# Nature of Radiation and DNA damage

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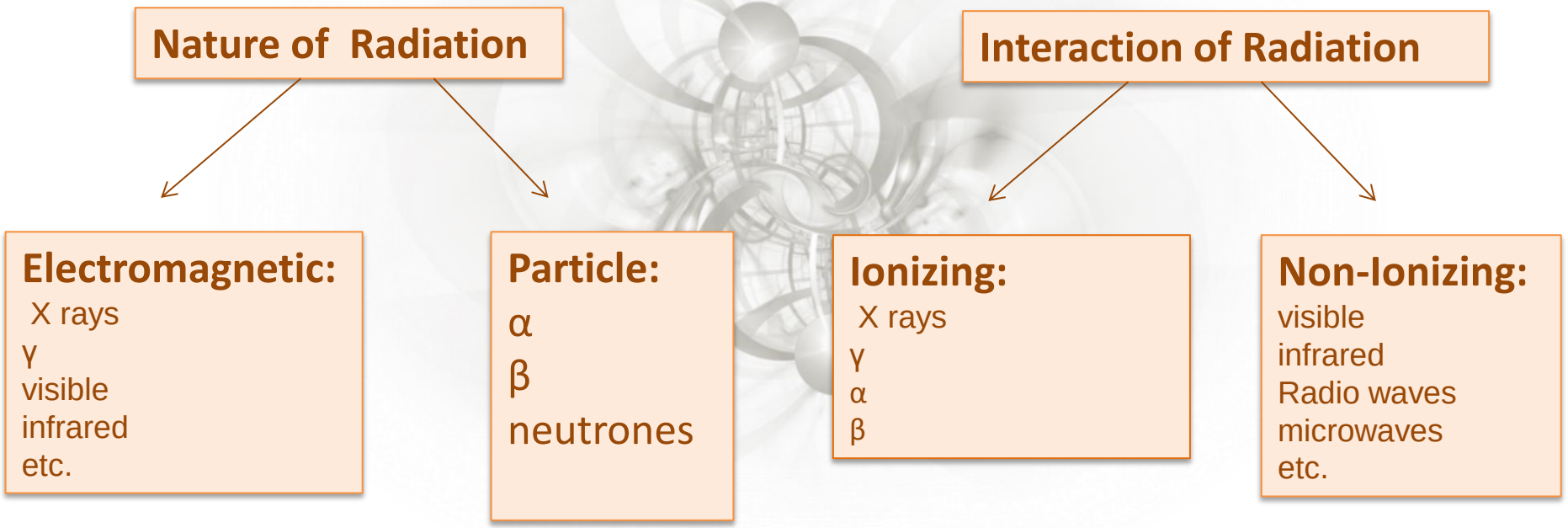
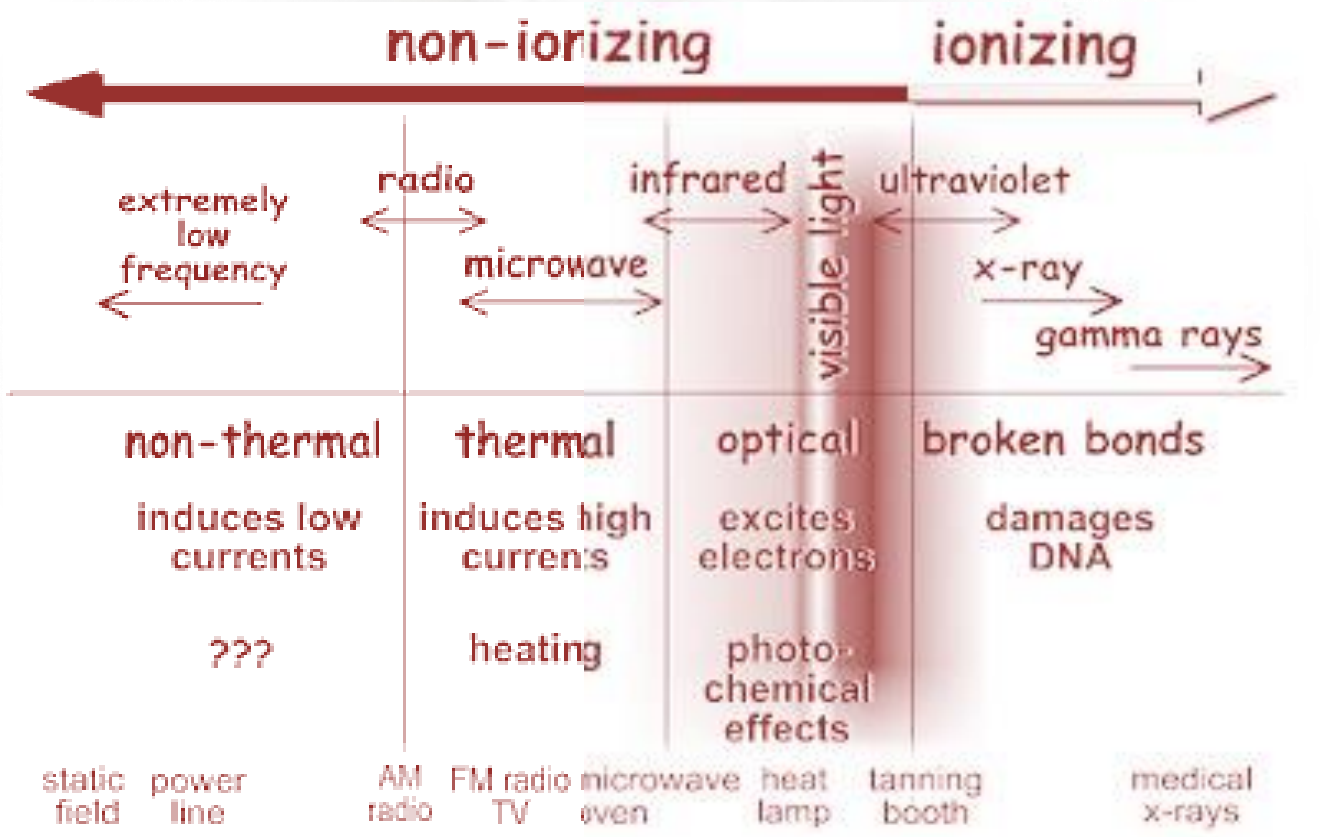
# What is Radiation?

- Radiation is **energy** travelling through space. Light, heat and sound are types of radiation.
- Radiation can have a form of **waves** or **streams of particles**.



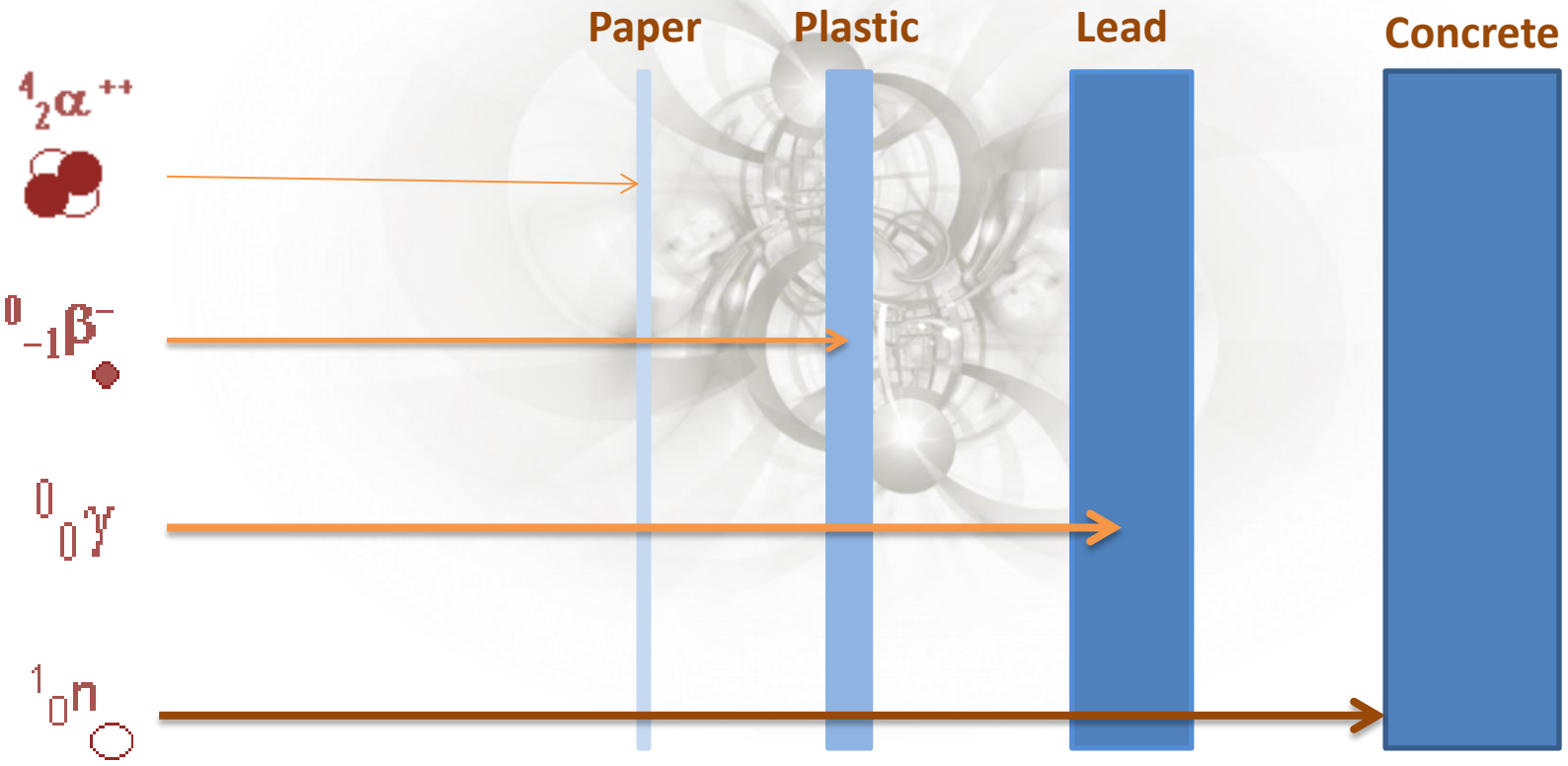
# Ionizing Radiation

- **Ionizing radiation** is radiation with enough energy to remove electrons from the orbit of an atom, causing the atom to become charged or ionized.



# Ionizing Radiation

- **Charged particles** interact strongly and ionize directly
- **Neutral particles** interact less, ionize indirectly and penetrate farther



# Ionizing Radiation

- **Alpha particle:** has two protons and two neutrons (helium nucleus). Has positive charge.
- $^{0}_{-1}e$ **Beta particle:** emission of electron from nucleus (neutron splits into the proton and electron)
- $^{0}_{1}e$ **Positron**: has same mass as electron but positive charge.

  Emitted from proton that splits into neutron and positive electron
- **Gamma Rays**: electromagnetic radiation. Emmition of photones from nuclues that is in excited state. Has the effect of moving the nucleus from a higher to a lower energy state
- **Neutrons**: high energy particles without charge

# Interaction of Gamma-radiation with Matter

**γ-rays** lose their energy when they pass through the matter , by:

- Interaction with the **orbital electrones**
- Interaction with the **nucleus** of the absorber atom

**γ-rays** may lose all their energy or only a part of it.

**Photoelectric Effect:**

γ-rays transfers **all** its energy to an **orbital electron** of the absorber atom whereby the electron (***photoelectron***) is ejected. The resultant vacancy in this shel can be filled by an electron from another shell and **X-ray is generated** from the transition.

**Compton Effect:**

γ-rays transfers **part of** its energy to an **electron in outer shell** of the absorber atom and the elctron is ejected. The photon with reduced energy **is deflected** in another direction.

# Radiobiology

**Some basic priciples:**

- The interaction of radiation with the cells is a **probability function**
- **Very quick** absorption of the energy.
- **Non selective interaction** – radiation can't „choose" witch cells will affect
- Radiation **always cause injury** as a consequence of energy absrobtion. However the effect depends on each tissue sensibility
- The produced lesions are **not specifc** – they can be produced also by other causes.

**LET - linear energy transfer**

Used in radiobiology and radiation protection for defining the **quality of an ionizing radiation beam**. LET focuses attention on the linear rate of energy absorption by the absorbing medium as the charged particle traverses the medium.

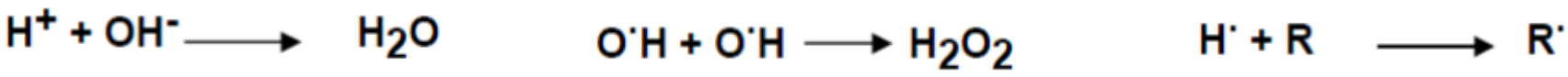
The unit reserved for the LET is **keV/µm** ..

# Direct and Indirect action

When the ionizing radiation is absorbed in biological material, the damage to the cell may occur in one of two mechanisms:

- **Direct**: transfer of energy (ionization) to **macromolecules such as DNA, RNA**. Damage is produceddirectly. This is the dominant mechanism in the interaction of high LET particles such as neutrons or alpha particles with biological material.

- **Indirect: intracellular medium** (mainly water) absorbs energy. Radiolysis is caused and ions **H+** and free radicals **(H•, OH•)** are released. These reactive species bring about the indirect radiation damage to biological system by reacting and damaging the molecules in cells.



# Steps of biological damage

TIME (s)

1. **PHYSICS**: absorption of energy:
   1. Ionization of atoms (high energy electron is ejected)
   2. Excitation: electrones from lower energy orbitals goes to higher energy ones

$10^{-18}$ - $10^{-12}$

2. **CHEMISTRY**:
   1. The high particle is moving through tissue produces free radicals in water.
   2. The free radicals may produce damage in DNA (breakage of chemical bonds)

$10^{-12}$ - $10^{-6}$

3. **BIOLOGY**:
   1. Biochemistry: lesion and reparation of genome.
   2. cell/tissue: quick and late effects

$10^{-3}$ - hours/days/generations

# DNA damage

**Types of DNA damage:**

- **Single strand breaks (SSB):** break sugar/phosfate or sugar/base. Break in one or both strands. Cell can easily repair this damage**.**
- **Double strand break (DSB):** breaks in both strands in proximal places. Formed as the consequence of the attempted repair of UV radiation-induced base damage in DNA.
- **Nitrogenous base damage**: hidroxilation, dissemination, loss of base. Bases are not iqualy sensitive to radiation: thymine>cytosine>>adenine>guanine
- **Damaged sugars**
- **DNA strand cross-links**
- **Multiple localized damage**: containing all types of damages

**The higher the dose of radiation is – more lesions are produced ad more strand breaks occurs**

# DNA reparation and Mutations

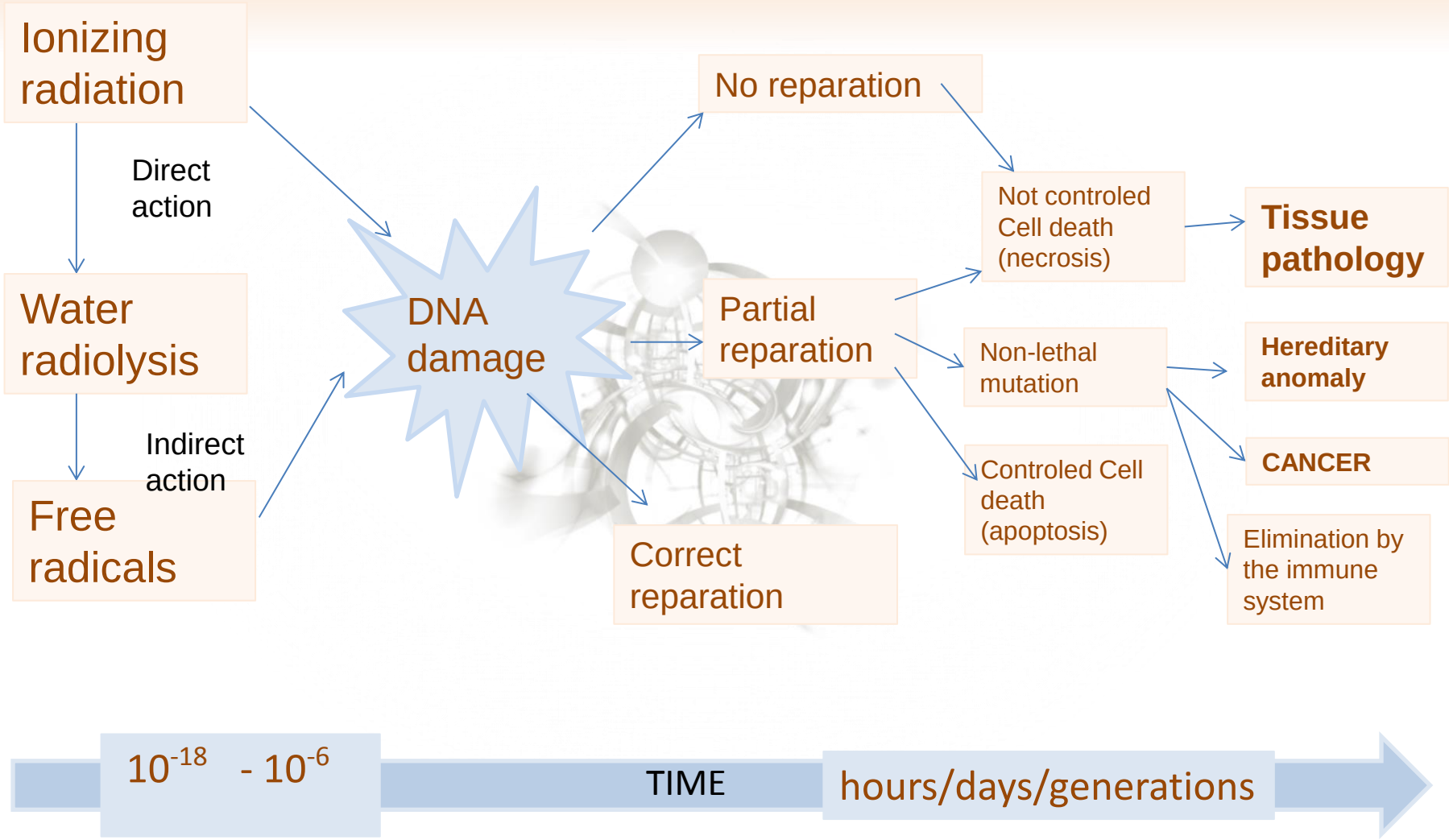
**Cell has mechanisms of DNA reparation. If the lesion is not repaired mutation appears.**

**Results of the DNA break reparation:**

- Union correct -> no biological impact
- No union -> deletion
- Union incorrect-> chromosomic aberration or structural anomalies.
    - Non-stable aberrations: lead to cell death
    - Stable abrrations: cell is compatible to survive

- **MUTATION**:
    - Affects both **somatic** and **germ** cells
    - Radiation induced mutation are **not specific**.
    - Radiation increases **frequency** of mutations
    - **No treshold dose**. Any radiation can lead to mutation. Higher the dose is, higher is the probability of mutation (**cumulative effect**)

# Consequences of mutations



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