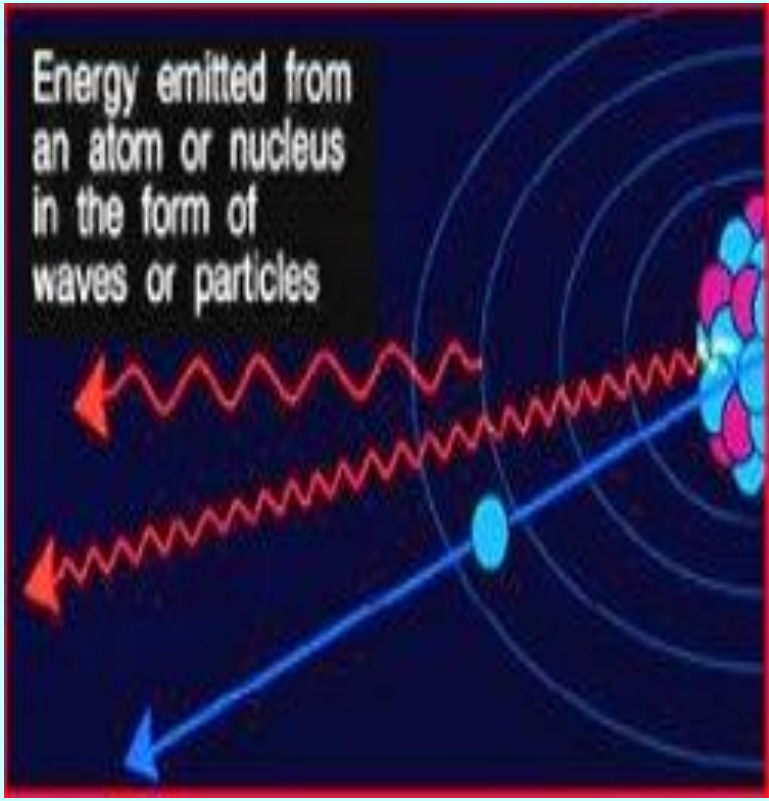
The Volgograd State Medical University
The Chair of hygiene and ecology

Lecture

ACTUAL ISSUES OF RADIATION HYGIENE. HYGINIC REQUIREMENTS FOR THE ORGANIZATION OF RADIATION PROTECTION IN RADIOLOGICAL DEPARTMENTS OF MEDICAL ORGANIZATIONS

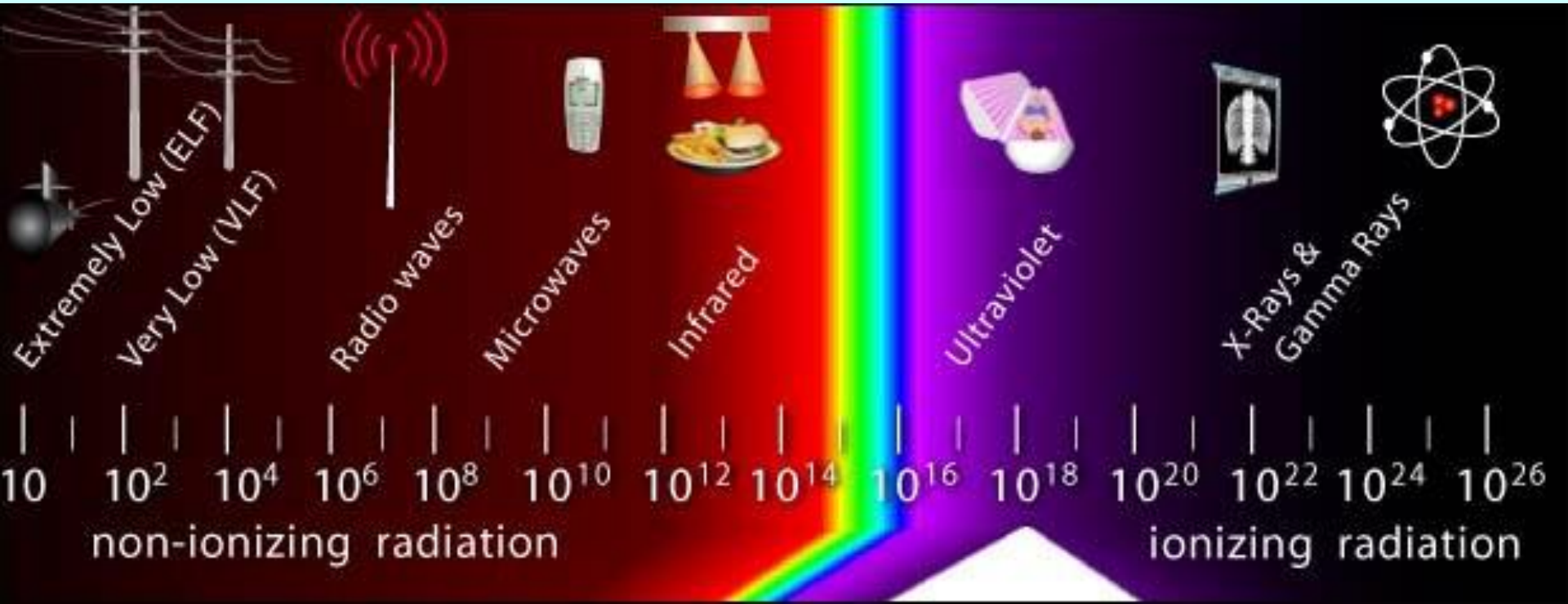
Radiation

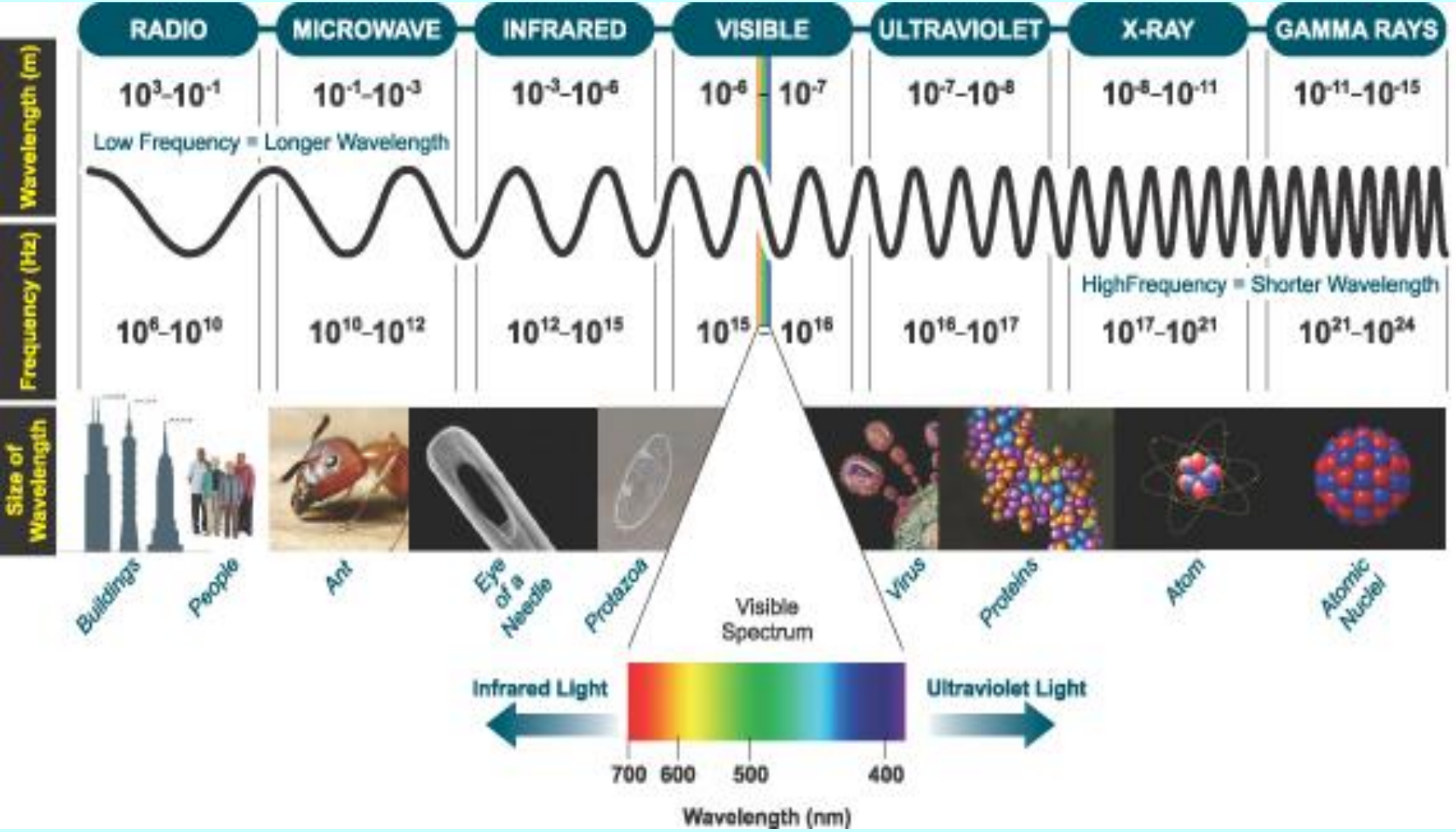
- is the emission (sending out) of energy from any source. X-rays are an example of radiation, but so is the light that comes from the sun and the heat that constantly comes off our bodies.



Types of radiation

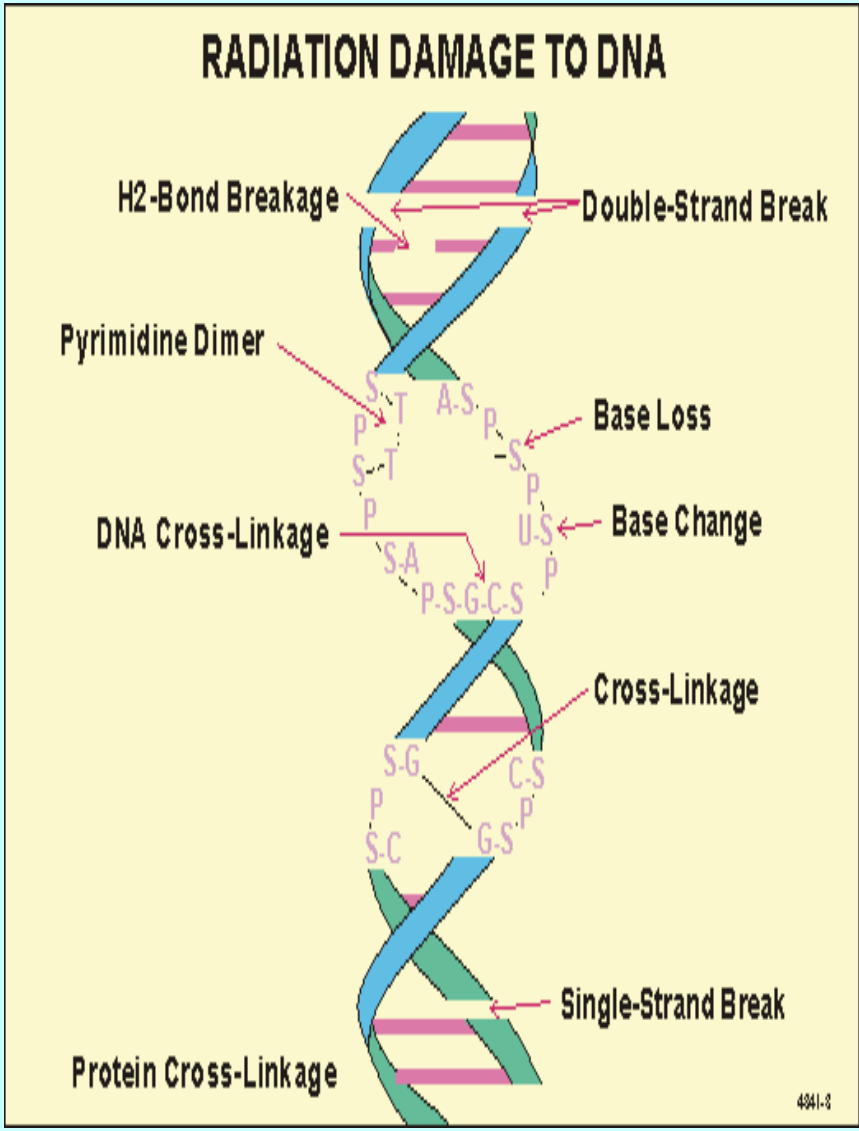
- Radiation exists across a spectrum from very high-energy (high-frequency) radiation to very low-energy (low-frequency) radiation. This is sometimes referred to as the *electromagnetic spectrum*. From highest to lowest energy, the main forms of radiation are:




RADIO
MICROWAVE
INFRARED
VISIBLE
ULTRAVIOLET
X-RAY
GAMMA RAYS
Wavelength (m)
Frequency (Hz)
Size of Wavelength
10^{3}–10^{-1}
10^{-1}–10^{-3}
10^{-3}–10^{-6}
10^{-6} – 10^{-7}
10^{-7}–10^{-8}
10^{-8}–10^{-11}
10^{-11}–10^{-15}
Low Frequency = Longer Wavelength
HighFrequency = Shorter Wavelength
10^{6}–10^{10}
10^{10}–10^{12}
10^{12}–10^{15}
10^{15} – 10^{16}
10^{16}–10^{17}
10^{17}–10^{21}
10^{21}–10^{24}
Buildings
People
Ant
Eye of a Needle
Protozoa
Virus
Proteins
Atom
Atomic Nuclei
Visible Spectrum
Infrared Light
Ultraviolet Light
700 600 500 400
Wavelength (nm)

Ionizing radiation

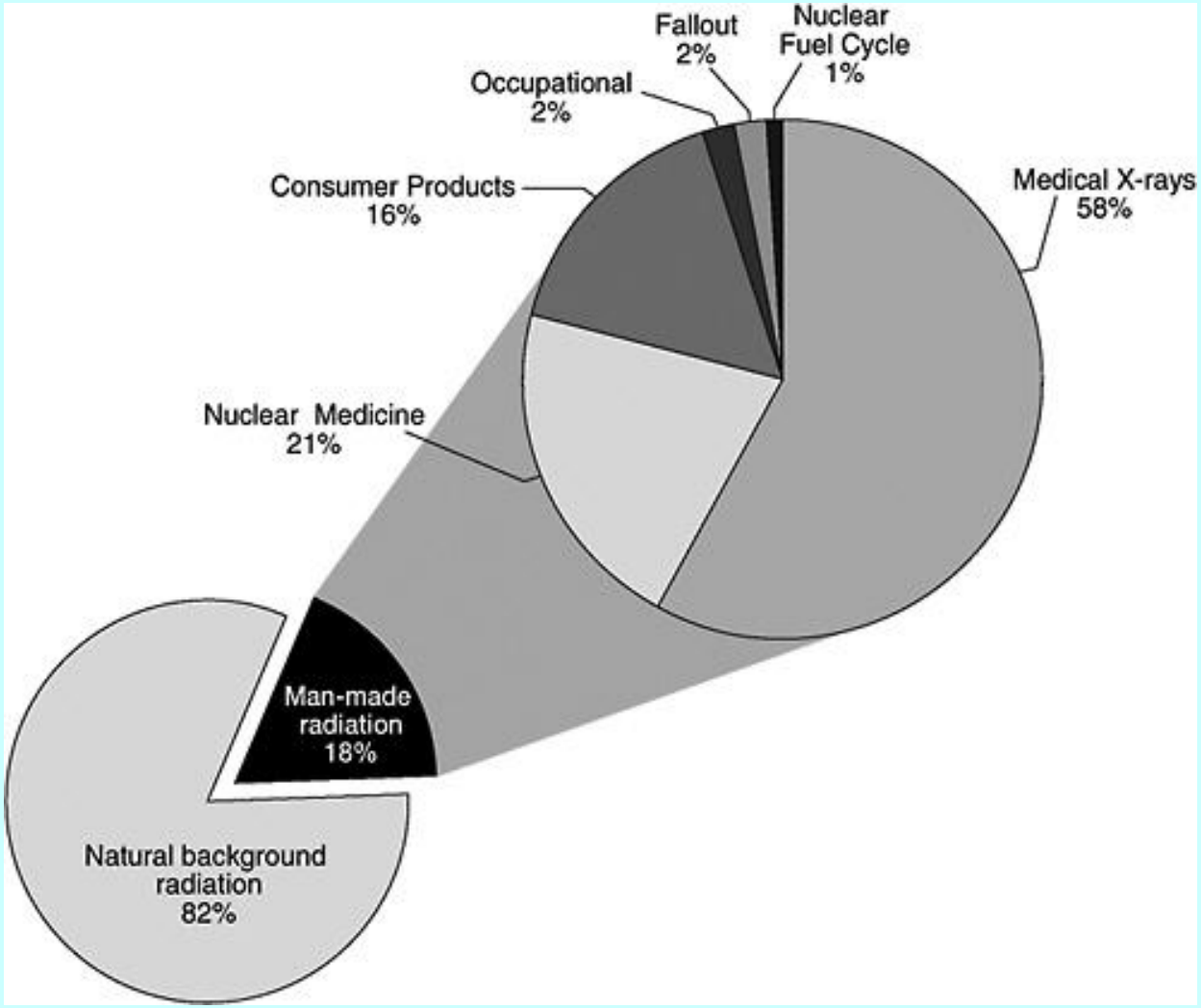
- is high-frequency radiation that has enough energy to remove an electron from (ionize) an atom or molecule. Ionizing radiation has enough energy to damage the DNA in cells, which in turn may lead to cancer. Gamma rays, X-rays, some high-energy UV rays, and some sub-atomic particles such as alpha particles and protons are forms of ionizing radiation.



Non-ionizing radiation

- is low-frequency radiation that does not have enough energy to remove electrons or directly damage DNA. Low-energy UV rays, visible light, infrared rays, microwaves, and radio waves are all forms of non-ionizing radiation. Aside from UV rays, these types of radiation are not known to increase cancer risk.

Ionizing Radiation Sources



- Average global dose: 2.4 mSv

Each person feels certain radiation load, which is composed of the following components:

1. **Natural background radiation, which consists of**
   a) **space radiation;**

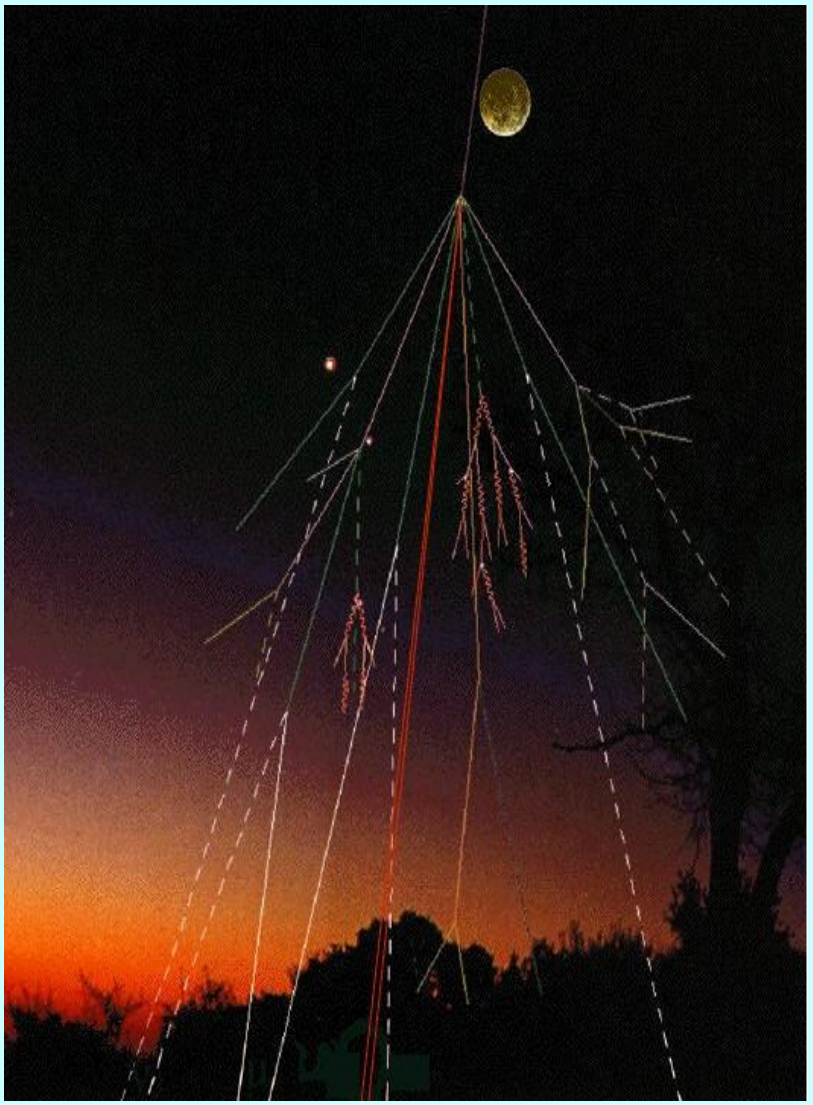
   b) **radiation of the Earth;**

   c) **internal radiation** (which is released mostly at the expense of radioactive potassium, which provides the work of heart muscle).

Natural background radiation

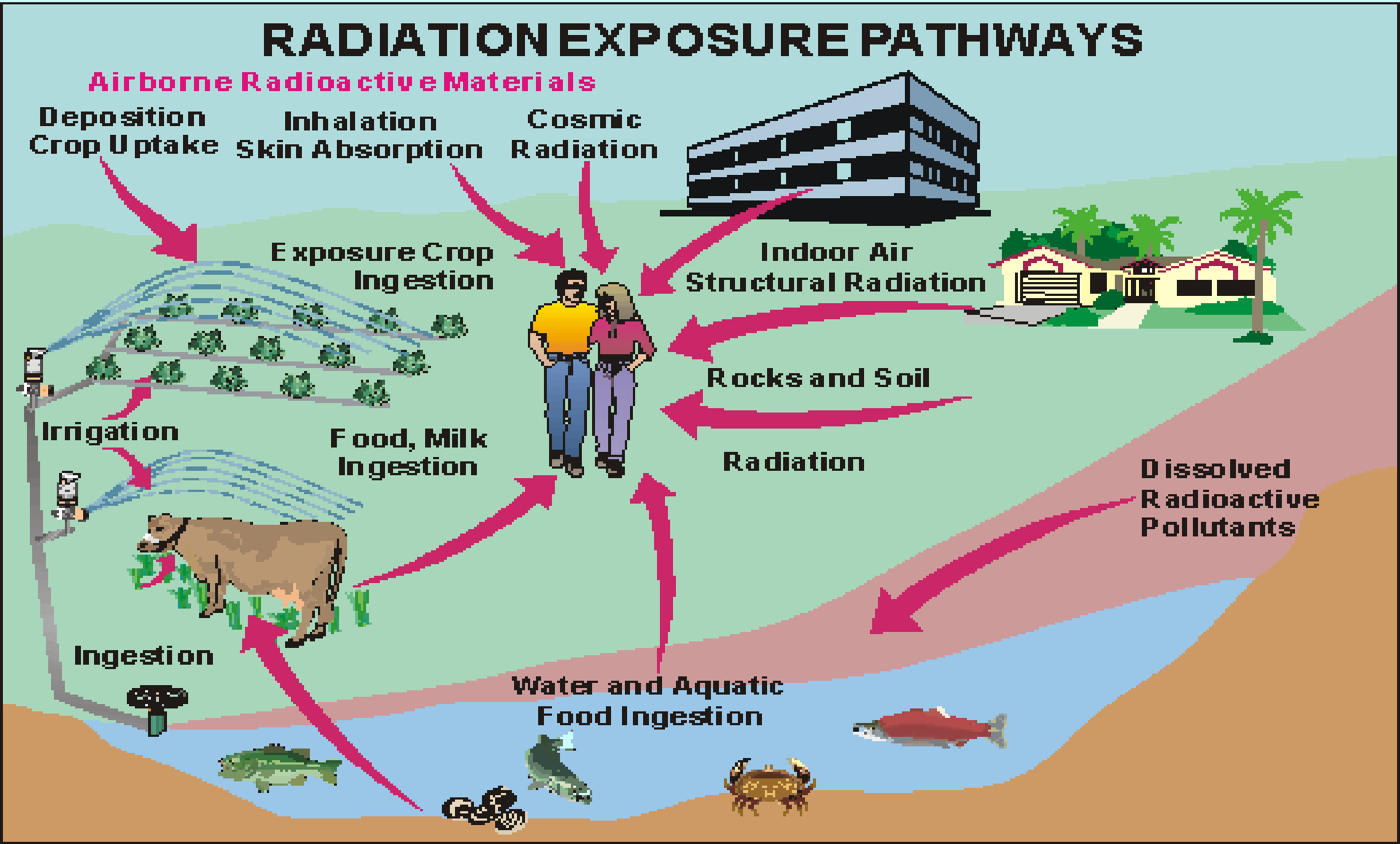
- **Cosmic rays**

are radioactive particles that hit the earth from outer space. They come from the sun and from other stars. The earth's atmosphere blocks a portion of these rays, but some of them reach the ground.



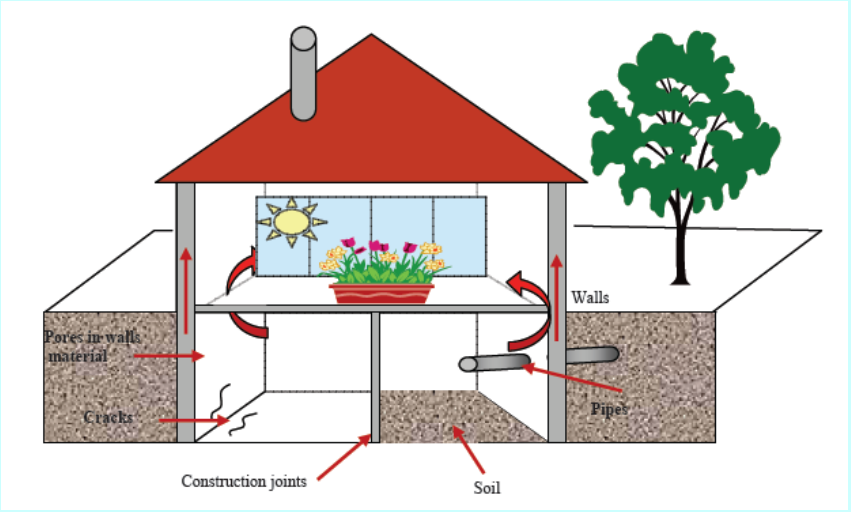
- Because the atmosphere blocks some cosmic rays, exposure is greater at higher altitudes. People are also exposed to higher levels of cosmic rays during airplane flights. Airline pilots and flight attendants, who spend many hours at high elevations, are exposed to more of these rays, but it is not clear if they have an increased risk of cancer because of it.

Radiation in the earth:

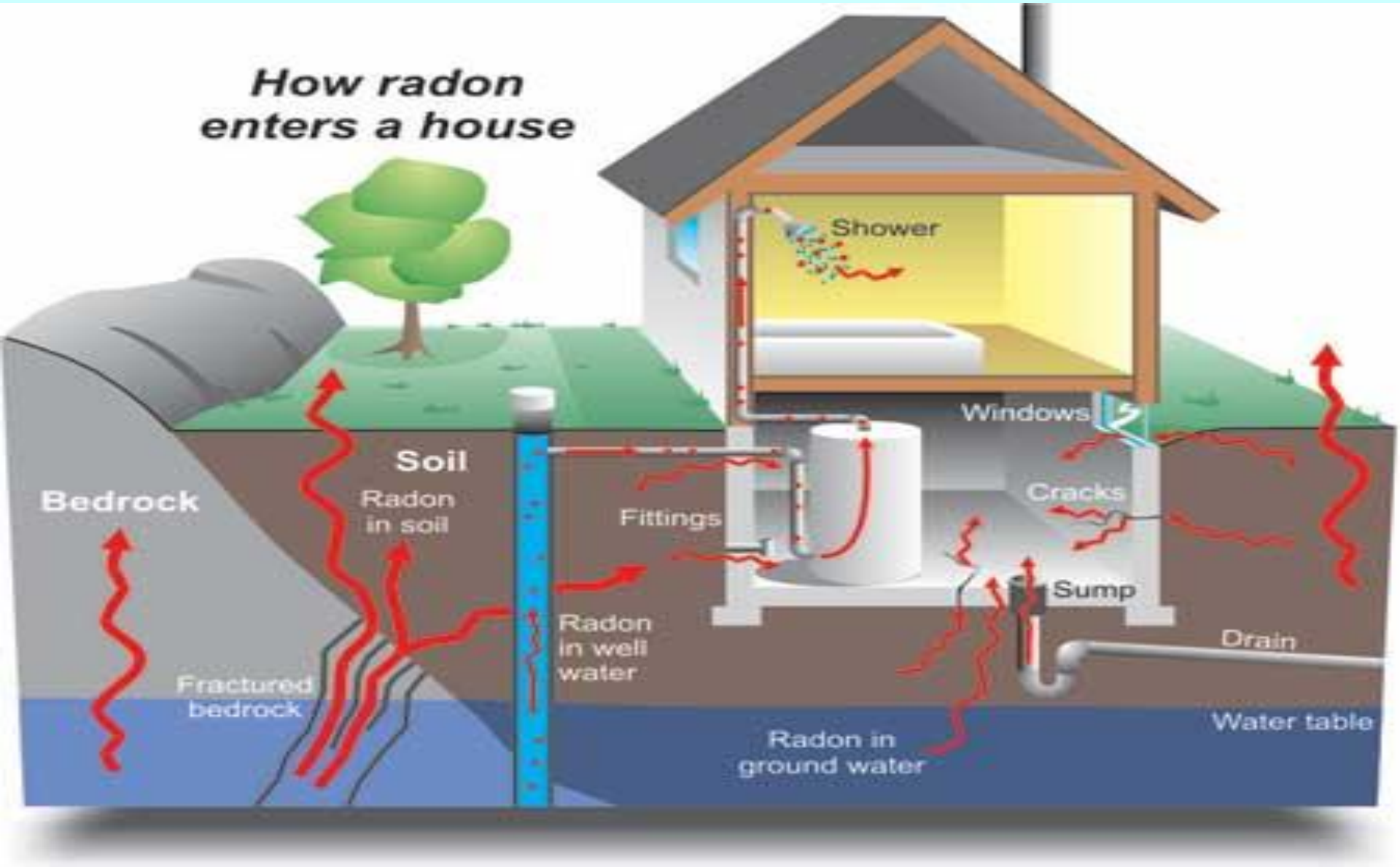


Radon

- Produced from radium in decay chain of uranium
- Escapes into air – short lived decay products emit alpha particles – stick to dust, inhaled, deposit in lung – high but localised radiation
- Second most important cause lung cancer



Radon:


How radon enters a house
Shower
Windows
Soil
Bedrock
Radon in soil
Fittings
Cracks
Sump
Radon in well water
Drain
Fractured bedrock
Water table
Radon in ground water

Radon

risk per 1000 of lung cancer by age 75 y

	Non-smoker	Smoker
0 Bq/m^3	4	100
100 Bq/m^3	5	120
400 Bq/m^3	7	160

Consumer products:

- Some consumer products contain small amounts of ionizing radiation. Tobacco products contain low levels of radiation, which may come from the soil it's grown in or the fertilizer used to help it grow. Tobacco may account for a significant portion of the yearly radiation that smokers are exposed to.

Typical Radiation Doses

Source	Dose
Natural Radiation	
5-hr jet airplane ride	3 mrem
Cosmic radiation	30 mrem
Internal (own body)	40 mrem/year
Consumer Products	
Building materials	4 mrem/year
Tobacco products	**5,300 mrem/year**
(Amount a smoker's lungs receive from 20 cigarettes per day)	
Medical	
Chest X-ray	8 mrem
CT scan	1000 mrem
Dental x-ray	1 mrem
Occupational	
Nuclear Power	450 mrem/year
Scientist	25 mrem/year
X-ray Technicians	120 mrem/year

Food and Drink

- Potassium-40 in particular is a major source of internal irradiation, but there are others.
- Some foods, for example shellfish and Brazil nuts, concentrate radioactive materials so that, even when there is no artificial radioactivity, people who consume large quantities can receive a radiation dose significantly above average.

Sources of Artificial Radiation

The second component of the radiation load is **medical radiation**.

Ionizing radiation is used in the diagnosis and treatment of some medical conditions. This can be in the form of radiation that penetrates from outside the body, or radioactive particles that are swallowed or inserted into the body.

Airport security scanners:

- In recent years, some airports have begun to use whole body scanners as a way to detect objects hidden by clothing. These scanners are different from the metal detectors most people are familiar with.

Using Ionizing Radiation in Medicine

What would ionizing radiation in medicine be used for?

There are 3 main uses of **ionizing radiation** in medicine:

- Treatment
- Diagnosis
- Sterilization

Imaging tests

- Certain types of imaging tests, such as X-rays, dental X-rays, CAT scans, mammograms, etc, and nuclear medicine tests (such bone scans, liver function tests).
- expose people to low levels of radiation in order to create internal pictures of the body (MRI and ultrasound exams do not use ionizing radiation).

Radiation therapy:

- Ionizing radiation is an effective way to treat certain kinds of cancer. During radiation therapy, high doses of ionizing radiation (much higher than those used for imaging tests) are directed at the cancer, resulting in the death of the cancer cells.

The Aim of Radiation Therapy

The aim of radiation therapy is to cause damage to the cancerous cells (minimizing the risk to surrounding healthy tissue).

The damage inflicted by radiation therapy causes the cancerous cells to stop reproducing and thus the tumor shrinks.

Unfortunately, healthy cells can also be damaged by the radiation.

Radiation Therapy

Radiation therapy uses ionising radiation to treat cancer i.e. to destroy cancerous cells.

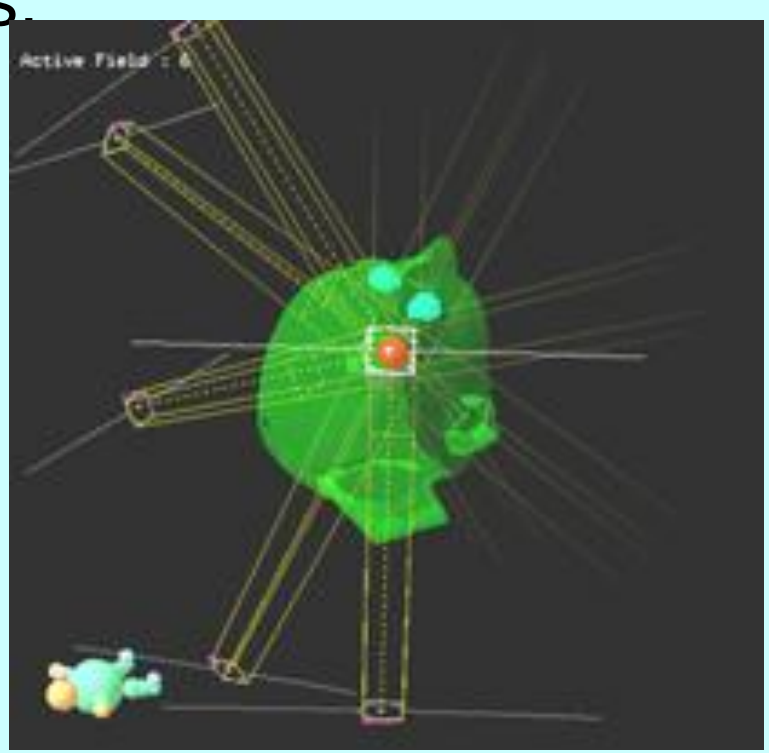
There are two techniques in radiation therapy that are used to treat cancer using ionising radiation:

- Radiotherapy
- Brachytherapy

Radiotherapy Treatment Planning

Every treatment using radiotherapy has to be rigorously planned. The planning process consists of three phases:

- Planning
- Simulation
- Treatment

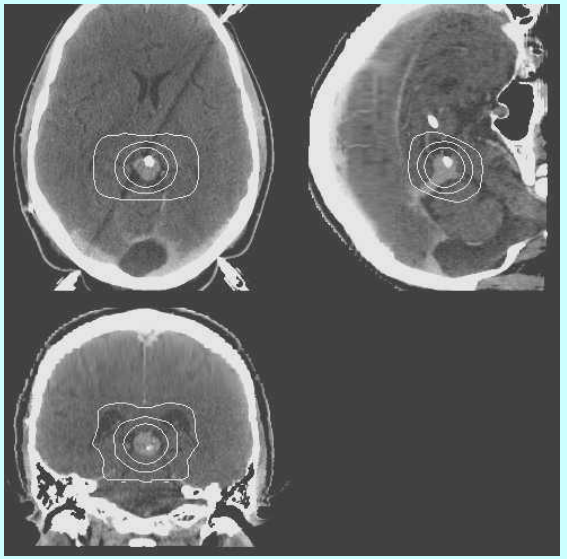


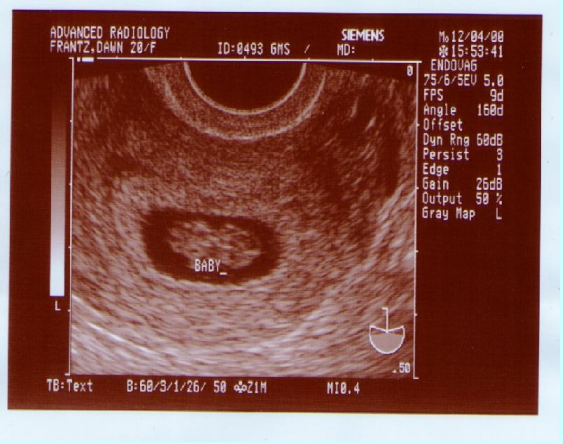
Radiotherapy Treatment Planning

Planning

The cancerous tumour has to be located so that its size and position can be analysed. This information can be obtained from:

- X-rays
- CT scans
- MRI scans
- Ultrasound images





Radiotherapy Treatment Planning

Simulation

Once the amount of radiation to be given has been accurately calculated, the patient then goes to the simulator to determine what settings are to be selected for the actual treatment using a linear accelerator.

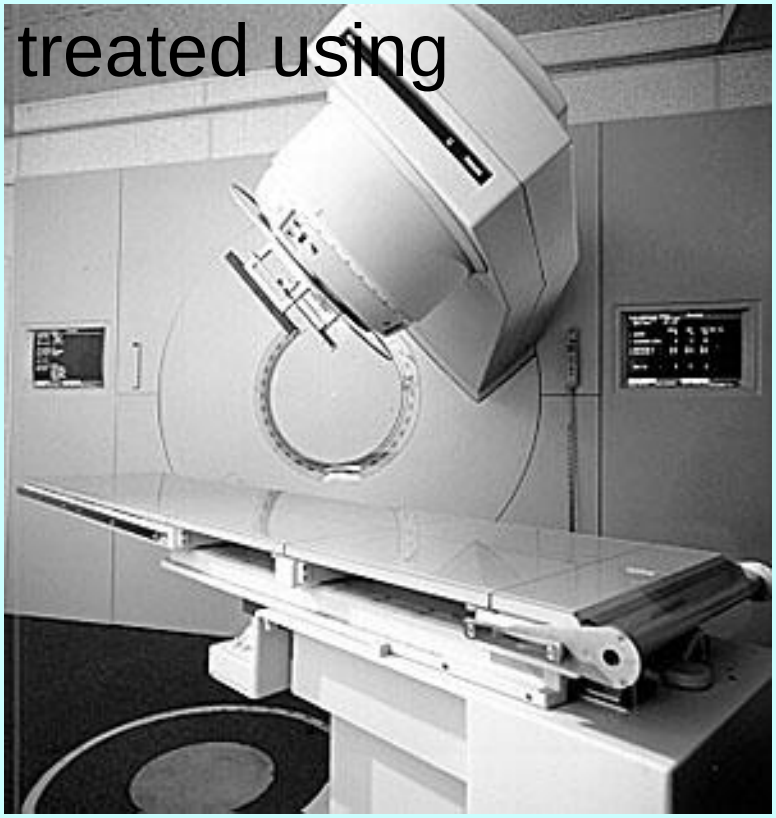
The settings are determined by taking a series of x-rays to make sure that the tumour is in the correct position ready to receive the ionising radiation.

Radiotherapy Treatment Planning

Treatment

Cancerous tumours can be treated using radiotherapy as follows:

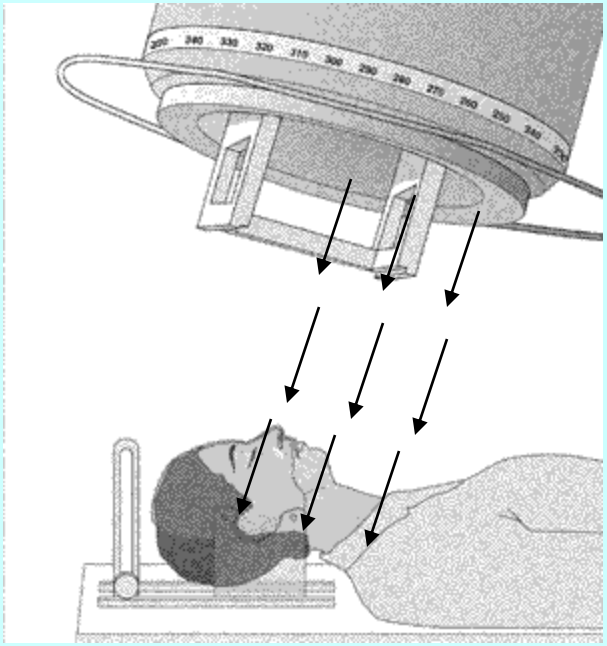
- Irradiation using high energy gamma rays.
- Irradiation using high energy x-rays.



Radiotherapy Treatment

Irradiation Using High Energy Gamma Rays

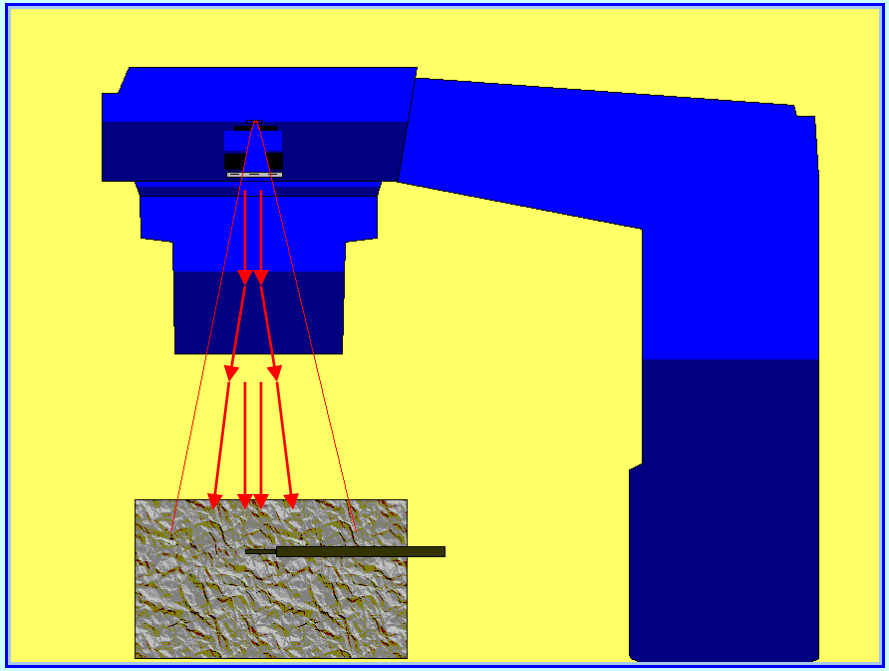
- Gamma rays are emitted from a cobalt-60 source – a radioactive form of cobalt.
- The cobalt source is kept within a thick, heavy metal container.
- This container has a slit in it to allow a narrow beam of gamma rays to emerge.



Radiotherapy Treatment

Irradiation Using High Energy X-rays

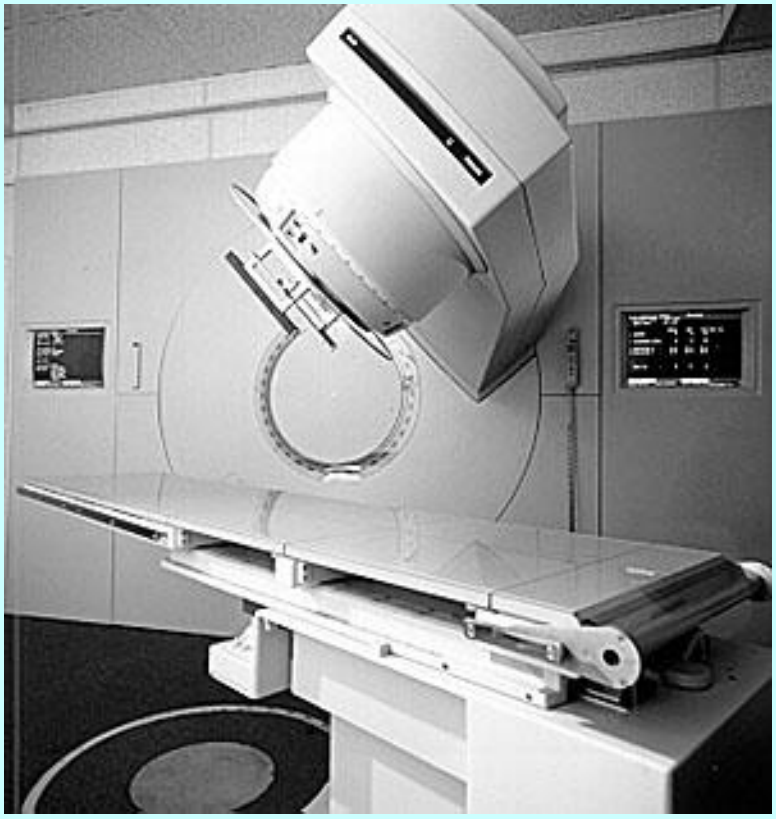
- The x-rays are generated by a linear accelerator (linac).
- The linac fires high energy electrons at a metal target and when the electrons strike the target, x-rays are produced.
- The x-rays produced are shaped into a narrow beam by movable metal shutters.



Treatment of Cancer

Radiotherapy

- The apparatus is arranged so that it can rotate around the couch on which the patient lies.
- This allows the patient to receive radiation from different directions.
- The diseased tissue receives radiation all of the time but the healthy tissue receives the minimum amount of radiation possible.
- Treatments are given as a series of small doses because cancerous cells are killed more easily when they are dividing, and not all cells divide at the same time – this reduces some of the side effects which come with radiotherapy.

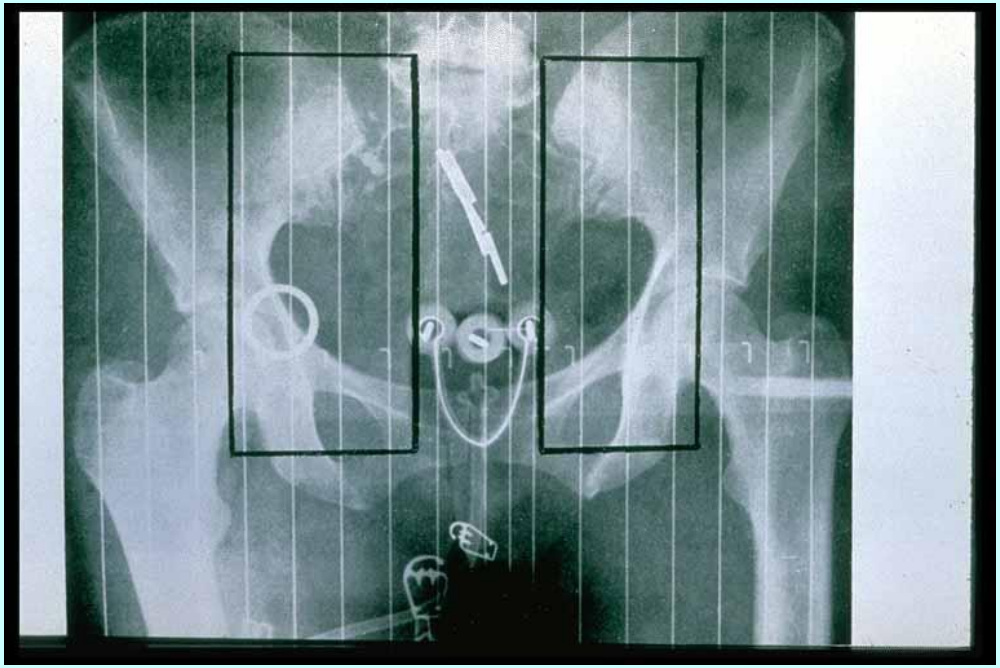


Radiation Therapy

Brachytherapy

Brachytherapy is used to treat the following cancers:

- Uterus
- Cervix
- Prostate
- Intraocular
- Skin
- Thyroid
- Bone



Tracers

There are many uses of ionising radiation based on the fact that it is easy to detect. In such applications, the radioactive material is used in the form of a tracer.

In nuclear medicine, a tracer is a radioactive substance which is taken into the body either, as an injection, or as a drink. Such a substance is normally a gamma emitter which is detected and monitored.

This gives an indication of any problems that may be present in body organs or tissues by how much, or how little, of the substance has been absorbed.

Nuclear Medicine

Tracers

It is important to be able to study internal organs, or tissues, without the need for surgery. In such cases, radioactive tracers can be injected into the body so such studies can take place. The path of these tracers can be detected using a gamma camera because of their radioactivity.

Such tracers consist of two parts:

- A drug which is chosen for the particular organ that is being studied.
- A radioactive substance which is a gamma emitter.

Tracers Used in Nuclear Medicine

Pharmaceutical	Source	Activity (MBq)	Medical Use
Pertechnetate	^{99m}Tc	550 - 1200	Brain Imaging
Pyrophosphate	^{99m}Tc	400 - 600	Acute Cardiac Infarct Imaging
Diethylene Triamine Pentaacetic Acid (DTPA)	^{99m}Tc	20 - 40	Lung Ventilation Imaging
Benzoylmercaptoacetyltriglycerine (MAG3)	^{99m}Tc	50 - 400	Renogram Imaging
Methylene Diphosphonate (MDP)	^{99m}Tc	350 - 750	Bone Scans

The third component is ionizing radiation, to which a person may be exposed at work.

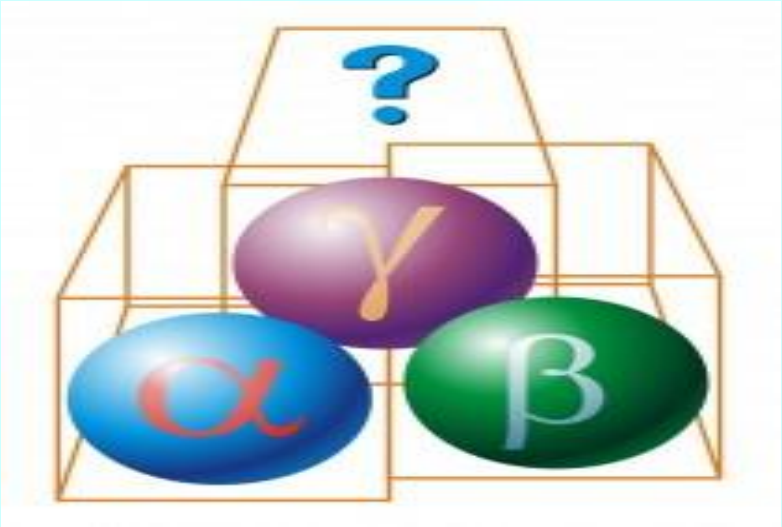
These people are medical workers, inspectors in various branches of industry (in metallurgy, geologists, geodesists, workers of atomic power stations).

- The fourth component is ionizing radiation in case of radiation or nuclear accidents.

Types of Radiation

- "Ionizing" radiation passes through matter and can cause some of its atoms to become electrically charged, or ionized. In living tissues, the ions caused by such radiation can affect normal biological processes.

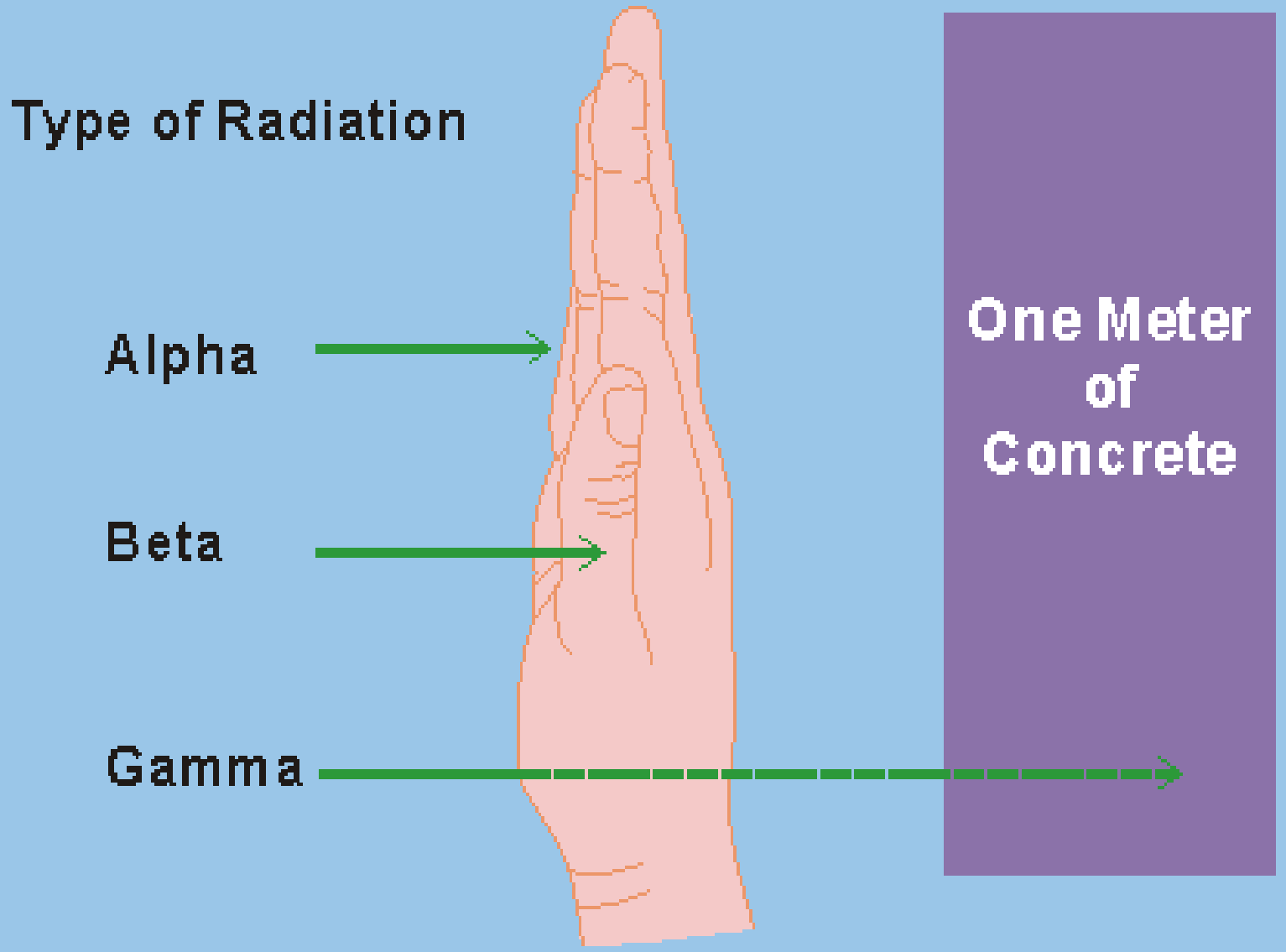
Ionizing radiation comes in several different forms:



- *Alpha particles* - are positively charged particles. They are easily stopped by paper or skin, and are only hazardous if alpha-emitting materials are swallowed or breathed into the body.

- *Beta particles* - are electrons and have a greater penetrating power than alpha particles, but can be stopped by thin layers of water, glass or metal. However, beta emitting material can be hazardous if taken into the body.
- *Gamma and X rays* - are electromagnetic radiations similar to light and radio waves but with shorter wavelengths. They are very penetrating and heavy shielding materials like lead and concrete are needed to stop them.

RELATIVE PENETRATING POWER OF ALPHA, BETA, AND GAMMA RADIATION



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Sources of Ionizing Radiation:

Medical therapy:

X rays

β particles

γ rays

Radiation Nuclear weapon detonations:

α particles

γ rays

Neutrons

Nuclear reactors:

β particles

γ rays

I. Radiation safety in work with radio-active substances and sources of ionizing radiation in hospitals

- The basic rules of radiation safety are stated in the document, which is usually referred to as «Norms of radiation safety”.

There are the following groups of people who are exposed to the effect of ionizing radiation:

Group A – includes personnel workers (for example, personnel workers of the radiation department at clinics and in hospitals, personnel workers of atomic power stations …)

Group B – includes a certain number of people;

Group C – includes the population of the whole region, territory, republic, country

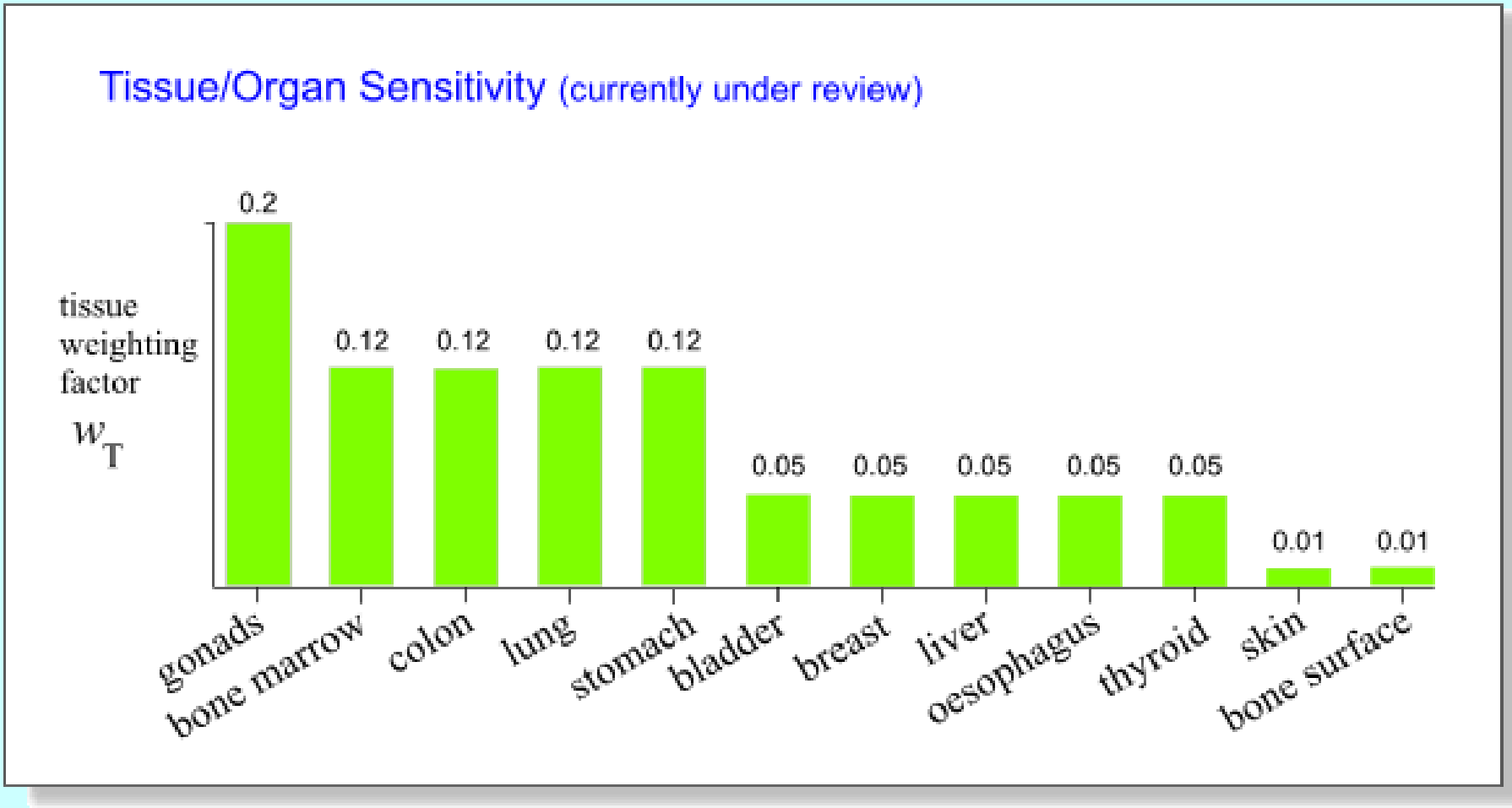
According to the norms of radiation safety, one can distinguish three groups of critical organs:

1 st group – Cells most affected:
Rapidly dividing cells:
small intestines, gonads, red bone marrow.

2 nd group – muscles, thyroid gland, adipose tissue, liver, kidneys, spleen, digestive system, lungs, lens and some other organs excluding those which belong to the 1 st and 3 rd groups of critical organs.

3 rd group – skin, bone tissue, hands, forearms, legs.

Varying tissue sensitivities



Principles of protection in work with radioactive substances and sources of ionizing radiation.

- 1. Close sources are the sources of ionizing radiation which exclude the emission of radioactive substances into the environment.

- - quantitative protection which means that people must work with minimum amounts (quantities) of radioactive substances. This principle is based on the reduction of radiation dose rate in a direct proportion
- - time protection which means that we must reduce the time of work with the sources of ionizing radiation. Reducing the time of work with the sources of ionizing radiation, it is possible to reduce radiation doses substantially

- - distance protection is a simple and reliable way of protection. It is provided with sufficient removal of workers from the radiator
- - shield protection is based on the ability of materials to absorb radioactive radiation. Depending on the kind of ionizing radiation, various materials are used in producing the shields and their thickness is determined by the radiation dose rate

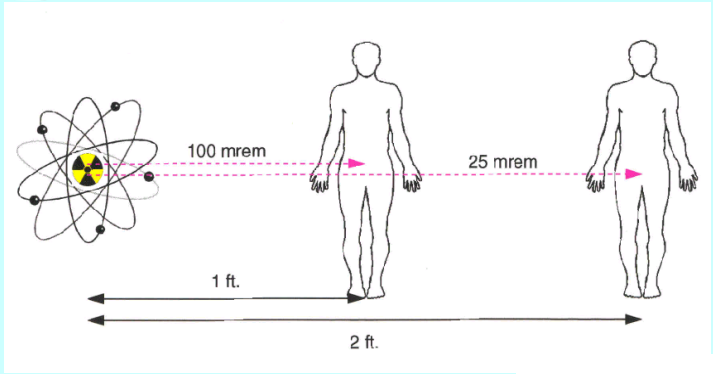
ALARA

As Low As Reasonably Achievable

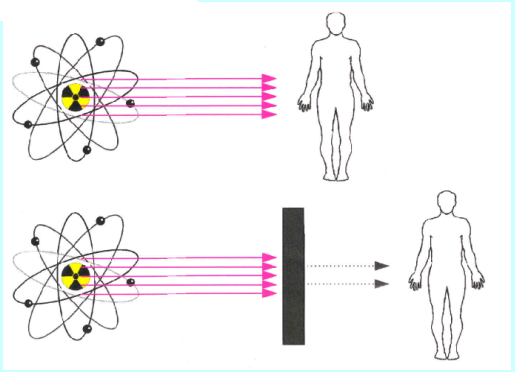
ALARA Techniques:

- Time - (Reduce)

- Distance – (Increase)



- Shielding – (Proper Shielding)



Reduce Radiation Doses

2. Principles of protection in work with open sources

- Open sources are sources of radiation which enables the emission of radioactive substances into the environment. In this case either external or internal irradiation of the personnel is possible. Such conditions can take place in releasing radioactive isotopes into the environment, such as gases, aerosols, etc.

Principles of protection

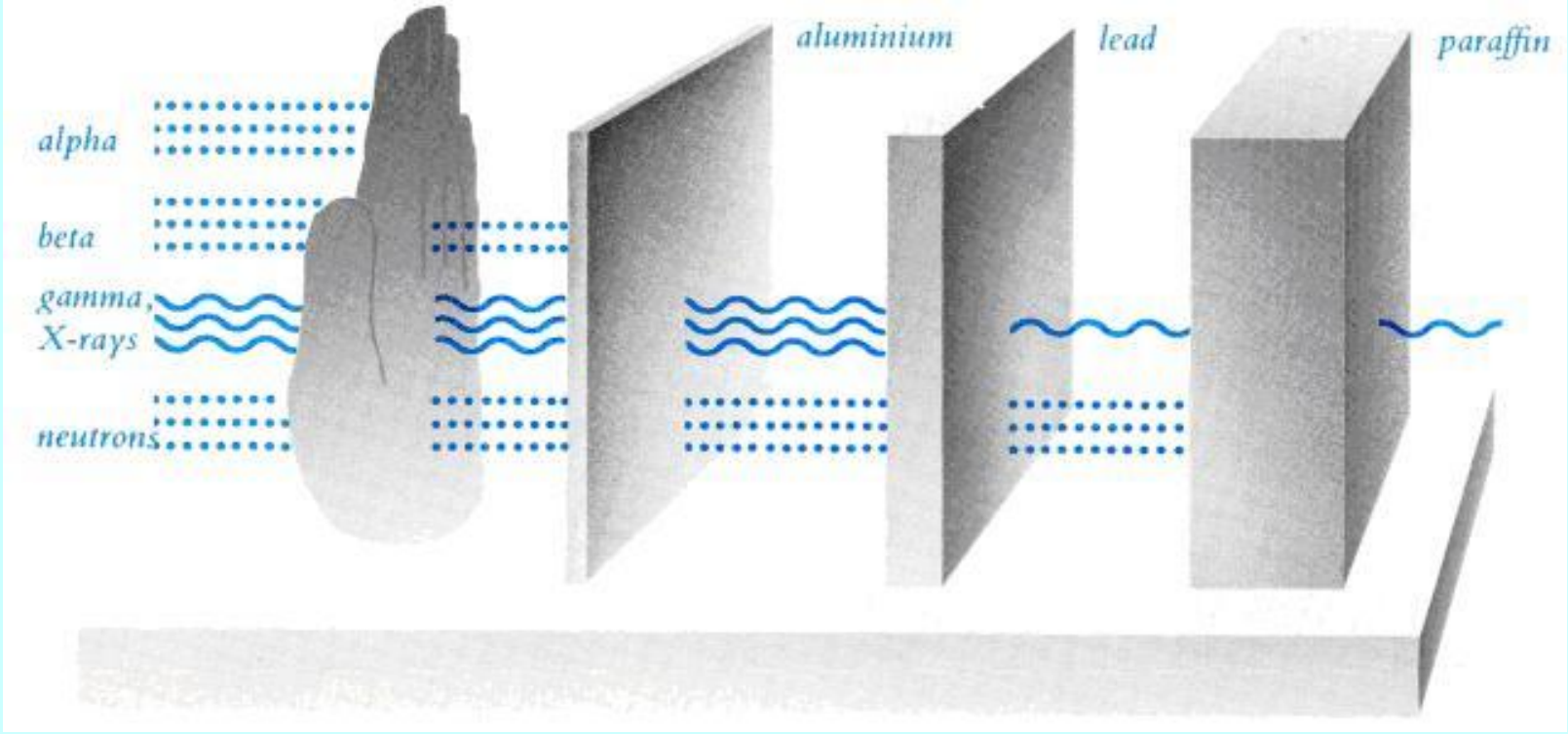
- 1. Hermetic sealing of the industrial equipment aimed at isolation of production processes, which may be the source of emission of radioactive substances into the environment. For example, boxes, manipulators, mechanical hands and others.

Principles of protection

- 2. Planning measures promote maximum isolation of the work with radioactive substances from the other rooms.

Principles of protection

- 3. The use of sanitary and technical devices and equipment. The use of special protective materials. Ventilation management, which is necessary for the protection of the air environment against radioactive pollution in work rooms. As a rule, a ventilating pipe is installed so that the incoming air prevails above outcoming.



- The materials which can easily absorb radioactive substances are **wood, brick, concrete, ceramic, slab, linoleum**.
- The materials with a less degree of absorption radioactive substances are **glazed slab, enamel, epoxide resins, some plastic.**

Principles of protection

- 4. The use of means of individual protection (overalls, special boots, etc.) and sanitary cleansing of the personnel.

- Protective clothing such as lab coats, gloves & safety glasses

- Self-monitoring to reduce the spread of radioactive contamination

Principles of protection

- 5. Following the rules of personal hygiene. It is necessary to meet the requirements of the so-called radiation aseptic in work with open sources of ionizing radiation. Radiation aseptic is a number of measures aimed at prevention of releasing radioactive substances on overalls and on the skin.

Principles of protection

- 6. Medical personnel health control. According to the “Norms of radiation safety”, people under 15 are not allowed to work with the sources of ionizing radiation. The individuals of group A must be examined thoroughly while applying for a job. Only people without medical contraindications are admitted to work. Women are not allowed to work with the sources of ionizing radiation during pregnancy and lactation.

Possible types of irradiation of the population:

External irradiation

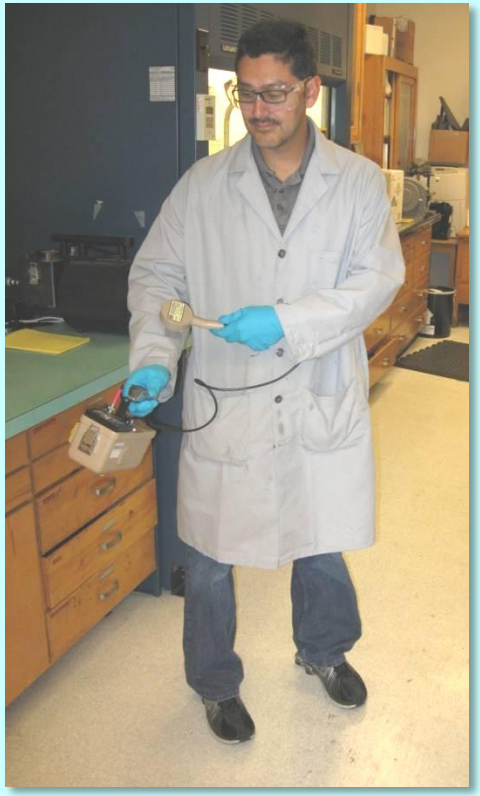
- - from radio nuclides in the air. It causes gamma - radiation from inert radioactive gases, isotopes of iodine and products of division from radioactive clouds.
- - from the radioactive deposits which have been released on the Earth´s surface. It usually results in irradiation of the whole body from precipitations on the Earth´s surface, buildings and roads.

Upon Completion of Work

Hand washing is a good work practice and an important final step after working with any radioactive material.

Upon Completion of Work

Be sure to survey yourself



Internal irradiation

- - the result of breathing in radio nuclides from radioactive clouds. It usually results in irradiation of internal organs and tissues
- - result of the use of contaminated food and water. Radioactive substances in the digestive system may be resulted from either direct contamination of the products consumed by the population, or from the use of the products, including meat and dairy, produced on contaminated fields.

Exposure time

- also has an effect on the amount of damage that may occur after exposure to radiation.
- Longer exposures increase the chance that damage will occur. However, if there is sufficient time between periods of exposure, the body has time to repair the damage. Thus a higher total exposure may be tolerated than if the exposure were to occur at one time. This effect is similar to how our bodies react to exposure to the sun. Too much sun at once can cause a sunburn, but short exposures and the use of sunblock help to limit the effects of the sun on our skin.

The most effective protective measures are the following:

- 1. Shelter.
- 2. Preventive dose of radio protectors.
- 3. Protection of respiratory organs.
- 4. Body protection.
- 5. Evacuation.
- 6. Sanitary cleansing.
- 7. Migration.
- 8. Restricted access to the territory.
- 9. Food control.
- 10. Clean-up of radioactive areas.

I. Shelter

- The shelter in rooms with closed windows and doors as well as with dead ventilation is suitable for the protection against external irradiation associated with gaseous clouds and deposits of radioactive substances on the ground. The shelter protects also against inspiration of radioactive aerosols. This is one of the simplest measures which is effective and does not do any harm if you have to shelter more than 12 hours.

II. Preventive dose of radio protectors.

- **Thyroid blocking**

This is a method for protecting the thyroid gland, which readily absorbs iodine. A stable, or non-radioactive, iodine such as potassium iodide, is taken in pill form to reduce the absorption by the thyroid gland of radioactive iodine-131, which may be present in the environment after a radioactive release. However, taking stable potassium iodide when it is not necessary, or in the wrong amounts, can be harmful. This protective measure is taken against inhalation irradiation. After getting into the human body radioiodine activity in the thyroid gland is 50%of the maximum dose in 6 hours and the maximum radioiodine activity may be reported in 1 or 2 days.

III. Protection of respiratory organs.

- It is possible to protect the respiratory organs with the help of such simple means, as handkerchiefs, paper napkins or towels. The efficiency of the protection can be increased by their humidifying.

IV. Body protection

- The protection of the body is aimed at the prevention of radioactive substance precipitation on the skin and hair. Any parts of the clothes, including caps, hoods, gloves and boots are suitable for this purpose.

V. Evacuation

- Evacuation is an urgent removal of people with the purpose of prevention or reduction of their irradiation.

VI. Sanitary cleansing

- is necessary only in case if the fact of the pollution of the skin and mucous membranes with radioactive substances has been reported. As a rule, to take a shower is enough establish this fact.

VI I. Clean-up of radioactive areas

- Clean-up of radioactive areas is accomplished by means of washing or clearing out with the help of special vacuum cleaners which are used for cleaning the roads, buildings and facilities as well as for the removal of the superficial layer of the ground. This counter-measure is usually taken at the advanced stage of the accident

Monitoring Instruments:

- **Film Badges for Personal Dosimetry (**Suitable for personal gamma and X-ray dosimetry)
- **Thermoluminescence Detectors**

- **Pocket Dosimeters**

- **Electronic Alarm Dosimeter**