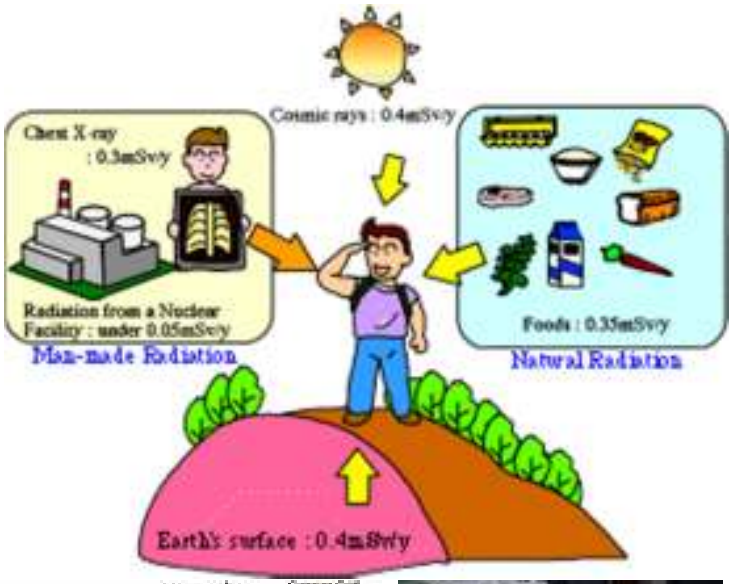
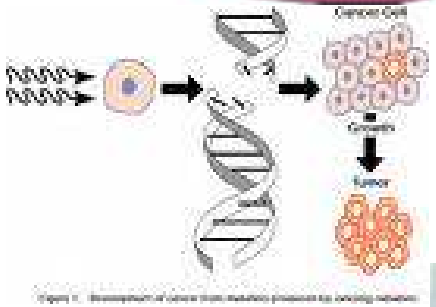
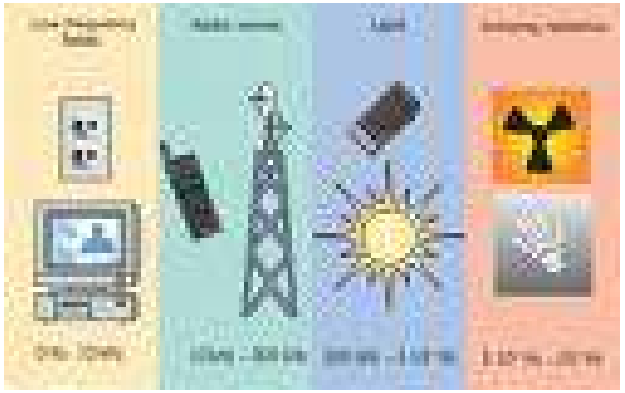
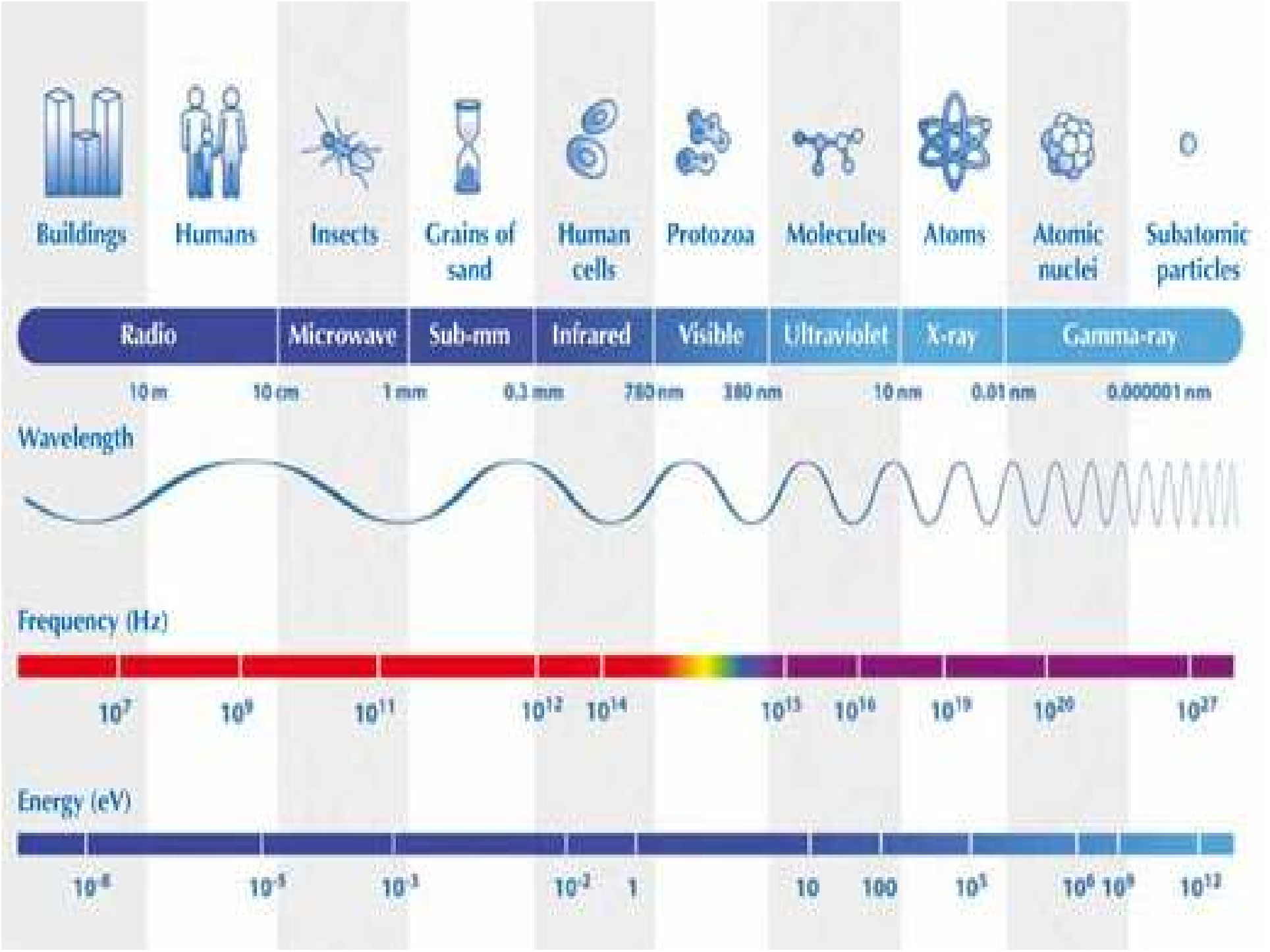
Radiations

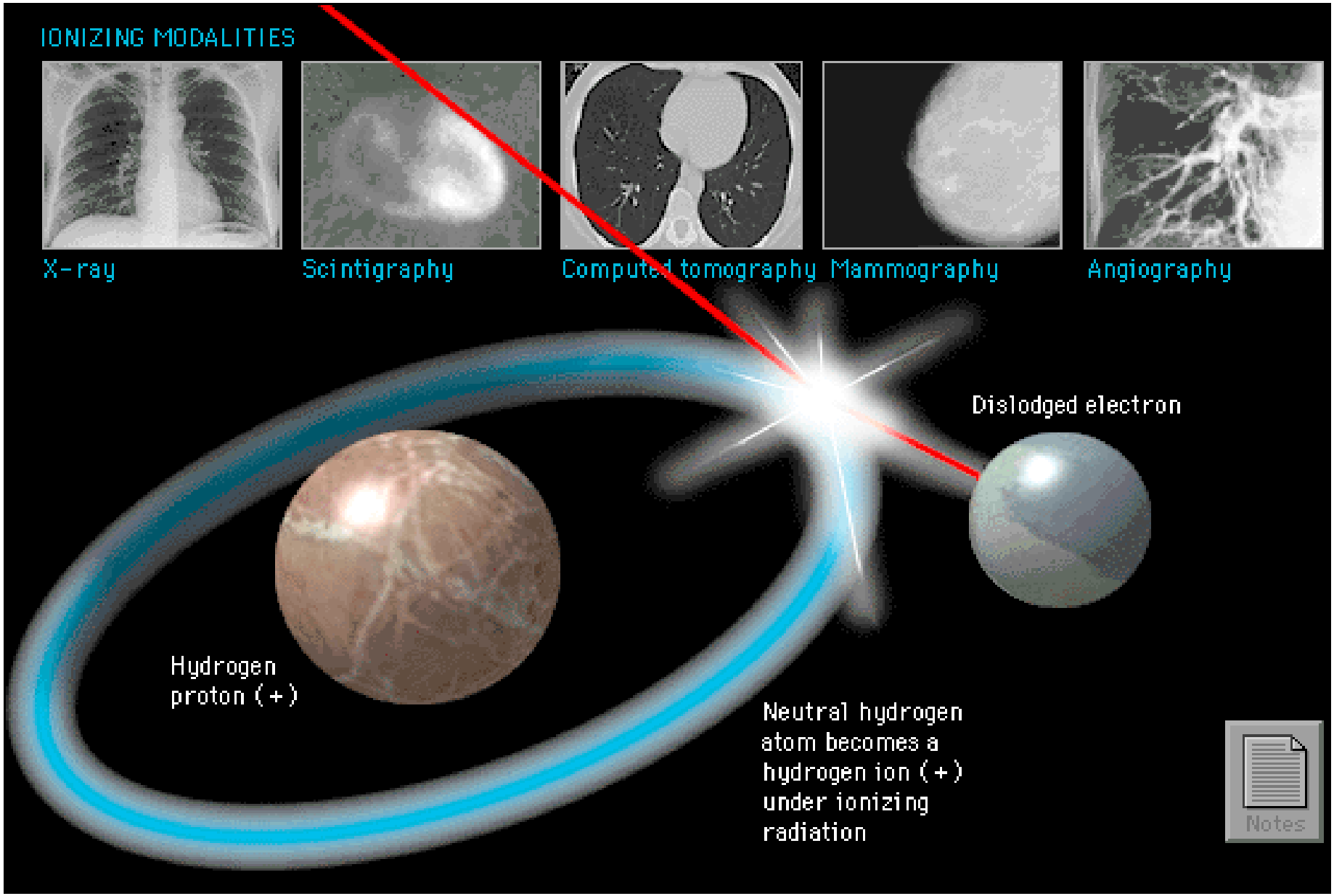




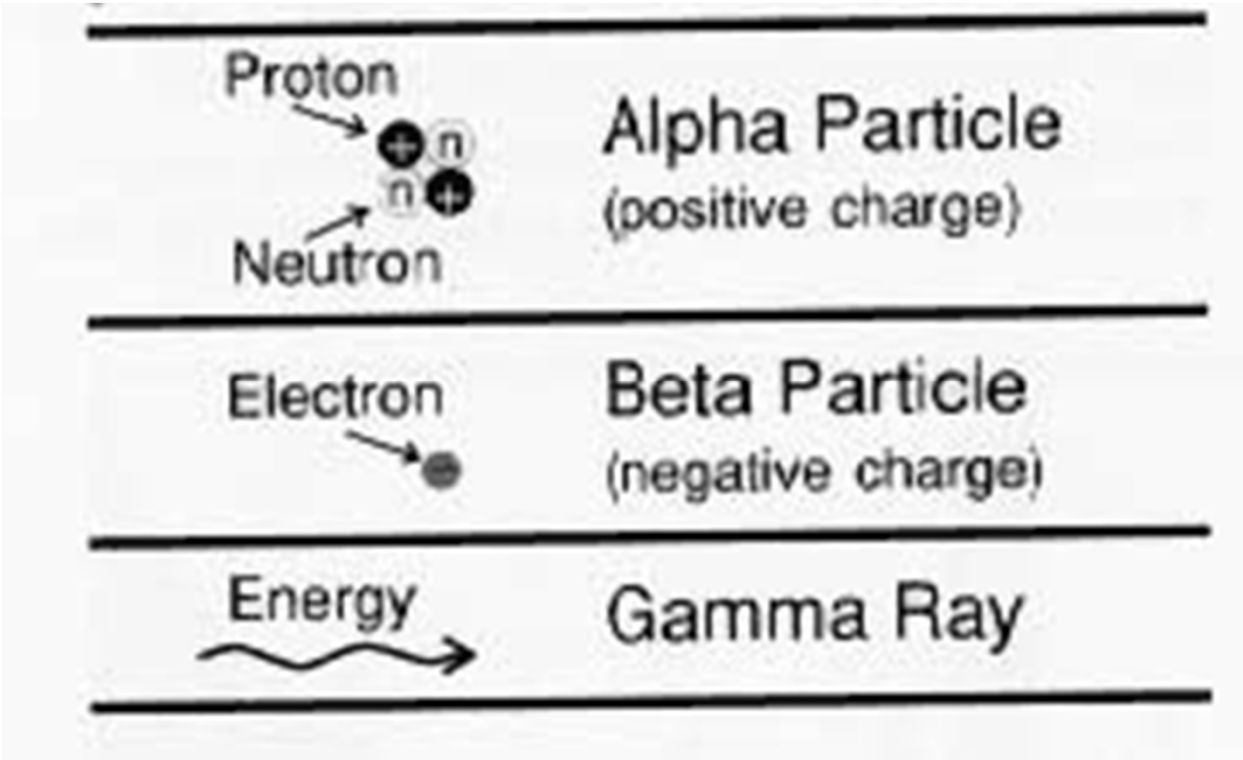


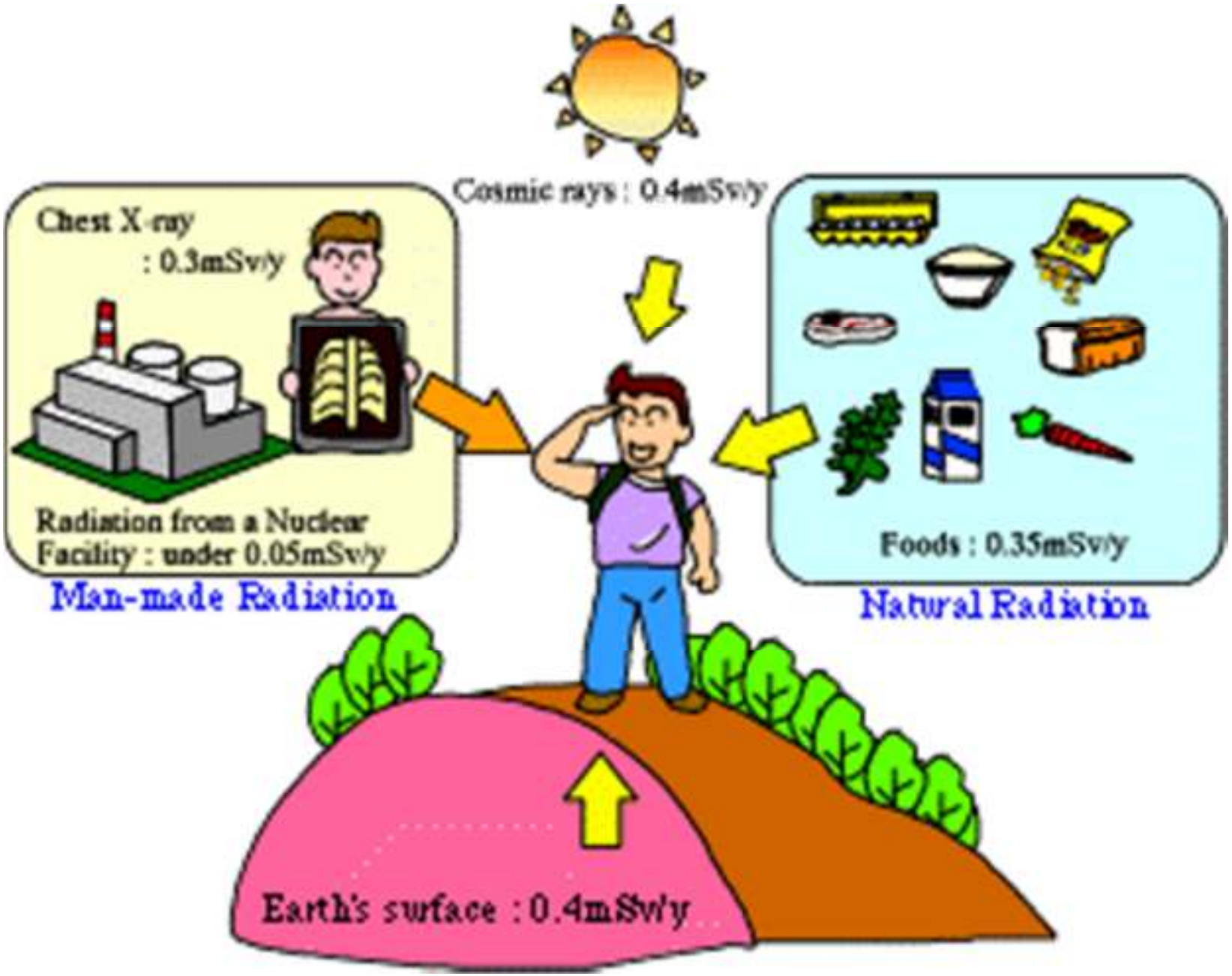
SU Department of Public Health


Buildings
Humans
Insects
Grains of sand
Human cells
Protozoa
Molecules
Atoms
Atomic nuclei
Subatomic particles
Radio
Microwave
Sub-mm
Infrared
Visible
Ultraviolet
X-ray
Gamma-ray
10 m
10 cm
1 mm
0.3 mm
780 nm
380 nm
10 nm
0.01 nm
0.000001 nm
Wavelength
Frequency (Hz)
10^{7}
10^{9}
10^{11}
10^{12}
10^{14}
10^{15}
10^{16}
10^{19}
10^{20}
10^{27}
Energy (eV)
10^{-6}
10^{-5}
10^{-3}
10^{-2}
1
10
100
10^{3}
10^{8}
10^{9}
10^{12}



Ionizing radiation

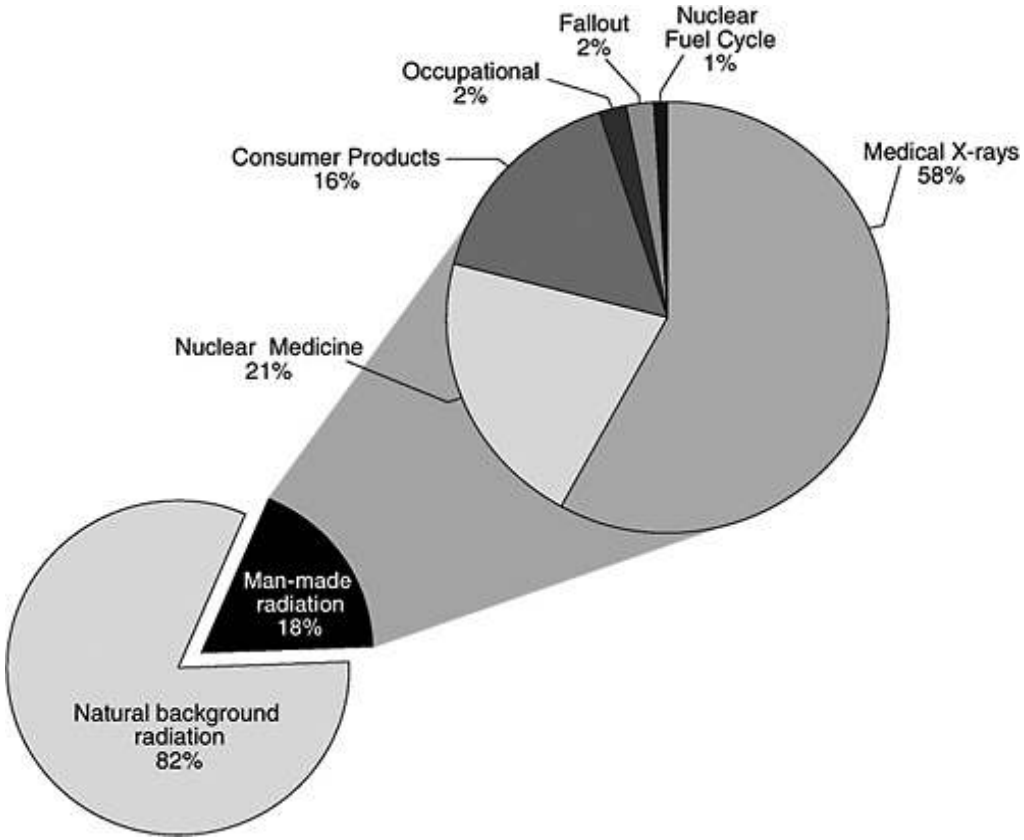

Proton
n
n
Neutron
Alpha Particle
(positive charge)
Electron
Beta Particle
(negative charge)
Energy
Gamma Ray


Cosmic rays : 0.4mSv/y
Chest X-ray
: 0.3mSv/y
Radiation from a Nuclear
Facility : under 0.05mSv/y
Man-made Radiation
Foods : 0.35mSv/y
Natural Radiation
Earth's surface : 0.4mSv/y

Many foods are **naturally radioactive**, and bananas are particularly so, due to the radioactive **potassium-40** they contain.

Sources of radiation
(Hu)man-made radiation

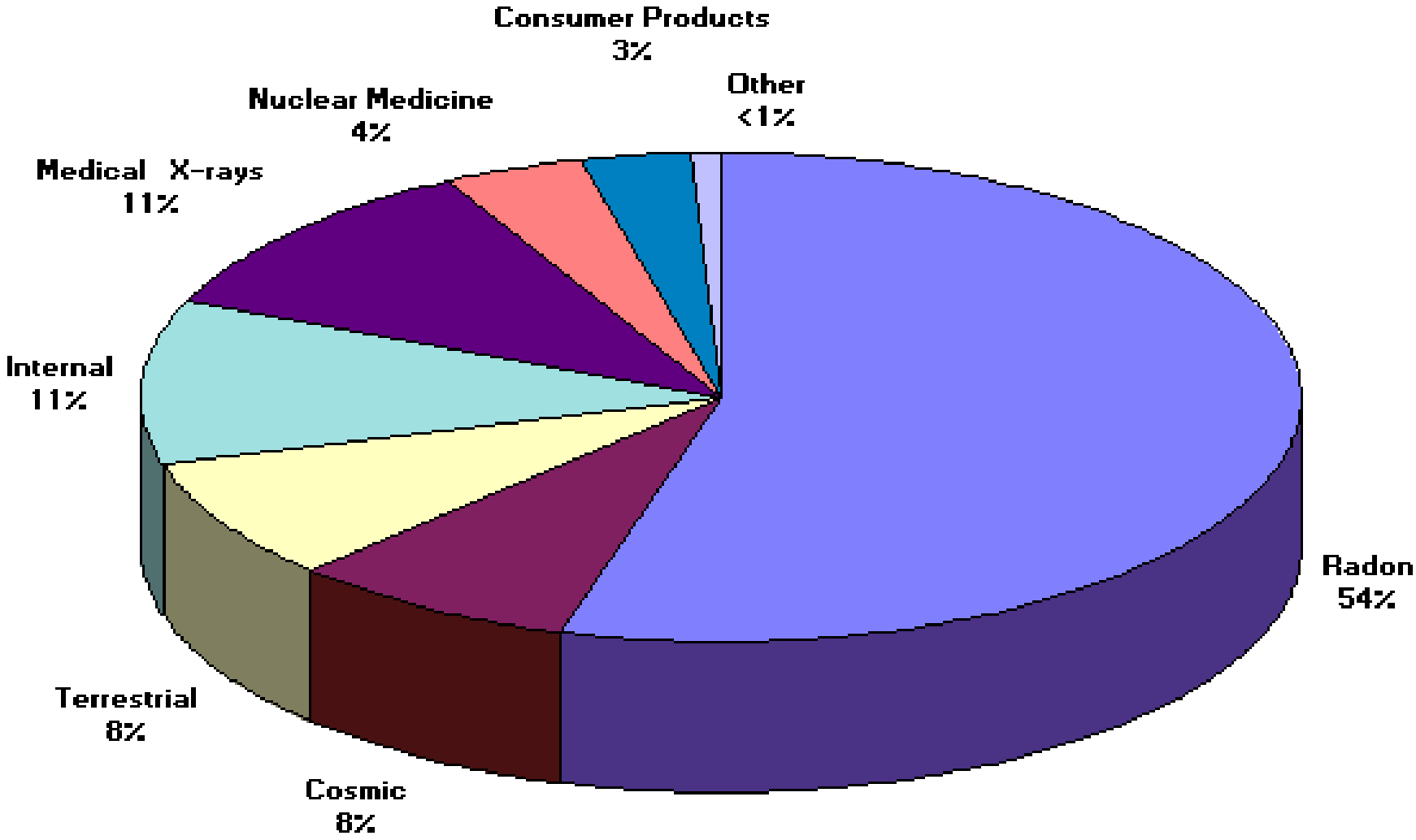
- Medical use (Dg: 0,3 mSv X-ray, isotope 0,03 mSv; Th: 0,3 mSv radiation, radioisotope 0,002 mSv)
- Fallout (0,01 mSv per year, total 3,7mSv)
- Nuclear power plant



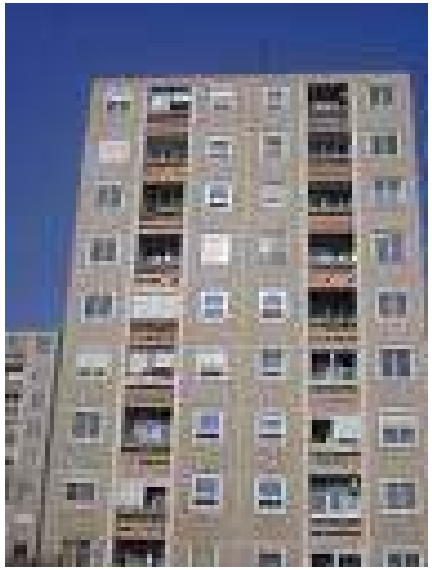
Radiation exposure caused by man-made radiation

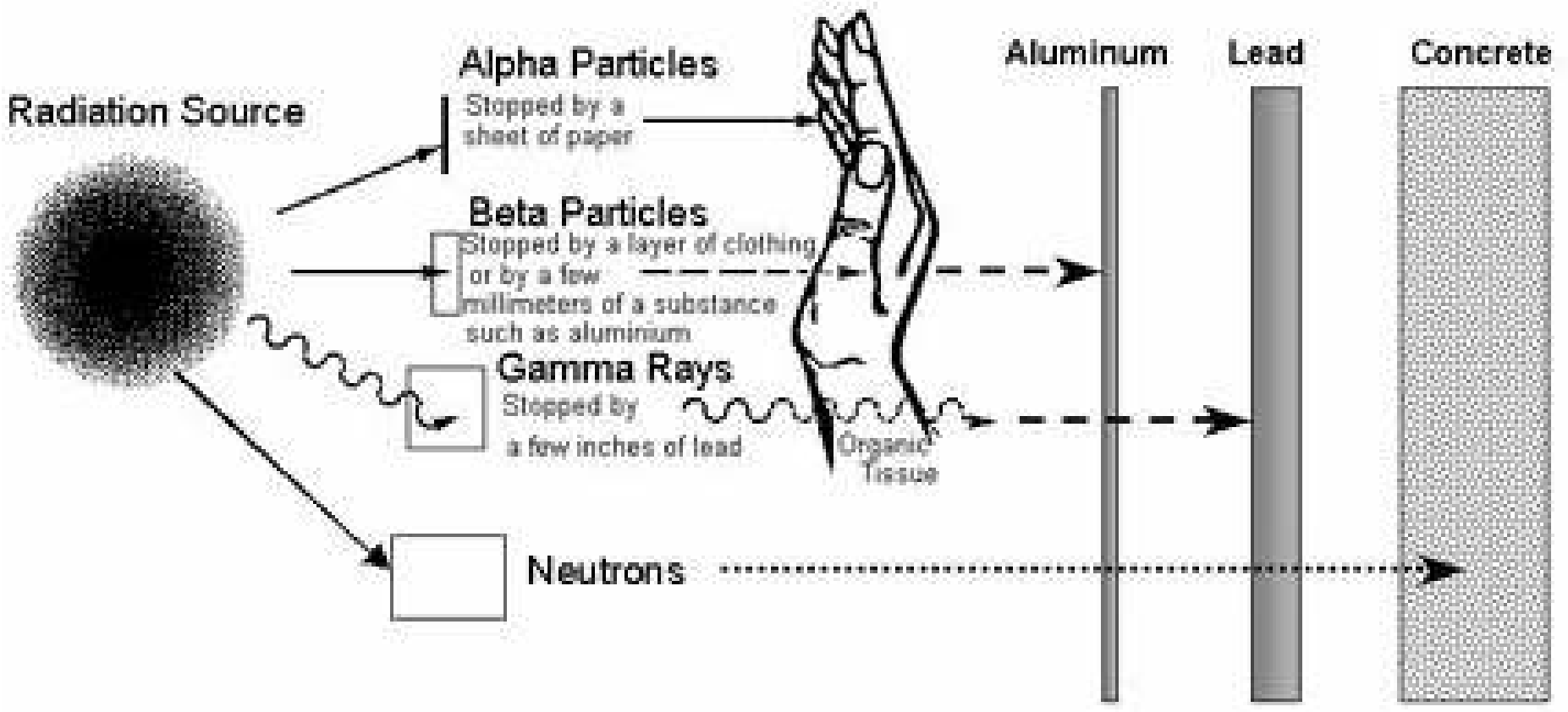
World average: 0,6 mSv, **in developed countries: 2 mSv**

Sources of Radiation Exposure to the US Population



The amount of natural ionizing radiation received by a person's body is expressed in units of mSv (milliSieverts).
This radiation comes **from cosmic rays from space, from earth, and from natural radioactive substances in food**.
This radiation amounts to about **2.4 mSv per person per year** (but in HUNGARY a little higher, why?)



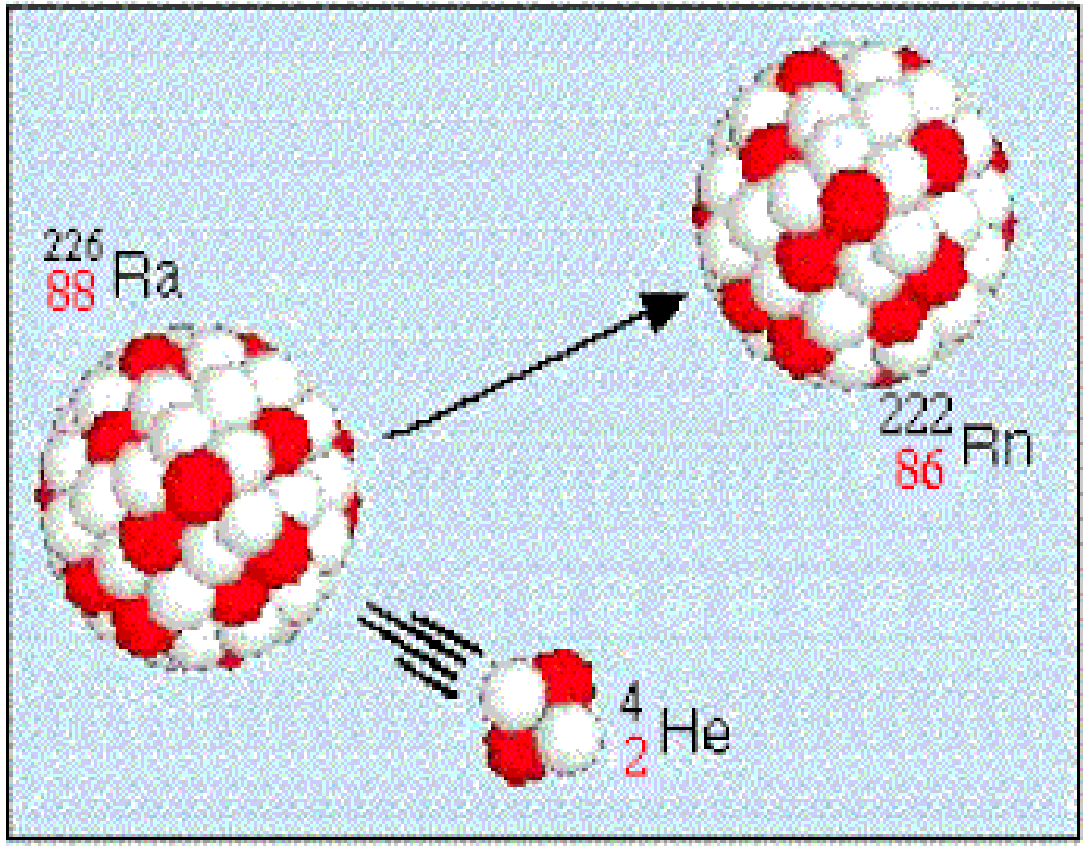

Radiation Source
Alpha Particles
Stopped by a sheet of paper
Beta Particles
Stopped by a layer of clothing or by a few millimeters of a substance such as aluminium
Gamma Rays
Stopped by a few inches of lead
Neutrons
Organic Tissue
Aluminum
Lead
Concrete

Types of Radiation and Their Different Affects on People

Alpha-

• Not able to penetrate skin.

• Can be harmful if inhaled, swallowed or absorbed through an open wound.



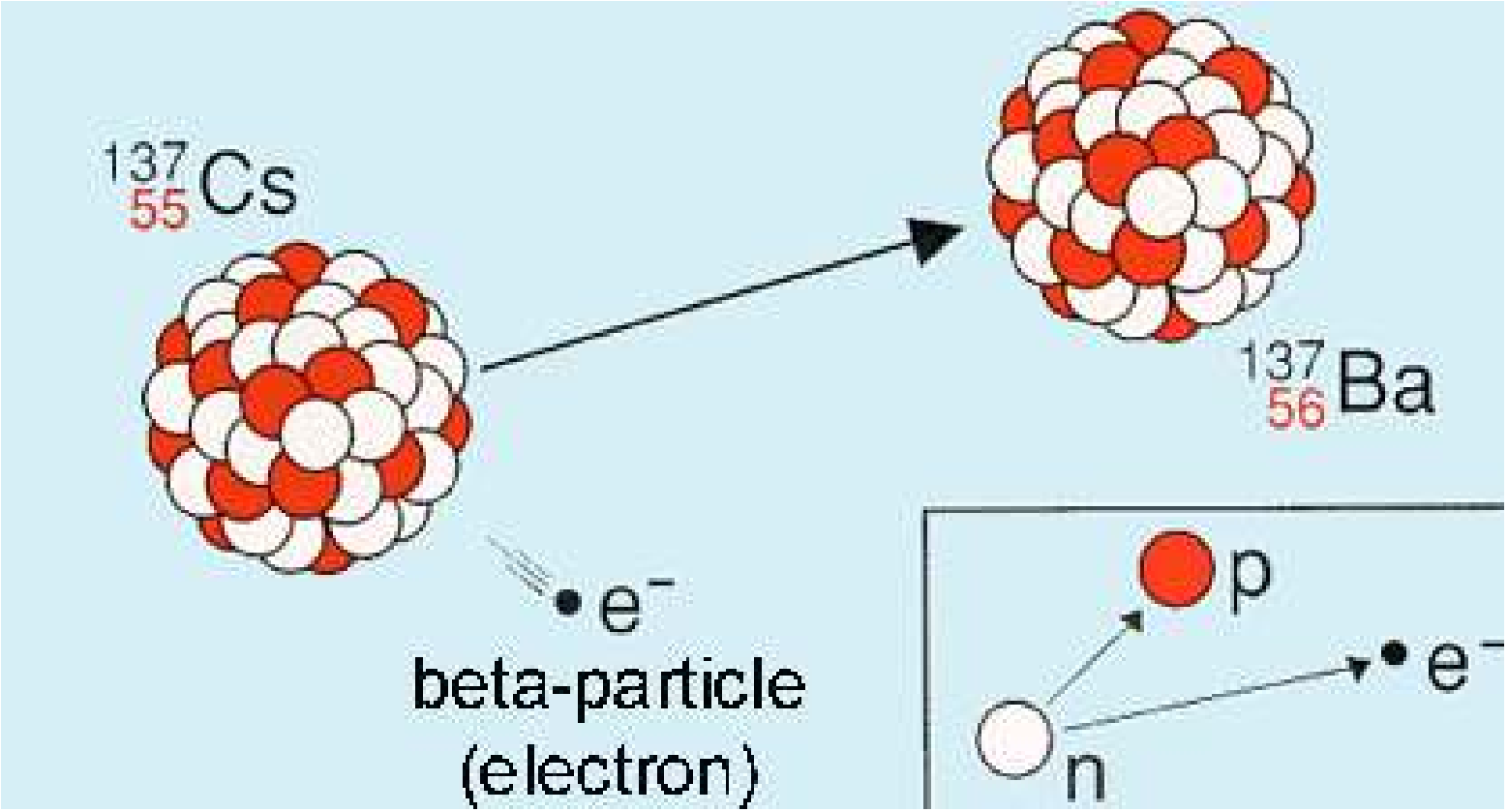
Source: http://nuclearchem.wikispaces.com/Radiation+Shielding

Beta-

• Beta Radiation is somewhat penetrating.

• The Beta rays can penetrate the first 'germinal layer' of skin.

• They may cause injury to the skin, but not the internal organs.

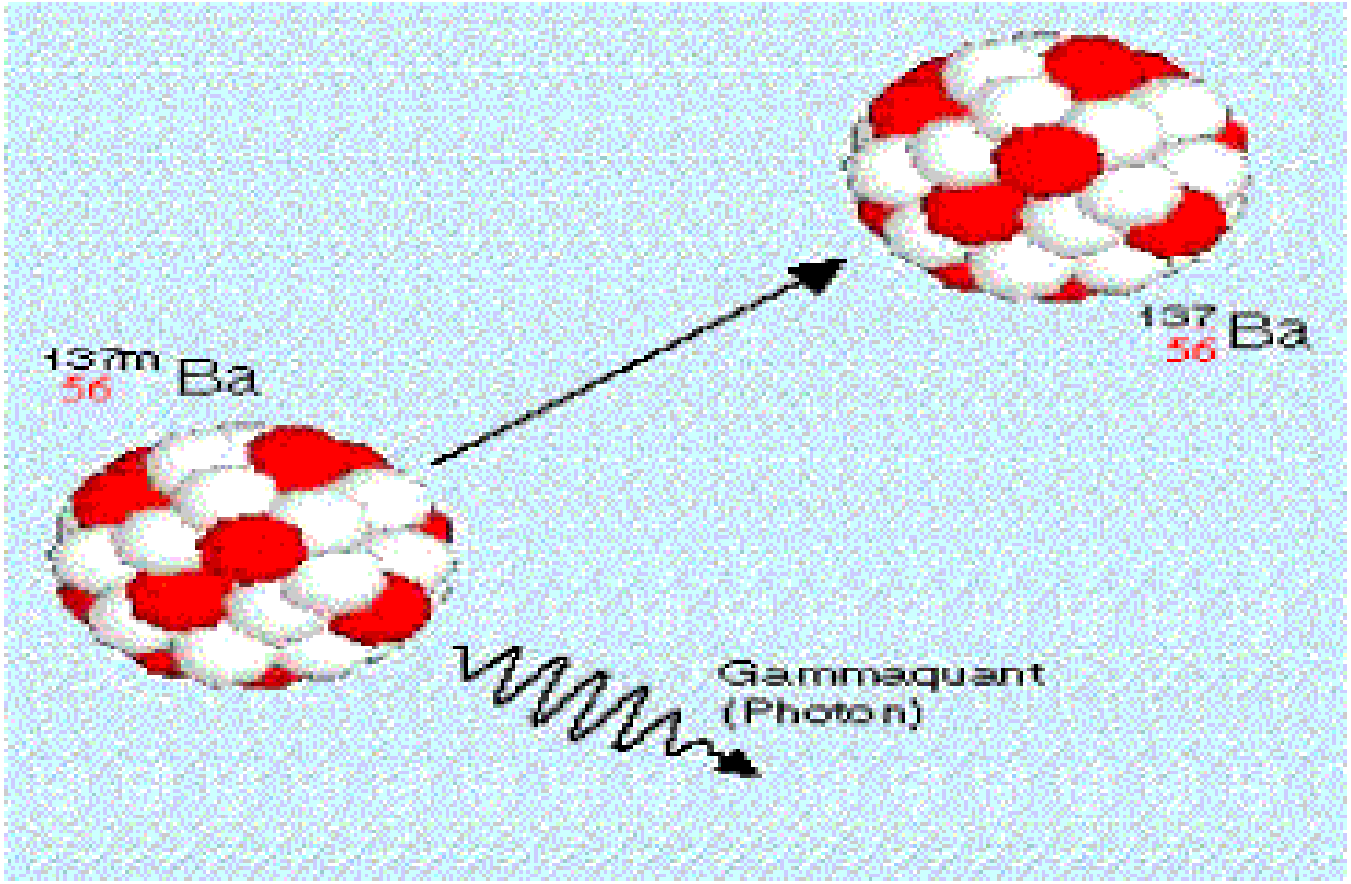


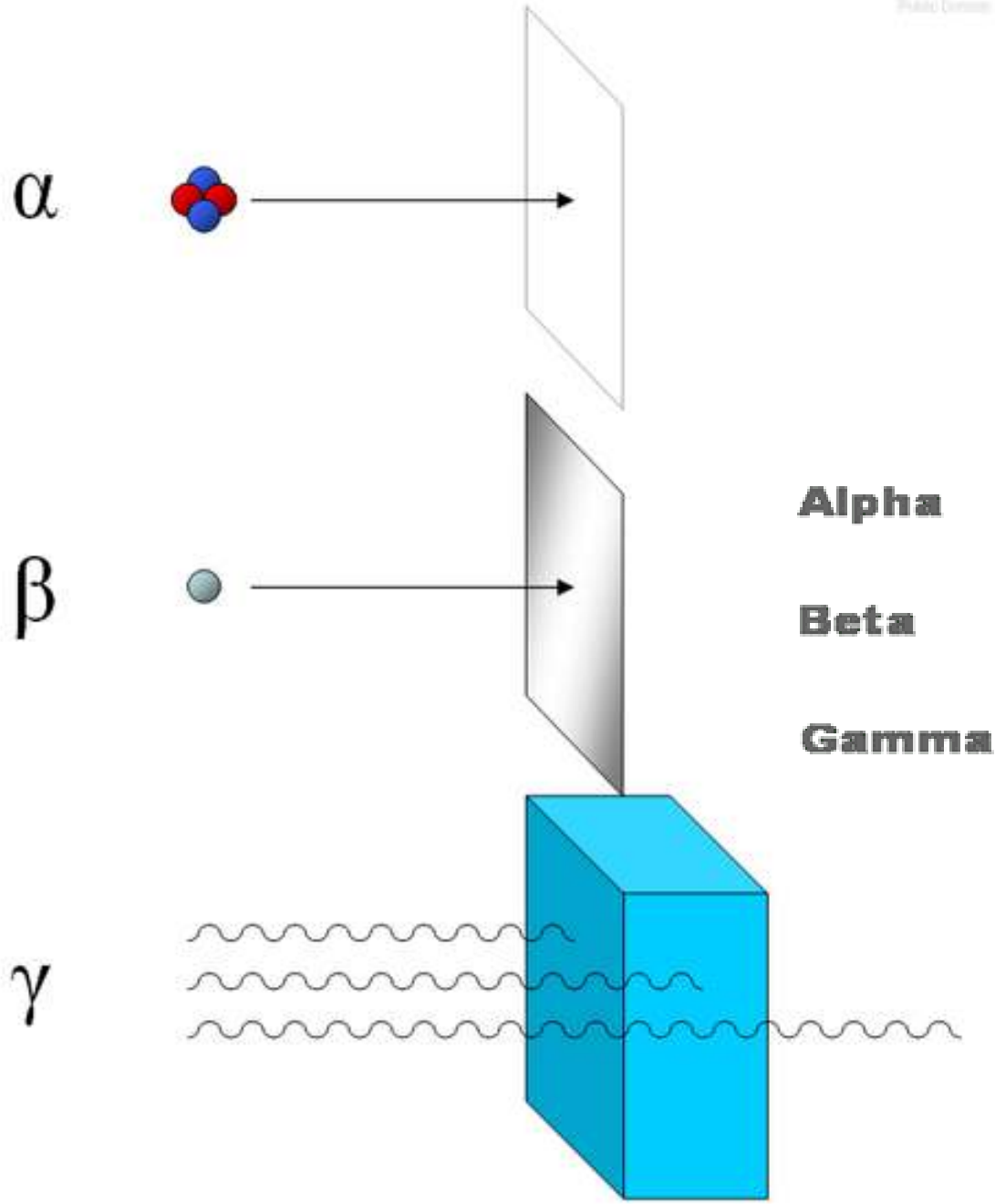
Gamma-

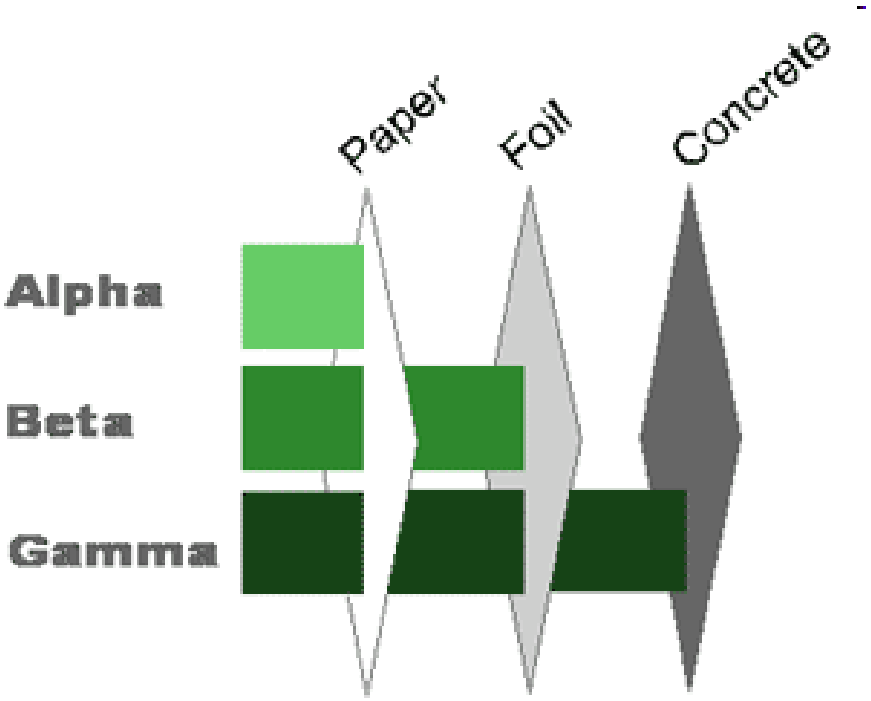
• Gamma radiation or x rays can travel many inches into the human tissue.

• Gamma rays are **electromagnetic radiation**, like visible light, radio-waves, and ultraviolet light.

• Gamma radiation is easily detected and is highly dangerous.




α
β
γ


Paper
Foil
Concrete
Alpha
Beta
Gamma

Dosimetry of ionizing radiation for radiation protection purposes

How high is radiation **emission**?

Radioactivity → radioactive decay/sec = *Becquerel* (Bq)

How large is the **dose** received?

Absorbed dose ($D_{T,R}$) → **J/kg** = *Gray* (Gy)

From which **type** of radiation?

Equivalent dose (H_T) = $\sum D_{T,R} \cdot \mathbf{w_R}$ → J/kg · c = *Sievert* (Sv)

With an overall **biological effect** of what magnitude?

Effective dose (E) = $\sum \mathbf{w_T} \cdot H_T$ → *Sievert* (Sv)

With a total **population effect** of what magnitude?

Collective effective dose (S) = $\sum \mathbf{E_i} \cdot \mathbf{N_i}$ → *Person-Sievert*

Absorbed dose: the **energy absorbed per unit mass**.

The **Gray (Gy)** is the energy deposition of a **joule per kilogram** in any material.

Equivalent dose: is the **absorbed dose averaged over a tissue or organ and weighted for the radiation quality** involved in the exposure.

A **radiation quality factor (QF)** is used in calculating an equvivalent dose.

1 Gy of x-ray does not have the same effect as 1 Gy of neutrons.

Effective dose: is the sum of tissue weighted equivalent doses in all tissues and organs of the body.

The tissue weighted factors represent the **relative contribution of that organ or tissue to the total health detriment**
due to the effects resulting from uniform irradiation of the whole body.

Radiation (w_R) weighting factors for ionizing radiation

Type of radiation	Energy level	Radiation weight. factor (w_R)
Photons, electrons, muons	entire energy spectrum	1
Neutrons Protons	<10 keV, >20 MeV	5
	>2 MeV	
Neutrons	10-100 keV, >2-20 MeV	10
Neutrons Alpha-particles, fission fragments, heavy nuclei	>0,1-2 MeV	20
	entire energy spectrum	

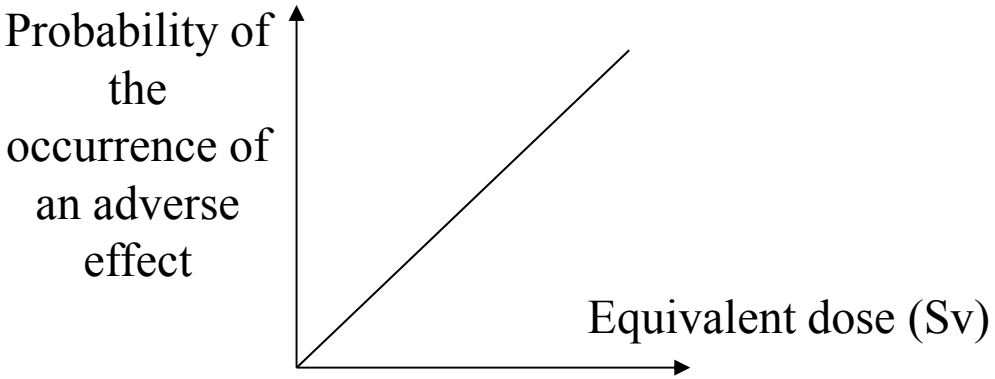
Tissue (w_T) weighting factors for ionizing radiation

Tissue / organ	Tissue weight. factor (w_T)
Gonads	0,2
Red bone marrow	0,12
Colon	0,12
Lungs	0,12
Stomach	0,12
Urinary bladder	0,05
Breast	0,05

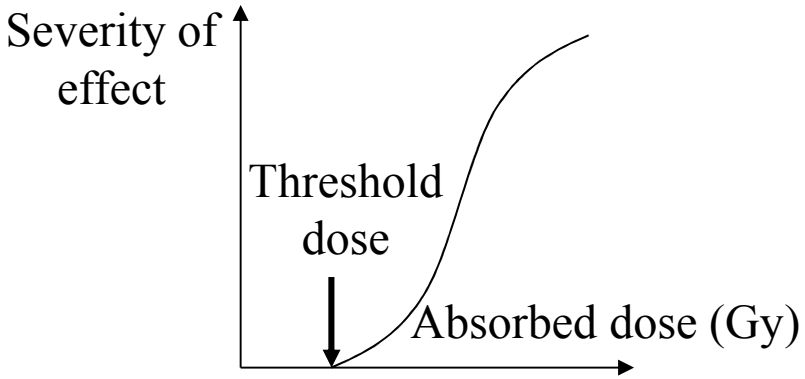
Tissue (w_T) weighting factors for ionizing radiation

Tissue / organ	Tissue weight. factor (w_T)
Liver	0,05
Esophagus	0,05
Thyroid	0,05
Skin	0,01
Bone surface	0,01
Remainder	0,05

Biological effects of ionizing radiation



Stochastic effects



Deterministic effects

Type of effect	Acute	Chronic
Deterministic *(large doses)*	local injury radiation sickness	cataracts, dermatitis, congenital abnormalities
Stochastic *(small & medium doses)*	-	malignant tumors genetic (hereditary) effects (only observed in animal models so far!)

Early diagnosis of radiation damage

1. ***Clinical symptoms*** [noticeable within first few hours depending on dose]

   - nausea, vomiting, fatigue, headache, diarrhea

2. ***Thermography*** [damaged areas may increase 3-4ºC]

3. ***Hematological symptoms*** [noticeable after 1-2 days]

   - lymphocyte count↓, granulocytes show transient increase then↓, platelet count↓

4. ***Genetic/cytogenetic tests***

   - dicentric chromosomal aberrations, micronucleus frequency, point mutations on the X chromosome

5. ***Biochemical changes***

   - Protein and nucleic acid degradation products (taurine, cysteine, creatine), tissue-damage-indicating enzymes (GOT, amylase)

RADIATION EFFECTS

Measurements in millisieverts (mSv). Exposure is cumulative.

HIGH RISK

Potentially fatal radiation sickness. Much higher risk of cancer later in life.

10,000 mSv: Fatal within days.

5,000 mSv: Would kill half of those exposed within one month.

2,000 mSv: Acute radiation sickness.

MODERATE RISK

No immediate symptoms. Increased risk of serious illness later in life.

1,000 mSv: 5% higher chance of cancer.

400 mSv: Highest hourly radiation recorded at Fukushima . Four hour exposure would cause radiation sickness.

100 mSv: Level at which higher risk of cancer is first noticeable

TOLERABLE LEVELS

No symptoms. No detectable increased risk of cancer.

20 mSv: Yearly limit for nuclear workers.

10 mSv: Average dose from a full body CT scan

9 mSv: Yearly dose for airline crews.

3 mSv: Single mammogram

2 mSv: Average yearly background radiation dose in UK

0.1 mSv: Single chest x-ray

EYES High doses can trigger cataracts months later.

THYROID Hormone glands vulnerable to cancer. Radioactive iodine builds up in thyroid. Children most at risk.

LUNGS Vulnerable to DNA damage when radioactive material is breathed in.

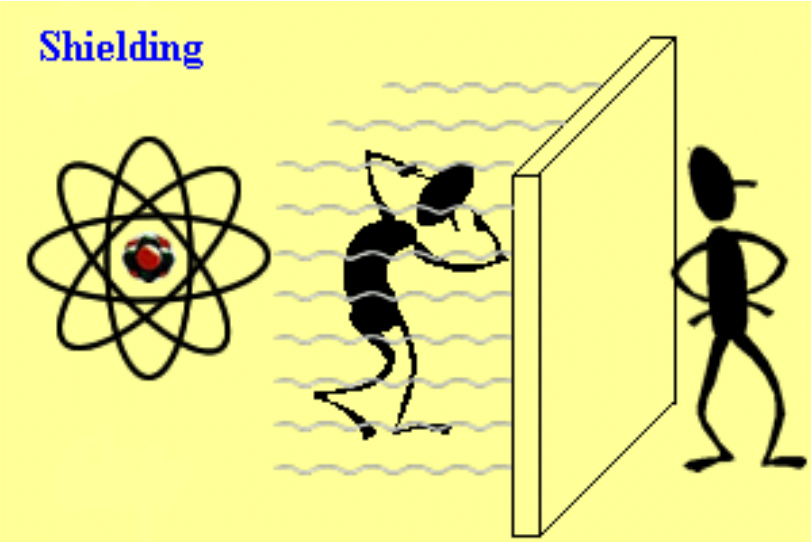
STOMACH Vulnerable if radioactive material is swallowed.

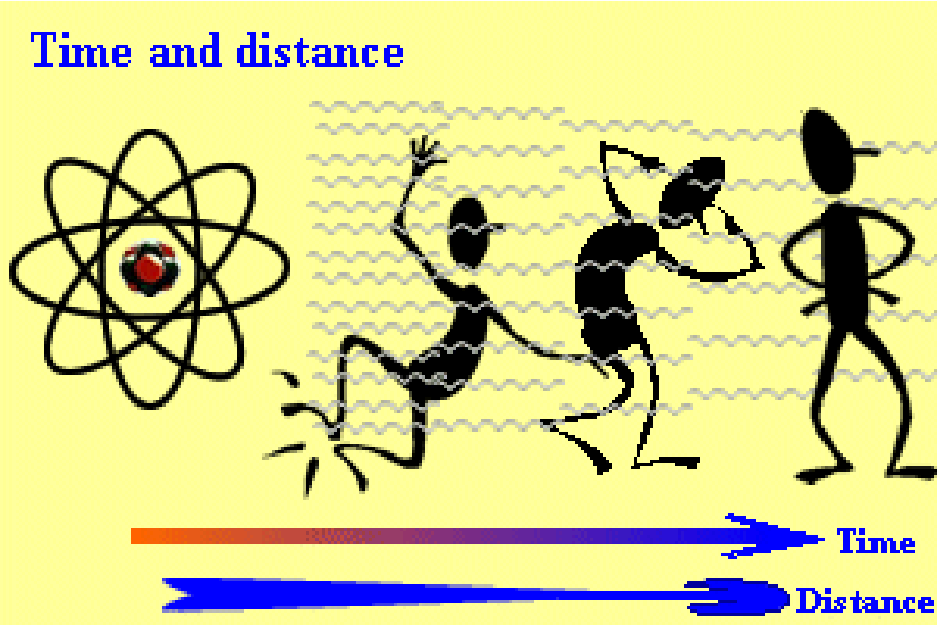
REPRODUCTIVE ORGANS High doses can cause sterility.

SKIN High doses cause redness and burning.

BONE MARROW Produces red and white blood cells. Radiation can lead to leukaemia and other immune system diseases.

What factors has an influence on the health effect of ionizing radiation?

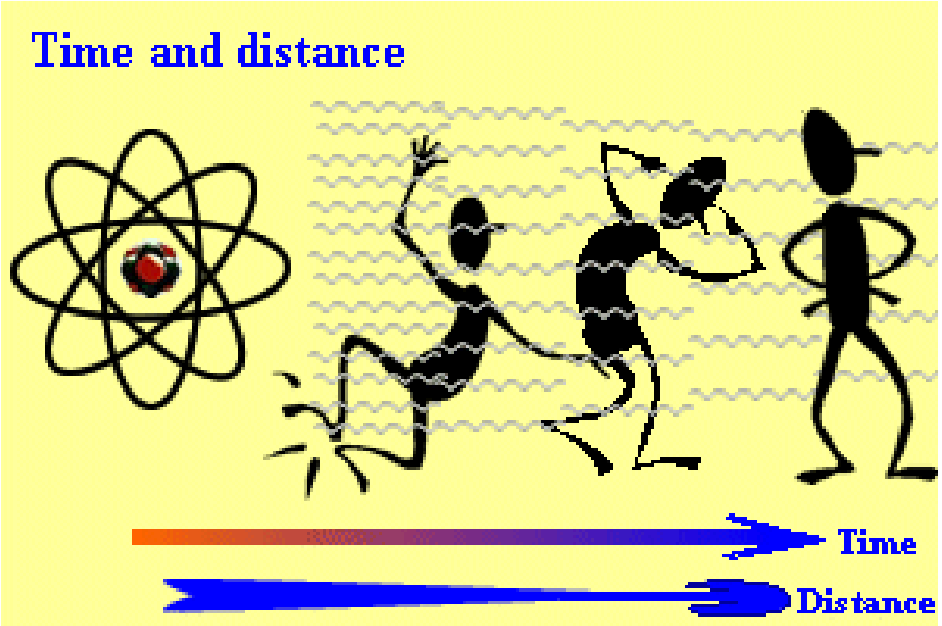


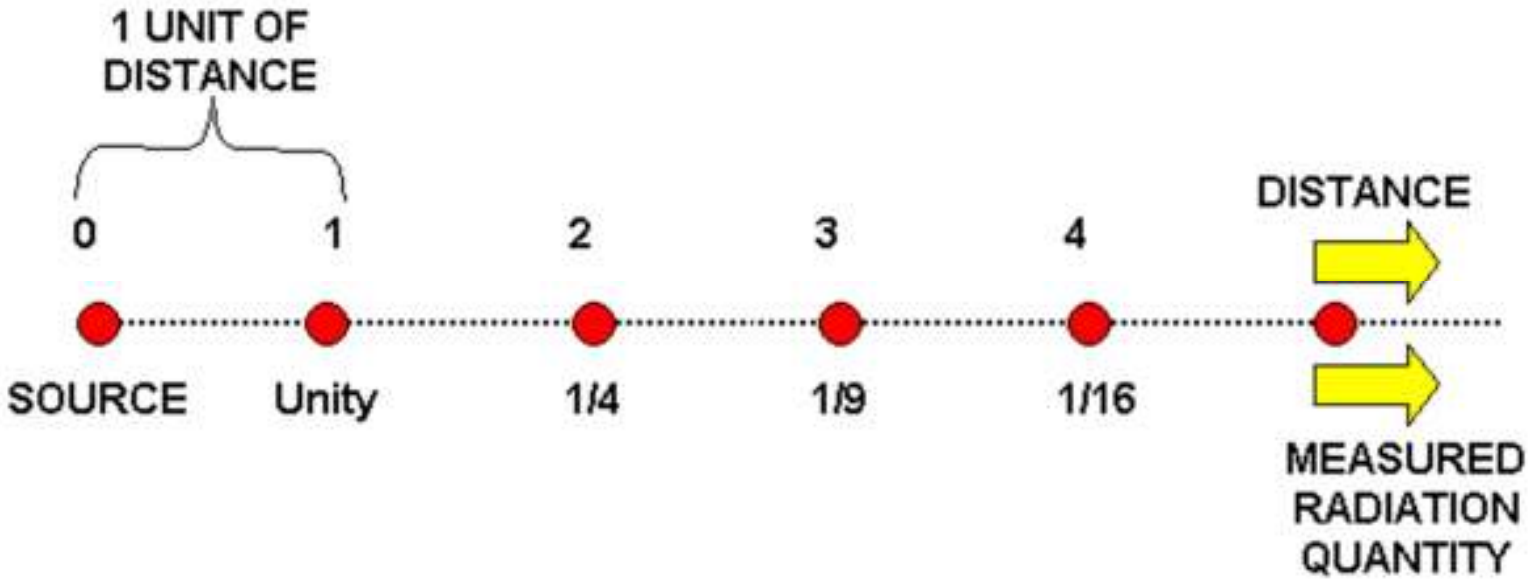


Engineered Controls

- distance
- shielding
- proper ventilation
- containment devices

Glove box


Time and distance
Time
Distance


1 UNIT OF DISTANCE
0
1
2
3
4
DISTANCE
SOURCE
Unity
1/4
1/9
1/16
MEASURED RADIATION QUANTITY

Administrative Controls

- **warning signs**
- **mass limitation** (limit the amount of radiation from the source)
- **safety procedures**
- **safety training**
- **personal protective equipment**

ALARA:

ALARA is a **philosophy** which means that exposures to radiation and chemicals is kept **AS LOW AS REASONABLY ACHIEVABLE**.

To achieve this goal:

this effort requires the coordinated effort of :

hazards must be evaluated before operations begin,

appropriate controls must be designed into the project.

Air-monitoring station in Japan

Monitoring of persons, incoming cargo, food, livestock and water arriving in Hong Kong from areas within 20 km of the nuclear power stations

A building in the 9th district of Budapest which is built with very low radon exposition

Most of the epithelial cellular damage is not from radon gas itself, which is removed from the lungs by exhalation, **but from radon's short-lived decay products (half-life measured in minutes or less).** When inhaled, these decay products may be deposited in the airways of the lungs and subsequently emit alpha particles as they decay further. **The increased risk of lung cancer from radon primarily results from these alpha particles irradiating lung tissues.** When an alpha particle passes through a cell nucleus, DNA is likely to be damaged. More specifically, available data indicates that alpha particle penetration of the cell nucleus may cause genomic changes typically in the form of point mutations and transformations.

Occupational and public exposure limits

Occupational: annual effective dose of 20 mSv

Special occupational limits:

youth – 16-18 yrs (6 mSv annually),

pregnant women are excluded from occupations involving exposure

Organ-specific (occupational):

lens: 150 mSv, *skin*: 500 mSv/cm^2

Public: annual 1 mSv effective dose

Nuclear Accident Scale

Source: http://thelede.blogs.nytimes.com/2011/04/12/a-look-at-the-nuclear-accident-scale/

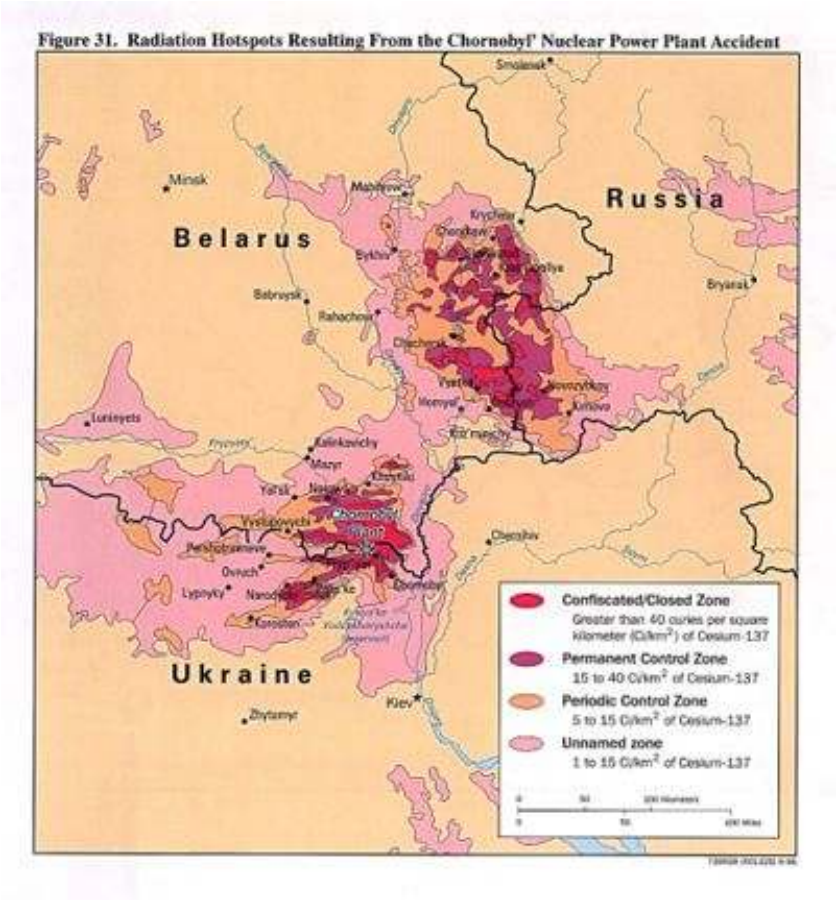
Chernobyl nuclear catastrophe

On 26 April, 1986 the plant's Unit 4 reactor was rocked **by a steam explosion**, followed by a hydrogen explosion and a **fire resulting in temperatures over 2,000°C**. The 1,000 ton **reactor lid was blown off** the core, **the nuclear fuel rods melted**, and more than 100 times the radiation of Hiroshima and Nagasaki combined was **released into the atmosphere** over the 10 days that the fire burned.

Chernobyl nuclear disaster

At least 30 person have died directly because of the big dose (from the plant's worker, firemen).

In 1995 the WHO had linked about 700 cases of **thyroid cancer** Among children and adolescent from Belarus, Russia and Ukraine, **including 10 deaths** and expected some increase in **leukemia**.



Radioactive iodine was the main health concern right after the accident (with half-life of eight days), **later contamination of soil with stroncium-90 and caesium-137**, which have half-lives of about 30 years.

Earthquake, tsunami, on 11 March 2011

Nuclear power plants of Japan

Fukushima Nuclear Power Plant Disaster on 11 March 2011 (1)

1.) At the time of the quake, **Reactor 4 had been de-fueled while 5 and 6 were in cold shutdown for planned maintenance**.
Immediately after the earthquake, the remaining reactors 1-3 shut down automatically, and **emergency generators came online** to control electronics and coolant systems.
However the tsunami following the earthquake quickly flooded the low-lying rooms in which the emergency generators were housed. **The flooded generators failed. As the pumps stopped, the reactors overheated due to** the high radioactive decay heat that normally continues for hours or days after a nuclear reactor shuts down.

2.) At this point, **only prompt flooding of the reactors with seawater could have cooled the reactors quickly enough** to prevent meltdown.
Salt water flooding was delayed because it would ruin the costly reactors permanently. Flooding with seawater was finally commenced only after the government ordered that seawater be used, and **at this point it was already too late to prevent meltdown**.

Source: http://en.wikipedia.org/wiki/Fukushima_Daiichi_nuclear_disaster

Satellite image of the four damaged reactor buildings

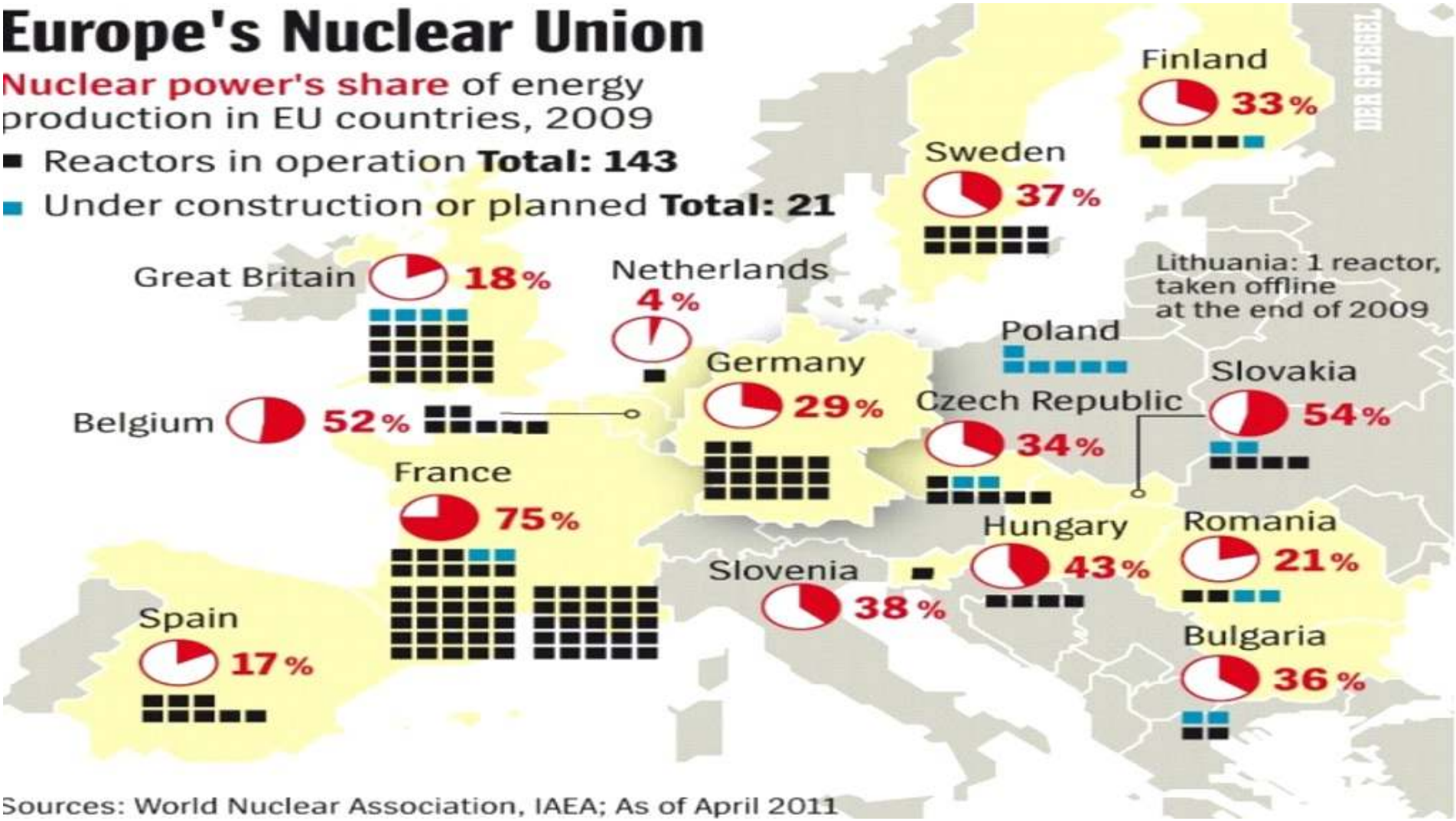
Fukushima Nuclear Power Plant Disaster on 11 March 2011 (2)

3.) In the intense heat and pressure of the melting reactors, a reaction between the nuclear fuel metal cladding and the remaining water surrounding them **produced explosive hydrogen gas**.
As workers struggled to cool and shut down the reactors, several **hydroge-air chemical explosions occurred**.

4.) Concerns about the repeated small explosions, the atmospheric venting of radioactive gasses, and the possibility of larger explosions led to an **evacuation around the plant**.

5.) Significant amounts of **radioactive material** have been released **into ground and ocean waters**. Measurements taken by the Japanese government **30–50 km from the plant showed ceasium-137 levels high enough to cause concern**.

Japan towns, villages, and cities in and around the nuclear plant exclusion zone.
The 20 km and 30 km areas had evacuation and sheltering orders.


Europe's Nuclear Union
Nuclear power's share of energy production in EU countries, 2009
Reactors in operation Total: 143
Under construction or planned Total: 21
Finland
33%
Sweden
37%
Lithuania: 1 reactor, taken offline at the end of 2009
Great Britain
18%
Netherlands
4%
Poland
Germany
29%
Slovakia
54%
Belgium
52%
Czech Republic
34%
France
75%
Hungary
43%
Romania
21%
Slovenia
38%
Spain
17%
Bulgaria
36%
DER SPIEGEL
Sources: World Nuclear Association, IAEA; As of April 2011

What to do in case of a nuclear accident?

Emergency plan

Sheltering (absorbed dose for the body **more** than 5 mGy, for the thyroid 50 mGy)

Evacuation (absorbed dose for the body **more** than 50 mGy, for the thyroid 100 mGy)

Use of stable iodine (absorbed dose for the thyroid more than 100 mGy)

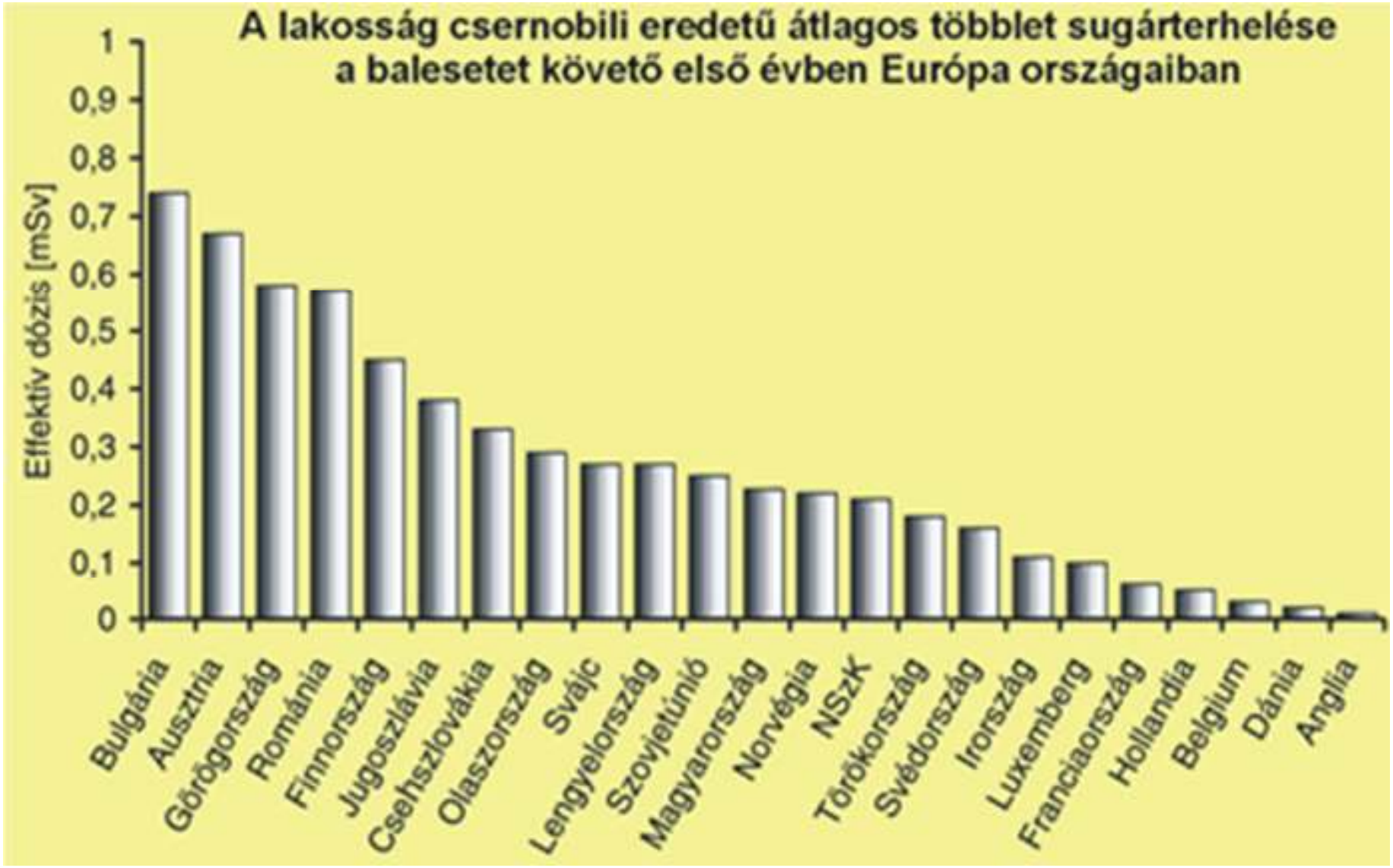
Administration of **pharmacological doses of stable iodine** can significantly decrease thyroid committed dose
by the following mechanisms:

a. by saturating active iodine transport into the thyroid and diluting the radioiodines taken up by the gland,

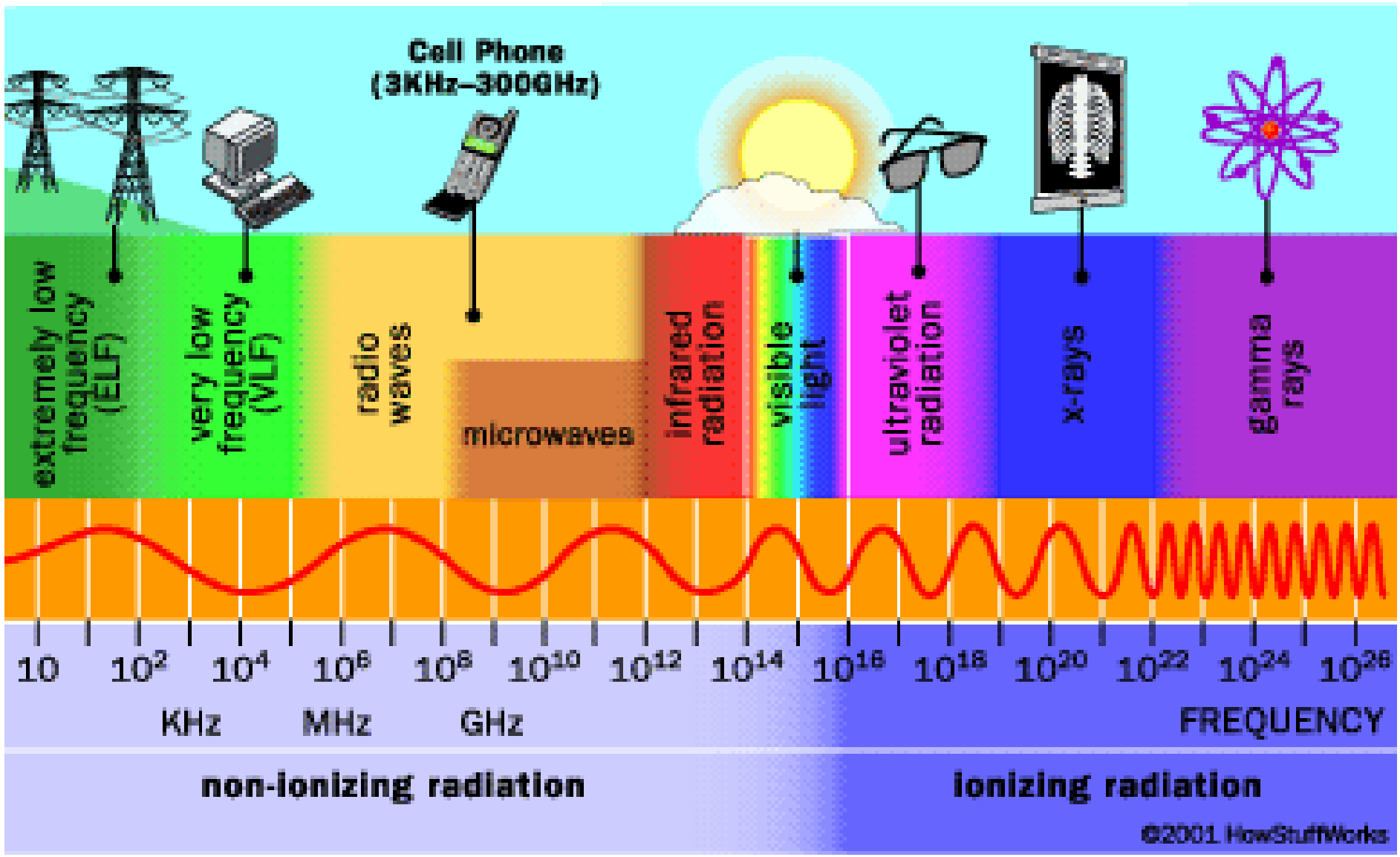
b. by increasing storage of stable iodine in the thyroid, thus leading to attainment of a new steady-state at lower level of (radio)iodine uptake,

c. by lowering circulating radioiodine and its thyroidal (re)uptake.

A **single dose of 130 mg of potassium iodine (KI) completely blocks the thyroid radioiodine uptake approximately 30 minutes after administration and keeps the suppression constant for about 24-30 hours**.
Such a dose will be about 25% effective 40 hrs after administration.



Surplus effective dose after the first year of the Chernobyl Nuclear catastrophe in European countries


Cell Phone
(3KHz–300GHz)
extremely low frequency (ELF)
very low frequency (VLF)
radio waves
microwaves
infrared radiation
visible light
ultraviolet radiation
x-rays
gamma rays
10
10^2
10^4
10^6
10^8
10^{10}
10^{12}
10^{14}
10^{16}
10^{18}
10^{20}
10^{22}
10^{24}
10^{26}
KHz
MHz
GHz
FREQUENCY
non-ionizing radiation
ionizing radiation
©2001 HowStuffWorks

Ultraviolet (UV) radiation is part of the **electromagnetic** spectrum emitted by the sun.

Whereas **UVC rays** (wavelengths of 100-280 nm) **are absorbed by atmospheric ozone**,
most radiation in the **UVA range** (315-400 nm) and about 10 % of **UVB rays** (280.315 nm) reach the Earth's surface.

Both UVA and UVB are of major importance to human health.

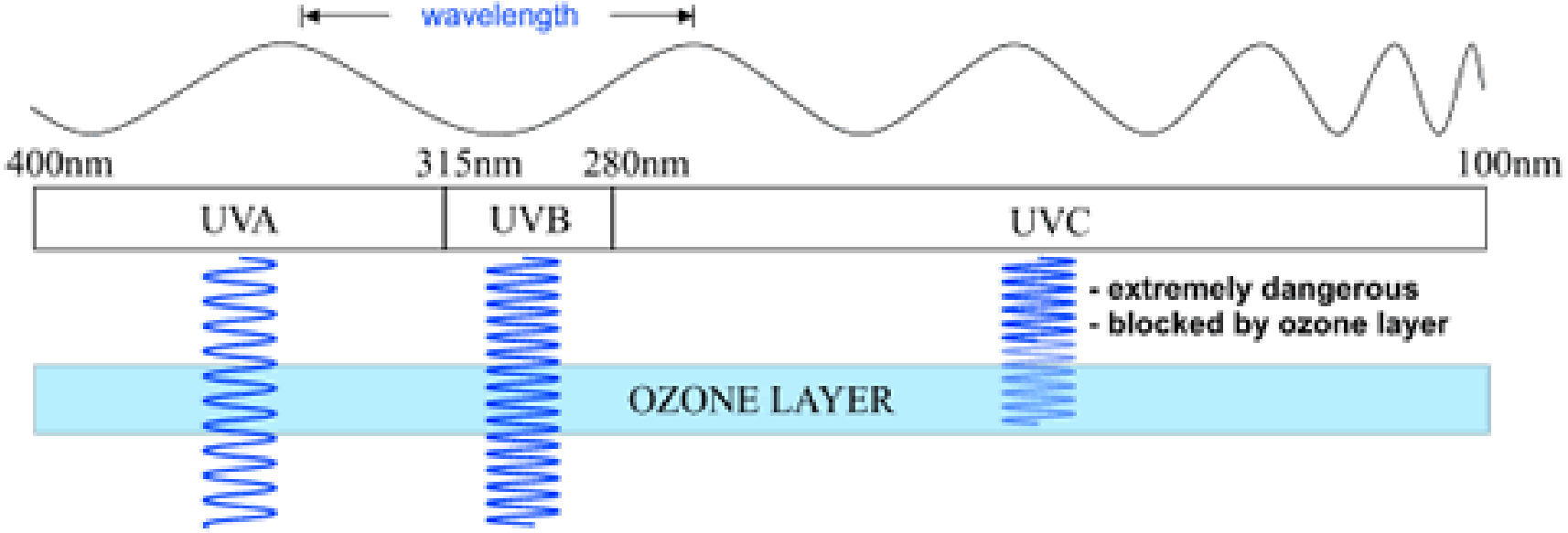
COUNTERTHINK

UV radiation

UV radiation

UV sterilisator

TYPES OF ULTRAVIOLET RADIATION

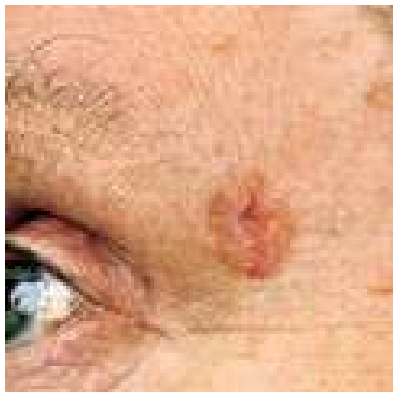


- premature ageing
- wrinkling of the skin
- implicated in skin cancer

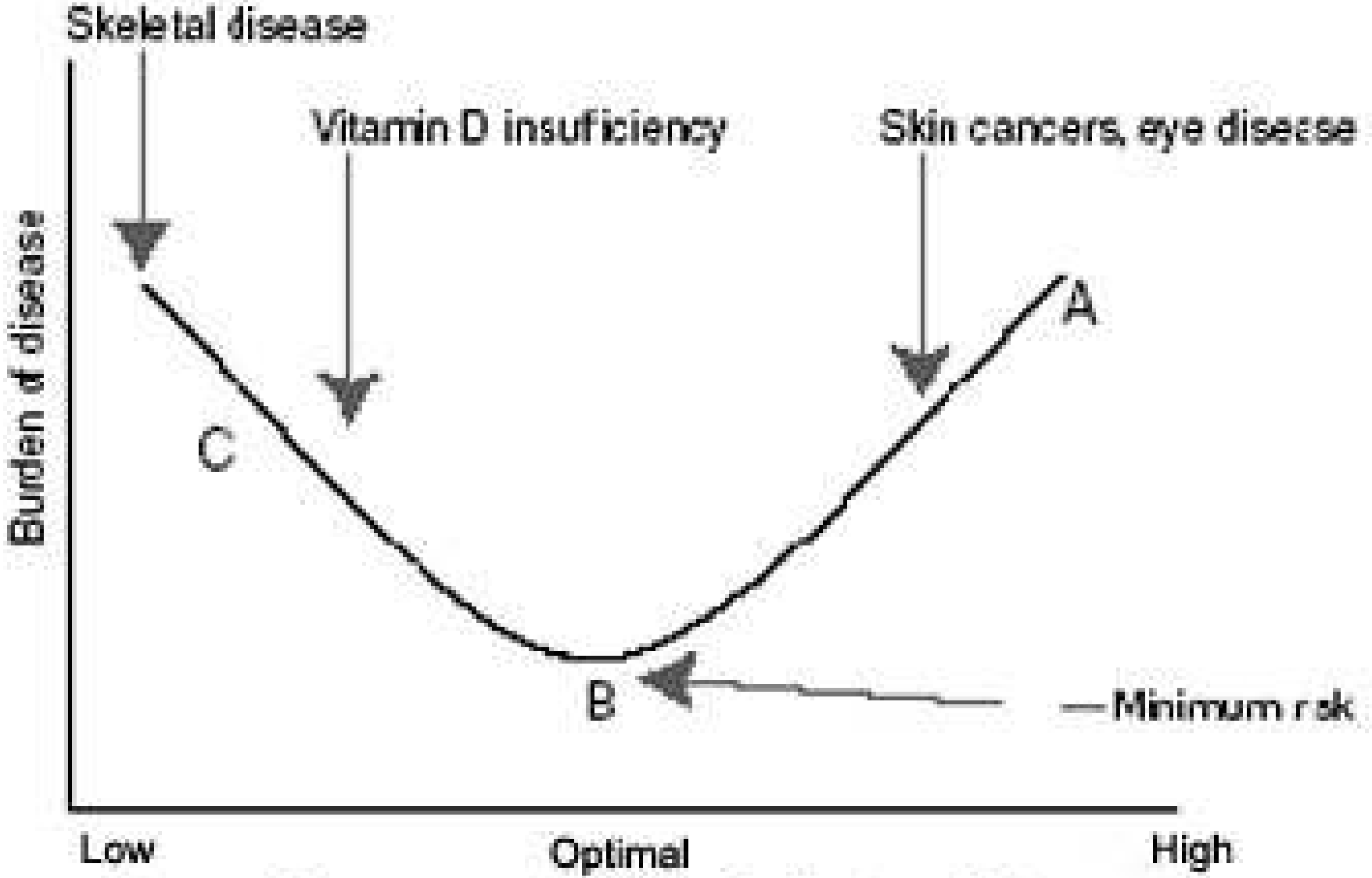
- skin cancer
- cataracts
- sunburn

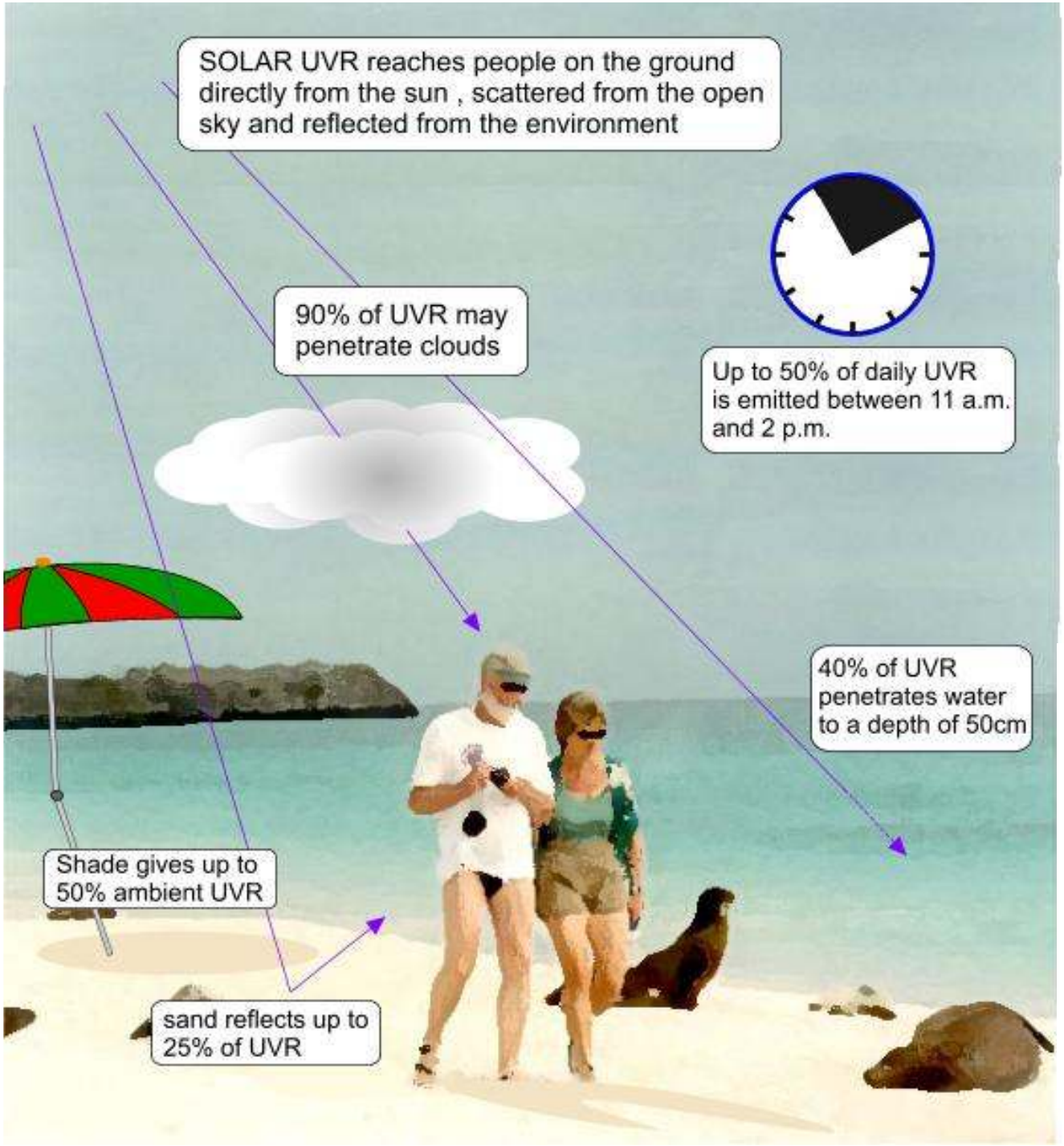
Sunburn

Photokeratitis



Basal cell carcinoma, squamous cell carcinoma and malignant melanoma

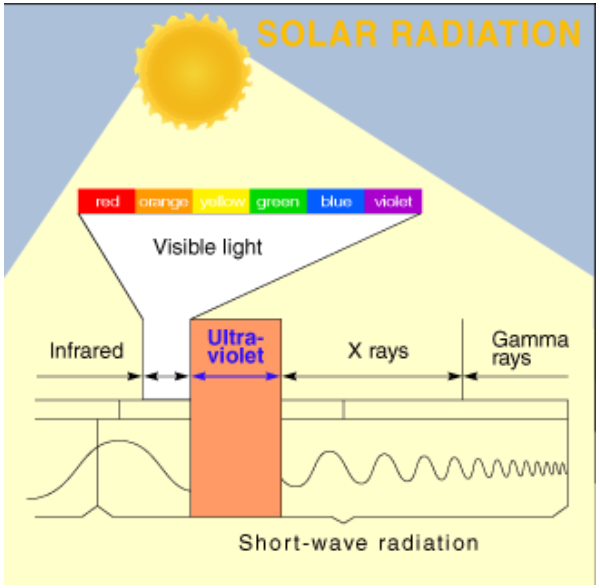

Skeletal disease
Vitamin D insufficiency
Skin cancers, eye disease
Burden of disease
A
C
B
Minimum risk
Low
Optimal
High
Personal exposure to UVR relative to skin type

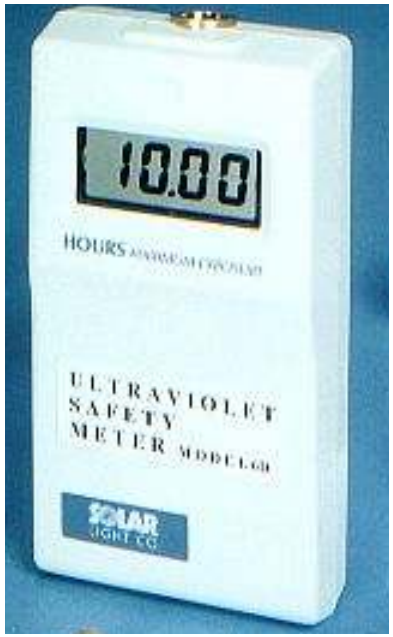

SOLAR UVR reaches people on the ground directly from the sun , scattered from the open sky and reflected from the environment
90% of UVR may penetrate clouds
Up to 50% of daily UVR is emitted between 11 a.m. and 2 p.m.
40% of UVR penetrates water to a depth of 50cm
Shade gives up to 50% ambient UVR
sand reflects up to 25% of UVR


1 2 3 4 5 6 7 8 9 10 11+
UV INDEX


Oregon
UV
3
017


UV INDEX 1
UV INDEX 2
UV INDEX 3
UV INDEX 4
UV INDEX 5
UV INDEX 6
UV INDEX 7
UV INDEX 8
UV INDEX 9
UV INDEX 10
UV INDEX 11+
NO PROTECTION REQUIRED
You can safely stay outside!
PROTECTION REQUIRED
Seek shade during midday hours!
Slip on a shirt, slop on sunscreen and slap on a hat!
EXTRA PROTECTION
Avoid being outside during midday hours!
Make sure you seek shade!
Shirt, sunscreen and hat are a must!


SOLAR RADIATION
red
orange
yellow
green
blue
violet
Visible light
Infrared
Ultra-violet
X rays
Gamma rays
Short-wave radiation



INTERSUN


solarwind
5000

❑Tanning beds and other tanning appliances

- involve considerable UV exposure
- a few contraindications of tanning (ICNIRP):
  - ✓ **age** < 18 years
  - ✓ **previous sunburn, or high risk skin type** (I, II)
  - ✓ a large number of **moles (naevi)**
  - ✓ **skin tumor in medical history or family history**
  - ✓ consumption of certain **photosensitizing drugs** (i.e.: tetracyclines, sulfonamides,)
- healthy use involves **technical monitoring of tanning beds** and **eye protection**

Microwave owen

A microwave telecommunications tower on Wrights Hill in Wellington, New Zealand.

Microwaves are **electromagnetic waves** with **wavelegths shorter than one meter and longer than one millimeter**, or frequencies between 300 megahertz and 300 gigahertz.

Microwave radiation of a level **that causes heating of living tissue is hazardous**.Still at issue is whether lower levels of microwave energy have bioeffects.

❑ Microwave ovens

- **home devices with intact protective grills are generally safe**
- according to certain studies, high output industrial ovens or damaged home ovens **may cause an increase in the frequency of miscarriages**
- pregnant women at risk of increased exposure at workplace should temporarily be offered alternative duties or suspended from work
- physiotherapeutic (diathermy) devices, which emit at RF and MW frequencies involve similar considerations (for both patients and staff)

Cancer?

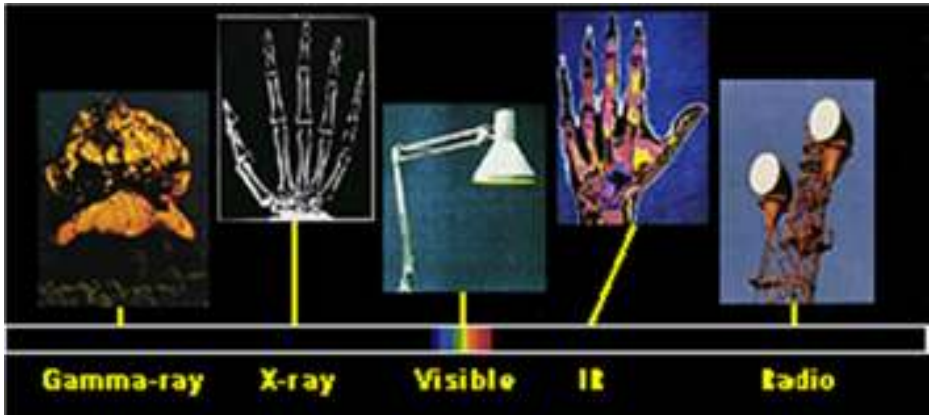
A study by the International Agency for Research on Cancer of 4,500 users found a statistically significant link between tumor frequency and mobile phone use.

What seems to matter is
the **power of the wave** hitting your head,

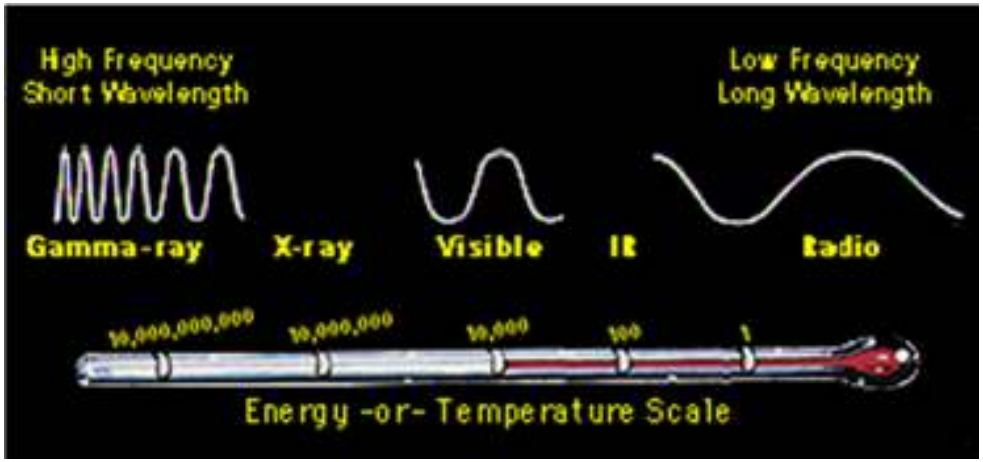
the **distance between sensitive tissue and high frequency waves**,

and the **duration of exposure**.

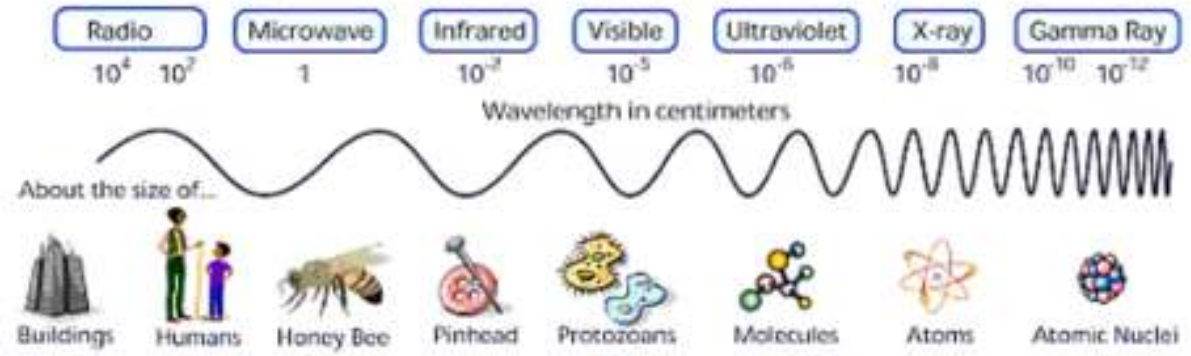
Indian monk with mobile phone

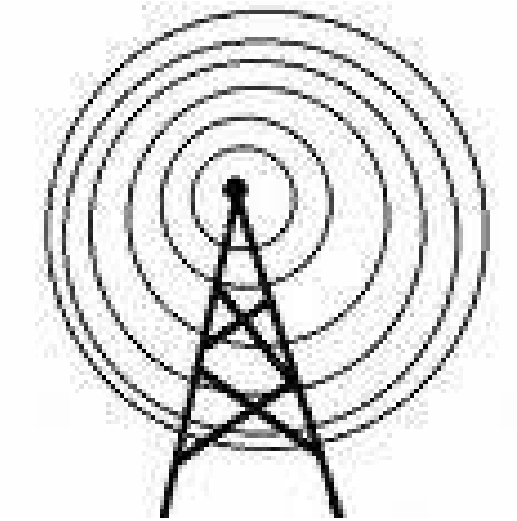


Radio waves, visible light, X-rays, and all the other parts of the electromagnetic spectrum are fundamentally the same thing, **electromagnetic radiation**.



The electromagnetic spectrum can be expressed in terms of **energy, wavelength,** or **frequency**.





acut injury (heat-injury)

carcinogenic effect?

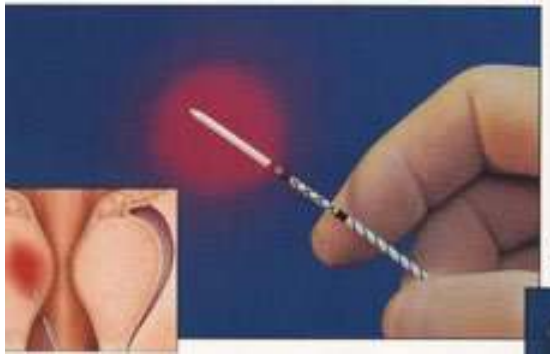
genetic effect?

cataract?

Laser (**l**ight **a**mplification by **s**timulated **e**mission of **r**adiation)
is made up of light waves that are nearly parallel to one another,
all travelling in the same direction.

Lasers emit beams of coherent light of a single color or wavelength and frequency in contrast to conventional light sources,
which produce random, disordered light wave mixtures
of various frequency,

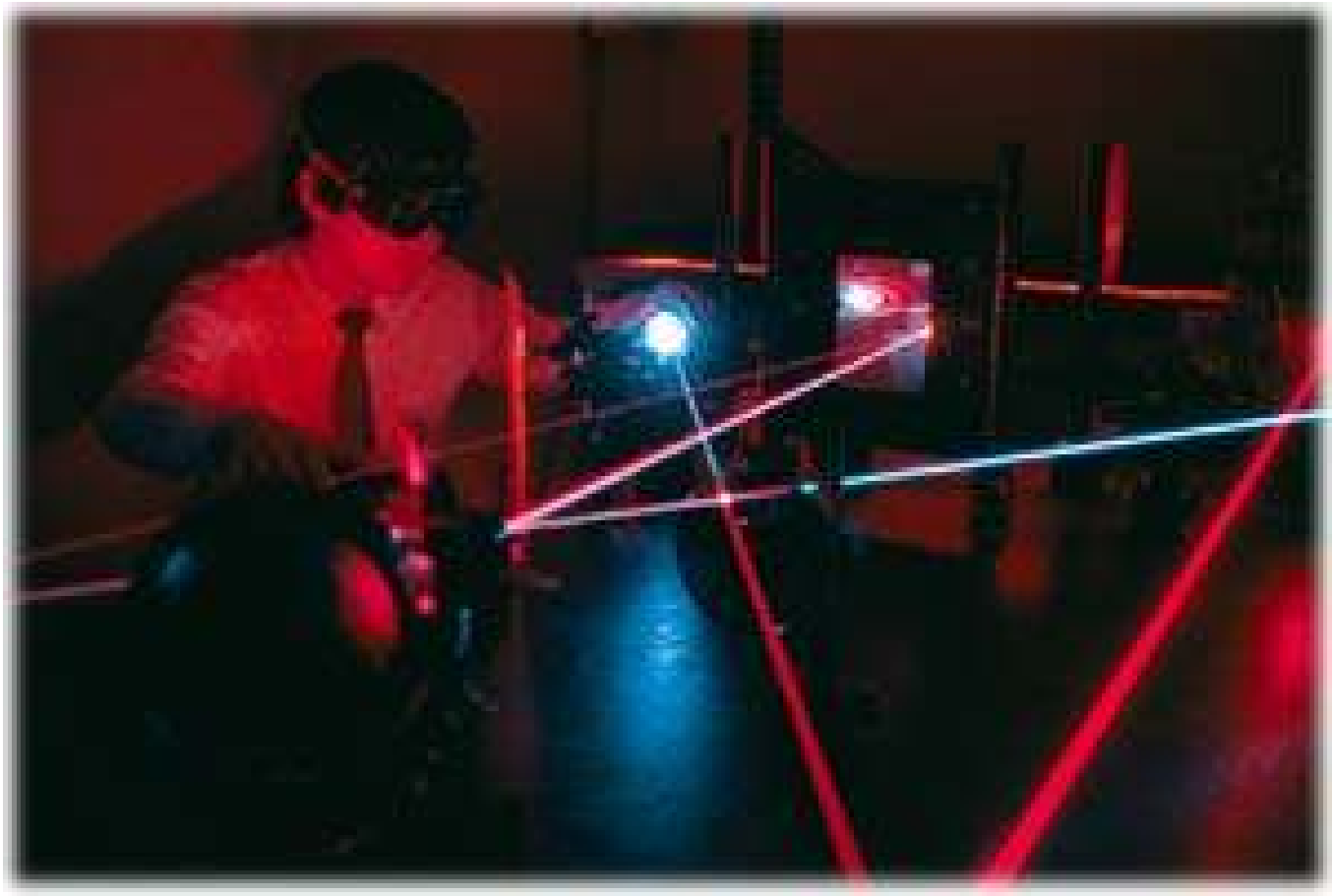
Laser



Lasers

- if pointed towards the eye, or reflected into the eye from a reflecting surface, **may cause retinal photocoagulation, cataracts or corneal damage**
- **high-output industrial laser can cause skin burns and extensive tissue damage**
- **following safety regulations is crucial**, use of protective eyewear

Laser



Yamamoto Kogaku Co. has developed laser **safety goggles and glasses** for workers associated with the operation of laser instrument.

Websites for further information

Hungarian sites (with English language support):

- www.osski.hu (Nat. Research Institute for Radiobiology and Radiohygiene)
- www.kfki.hu/~aekihp/index.html (Atomic Energy Research Institute)
- www.npp.hu (Paks Nuclear Power Plant)
- www.haea.gov.hu (Hungarian Atomic Energy Authority)

International sites:

- www.unscear.org (UN Scientific Committee on the Effects of Atomic Radiation)
- www.icrp.org (International Commission on Radiological Protection)
- www.icnirp.org (International Commission on Non-ionizing Radiation Protection)
- www.iaea.org (International Atomic Energy Agency)