	Capacity (MW) (2014)[16]	Nuclear share of electricity production, 2013[16]
1	United States	99,081	19.4%
2	France	63,130	73.3%
3	Japan	42,388	1.7%
4	Russia	23,643	17.5%
5	South Korea	20,721	27.6%
6	China	17,978	2.1%
7	Canada	13,538	16.0%
8	Ukraine	13,107	43.6%
9	Germany	12,068	15.4%
10	Sweden	9,474	42.7%
11	United Kingdom	9,243	18.3%
12	Spain	7,121	19.7%
13	Belgium	5,927	52.1%
14	India	5,308	3.5%
15	Taiwan	5,032	19.1%
16	Czech Republic	3,884	35.9%
17	Switzerland	3,308	36.4%
18	Finland	2,752	33.3%

Nuclear Medicine

Diagnostic Procedures

- Short half-life radioactive injection
- Pictures taken with special gamma camera
- Many different studies:
    - Thyroid
    - Lung
    - Cardiac
    - White Blood Cell

Bone Scans

Radiation Therapy

Used for treating cancer.

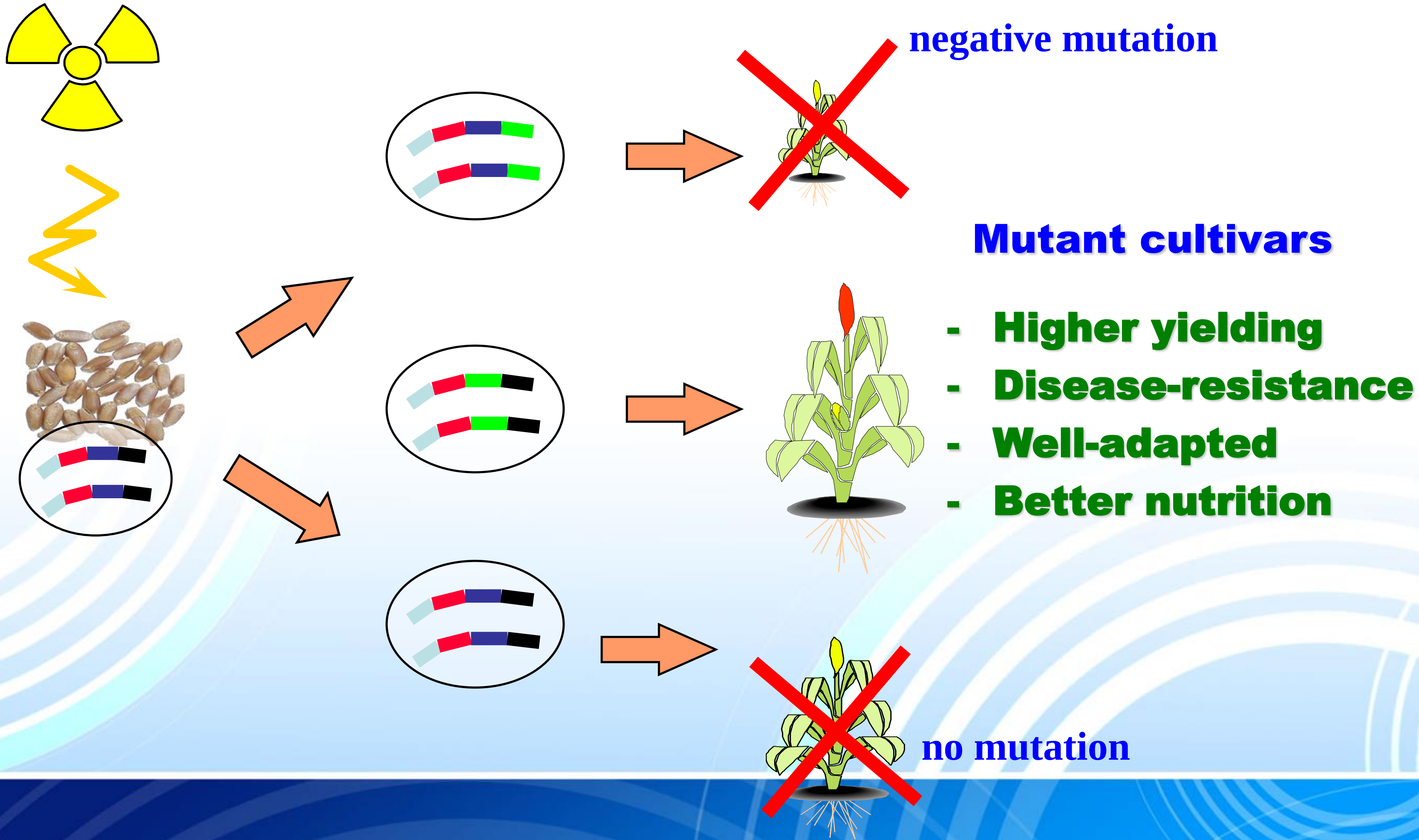
External Beam

Brachytherapy (implants)

Some Radioisotopes Used in Nuclear Medicine

Isotope	Half-Life	Medical Application
Ce-141	32.5 days	Gastrointestinal tract diagnosis; measuring blood flow to the heart
Ga-67	78 hr	Abdominal imaging; tumor detection
Ga-68	68 min	Detect pancreatic cancer
P-32	4.3 days	Treatment of leukemia, excess red blood cells, pancreatic cancer
I-125	60 days	Treatment of brain cancer; osteoporosis detection
I-131	8 days	Imaging thyroid; treatment of Graves' disease, goiter, and hyperthyroidism; treatment of thyroid and prostate cancer
Sr-85	65 days	Detection of bone lesions; brain scans
Tc-99m	6 hr	Imaging of skeleton and heart muscle, brain, liver, heart, lungs, bone, spleen, kidney, and thyroid; *most widely used radioisotope in nuclear medicine*

Crop improvement by mutation techniques



Mutation techniques

- Improving crop cultivation

- Enhancing biodiversity

- Increasing farmer's income





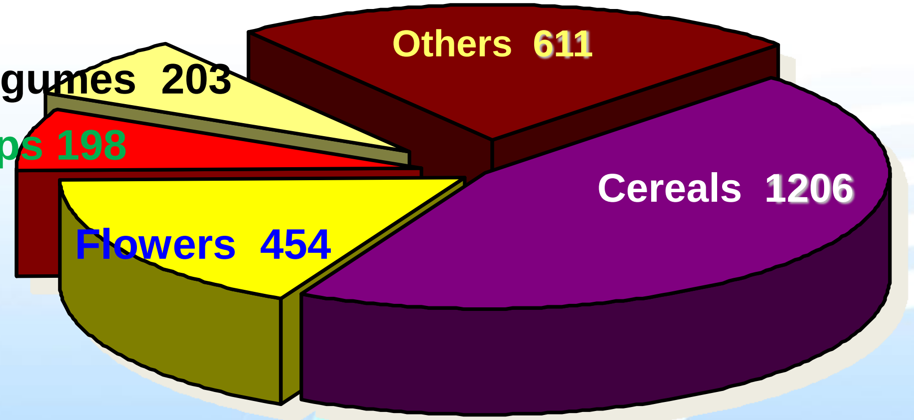


Crop improvement by mutation techniques

MUTANT VARIETIES (2006)

Total Number : 2672

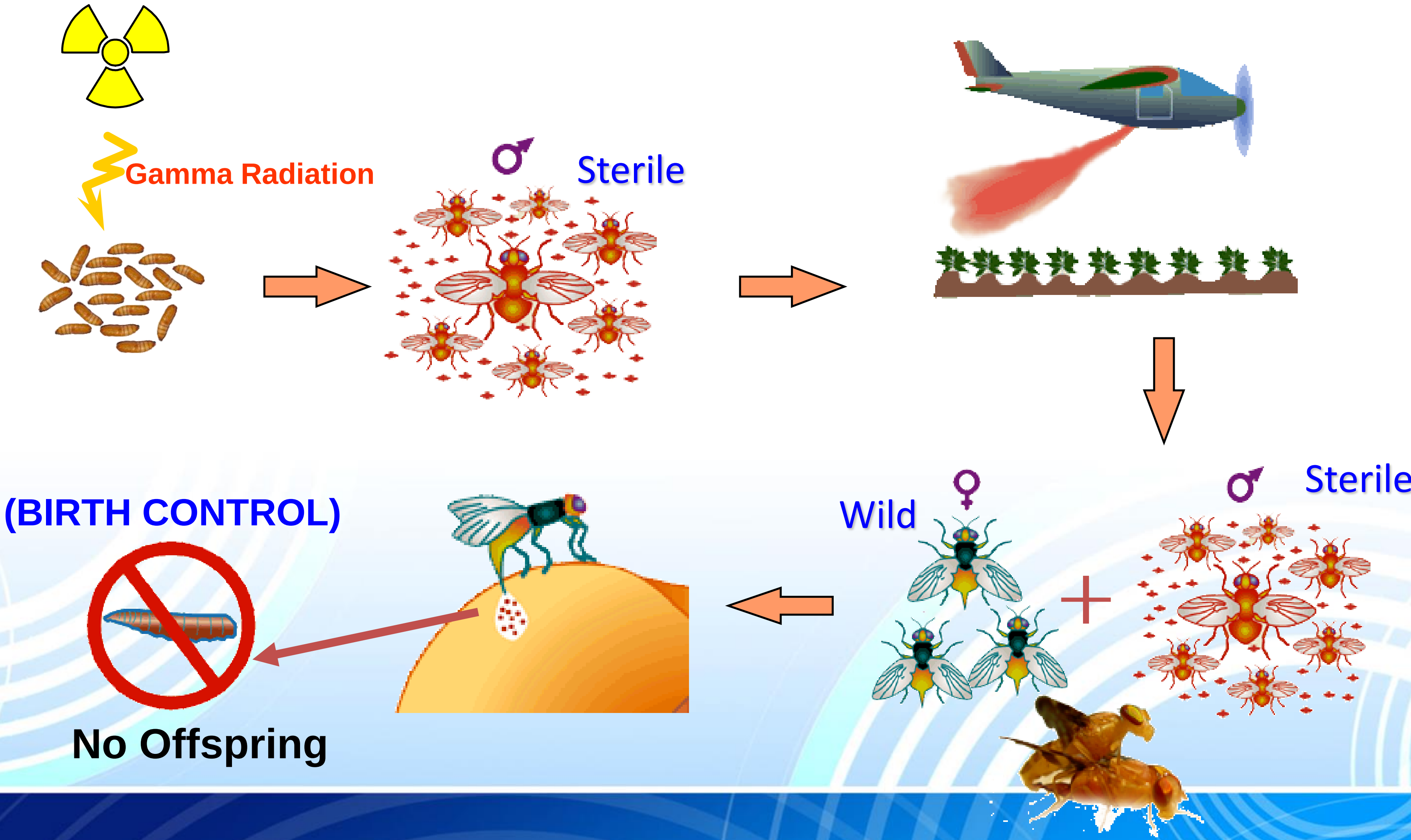
Plant Species : 170



Joint FAO/IAEA Programme
Nuclear Techniques in Food and Agriculture

Sources: FAO/IAEA Mutant Varieties Database

Insect Pest Control



Preservation of food and agricultural product by radiation

- ✓ An alternate method of food preservation by irradiation of X ray or gamma rays.
- ✓ It is used to prolong the shelf life of many food and agricultural products, destroy bacteria and microorganisms in food (pre packed or bulk) and grains(rice, corn..).
- ✓ The food exposed to controlled amount of ionizing radiation in shielded area for a specific time to achieve desirable objectives.
- ✓ The sources are gamma rays from Cobalt 60 or Cesium 137, X-rays up to 5 MeV or electron accelerators up to 10 MeV.

Does the irradiation process make food radioactive?

- ✓ Irradiation under controlled condition does not make food radioactive.
- ✓ Irradiation involves passing the food through and allow to absorb desired radiation energy.
- ✓ Radiation processing of food do not induce any radioactivity.

Food preservation

Onion and potato are irradiation by 0.05 to 0.15 kGy

Effect of gamma irradiation treatment in delay ripening

Pear delay in ripening and decaying of under ambient condition.

(a) After 7 days

(b) After 14 days

Peach after 7 days of ambient storage

Effect of gamma irradiation and edible coating treatment on storage quality of varieties (after 100 days of ambient storage.

Effect of gamma irradiation treatment on fungal growth of cherry after 9 and 35 days of storage under ambient and refrigerated conditions.

CONTROL (Ambient)

1.2 kGy (Ambient)

CONTROL (Refrigerated)

1.2 kGy (Refrigerated)

Effect of radiation processing on retention of dried apricot after 18 months of ambient storage.

Radioactive Consumer Products

Dentures

- Uranium is added to false teeth to provide a shine to the material (about 10% of the teeth)
- Concentration of uranium is quite low – about 300 parts per million

Radiation Detection Instruments

Photo by Carl Tarantino

Geiger Counter

Photo by Karen Sheehan

Liquid Scintillation Counter

Annual Radiation Dose Limits General Public vs. Occupational

Established by the
Nuclear Regulatory Commission

- General Public Limit - 100 mrem
- Occupational Limit - 5,000 mrem

Remember – We get approximately 300 mrem per year from natural background exposure.

For more information about radiation you may contact the Health Physics Society.

http://www.HPS.org

Health Physics Society
Specialists in Radiation Safety

Additional References

- Hall E. Radiation and life, 2nd ed. New York: Pergamon Press; 1984.
- Bushong SC. Radiologic science for technologists, 7th ed. St Louis, MO: Mosby, Inc.; 2001.


Thanks