

# Medical Biophysics I.

Introduction, Radiations  
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**SEMMELWEIS**  
EGYETEM 1769

# Objectives and methods of medical biophysics

## **Objectives:**

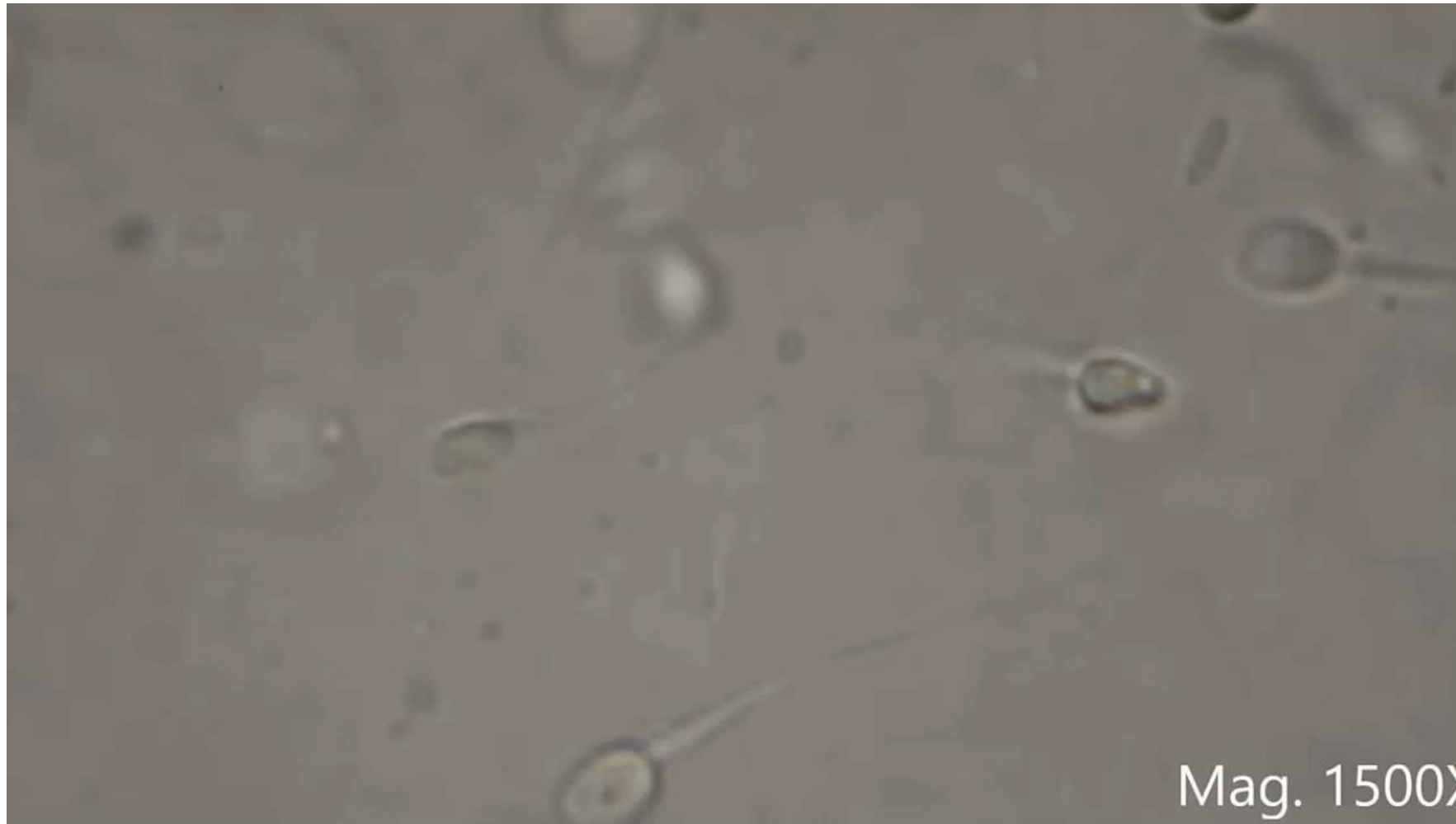
1. Provide a *physical* “description” of biomedical phenomena
2. Discuss and understand *physics*-based medical techniques

## **Methods:**

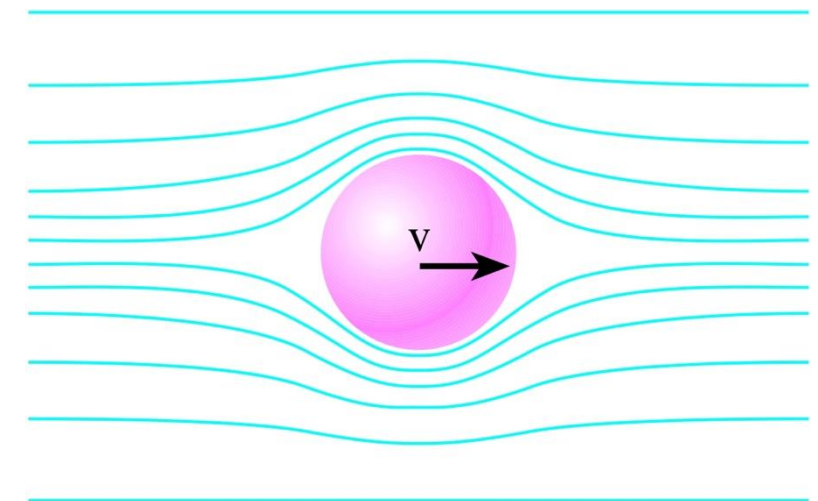
Biomedical phenomena and processes are

1. quantified
2. simplified

# Physical description of a biological phenomenon



Stokes' law:



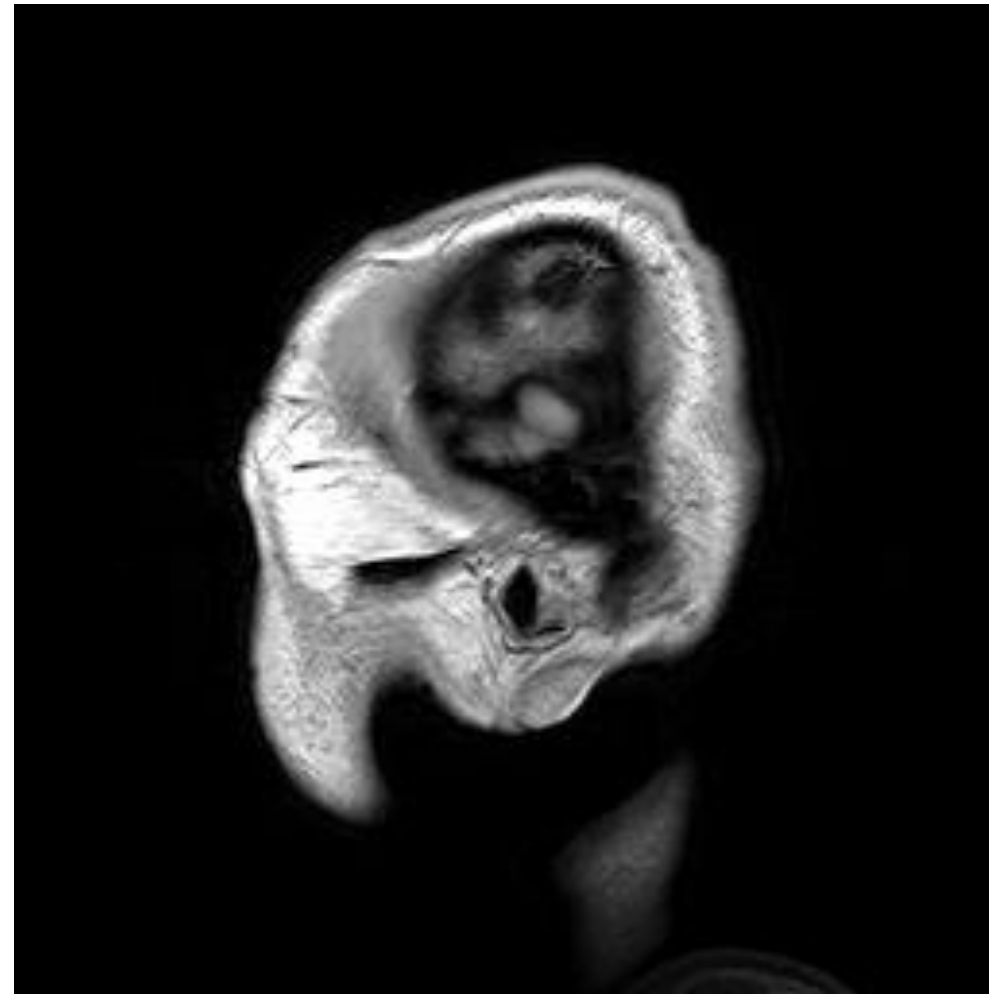
$$F=6r\pi\eta v$$

## Questions we might ask:

1. How much force ( $F$ ) is necessary for a spermatozoon to travel with a given velocity ( $v$ )?
2. How does it happen (what is the exact mechanism)? Can we build a predictive model?

# Understanding a physics-based medical technique

How does the MRI work?



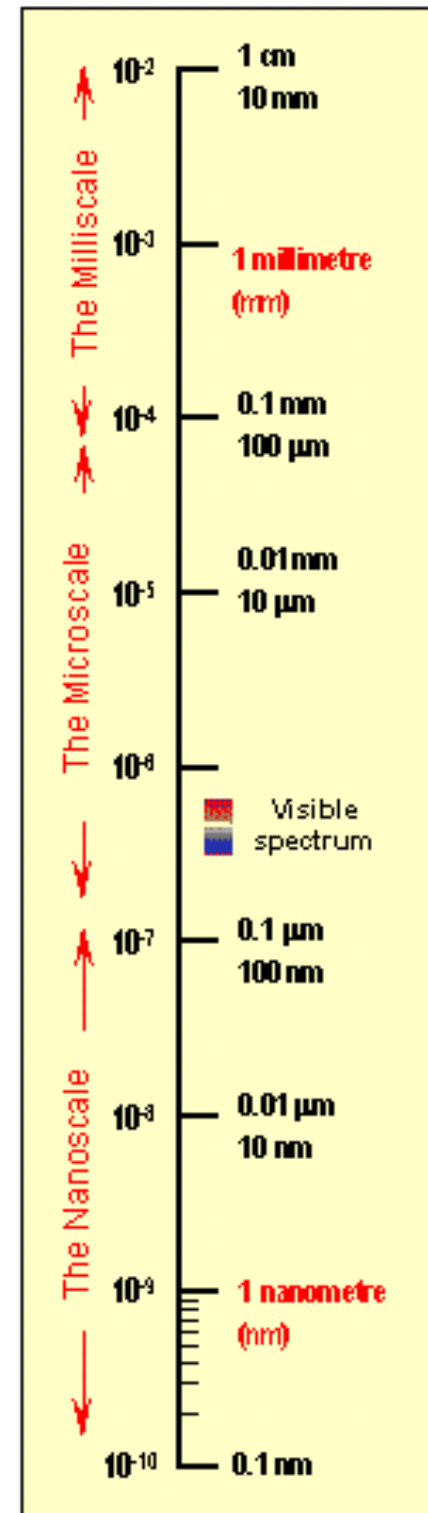
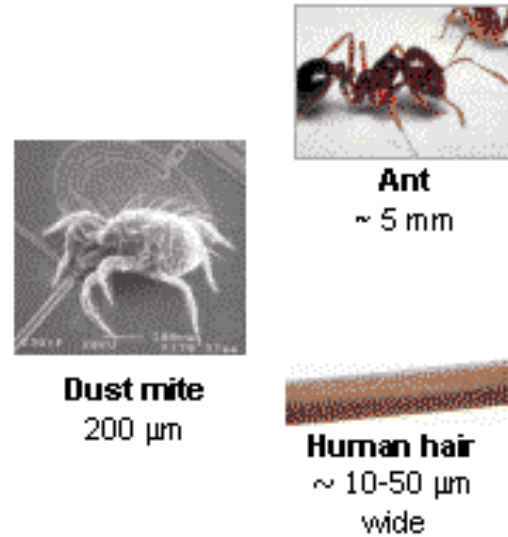
## Questions we might ask:

1. What is this? (Magnetic Resonance Imaging)
2. What physical phenomena are utilized? (magnetism, radiations, absorption, emission)
3. What can MRI reveal about the human body? (structure, function, tissue composition)

# Quantify Dimensions of Living Systems

Thermodynamics

$10^{23}$   
Atoms



$10^{10}$   
Atoms

Mesoscale



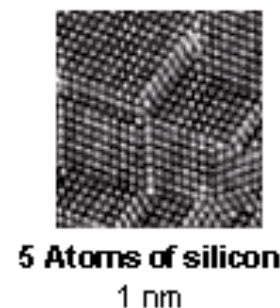
$10^3$   
Atoms



Quantum chemistry

$10^1$   
Atoms

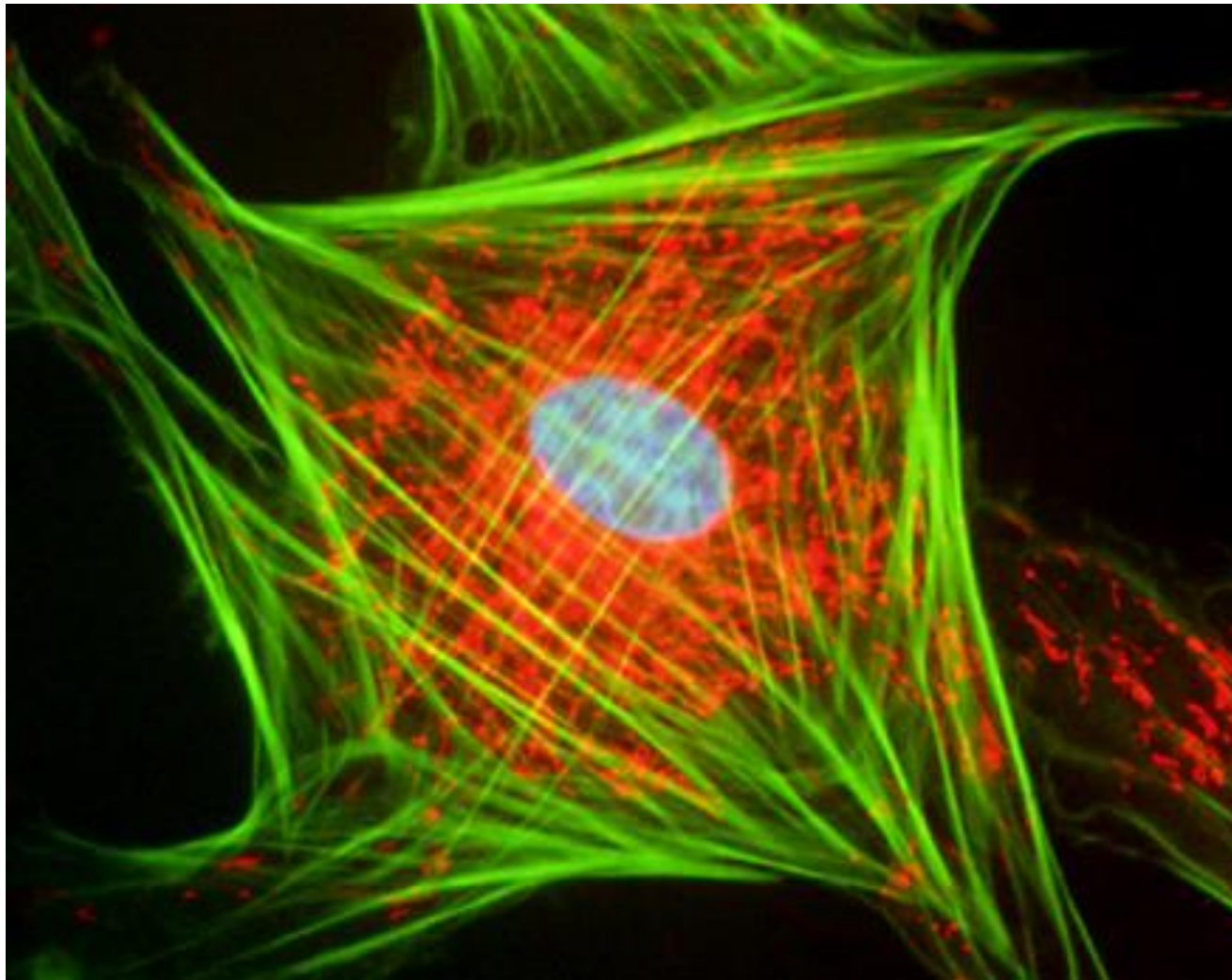
Quantum physics



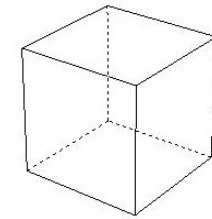
$10^0$  Atom

# Simplify

## Model of the cell and of a molecule

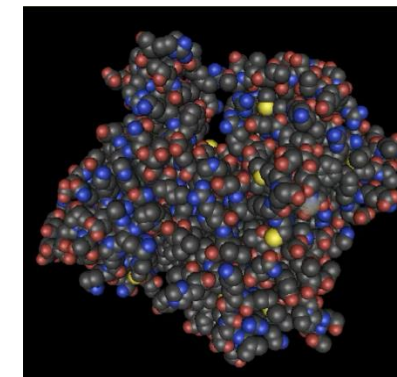
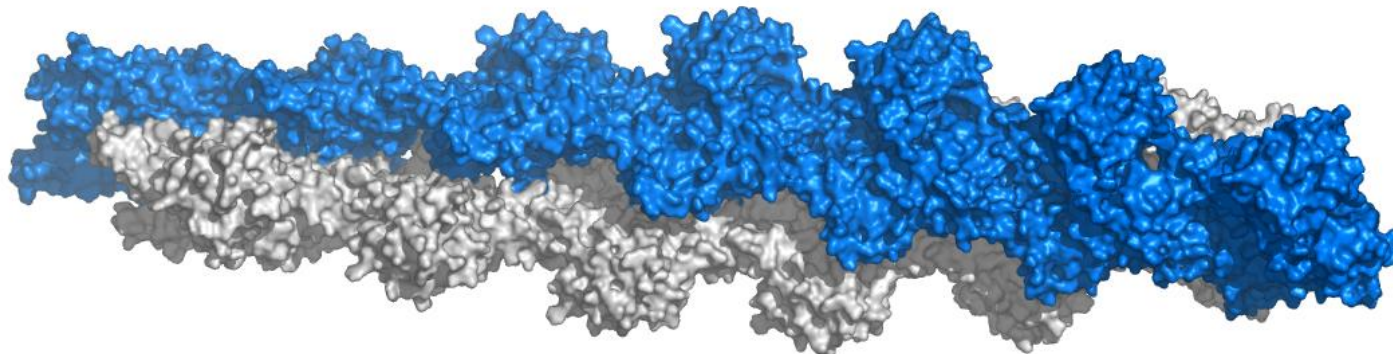


Simplified cell model: cube



	<b>Cell:</b> cube with 20 $\mu\text{m}$ edge	Analogue - <b>Lecture hall:</b> cube with 20 m edge
Size of actin molecule	5 nm	5 mm
Number of actin molecules	~500 thousand	~500 thousand
Average distance between actins	~250 nm	~25 cm

Actin filament  
(filamentous  
or F-actin)  
( $d=7$  nm)



Actin monomer  
(globular or G-actin)  
( $d=5$  nm,  $cc \sim 100 \mu\text{M}$ )

Deficiencies of the model: in reality the concentrations vary locally, and dynamics and collisions also take place.

# Radiation is everywhere



Emission spectrum of the H-atom



Orion Nebula



Source



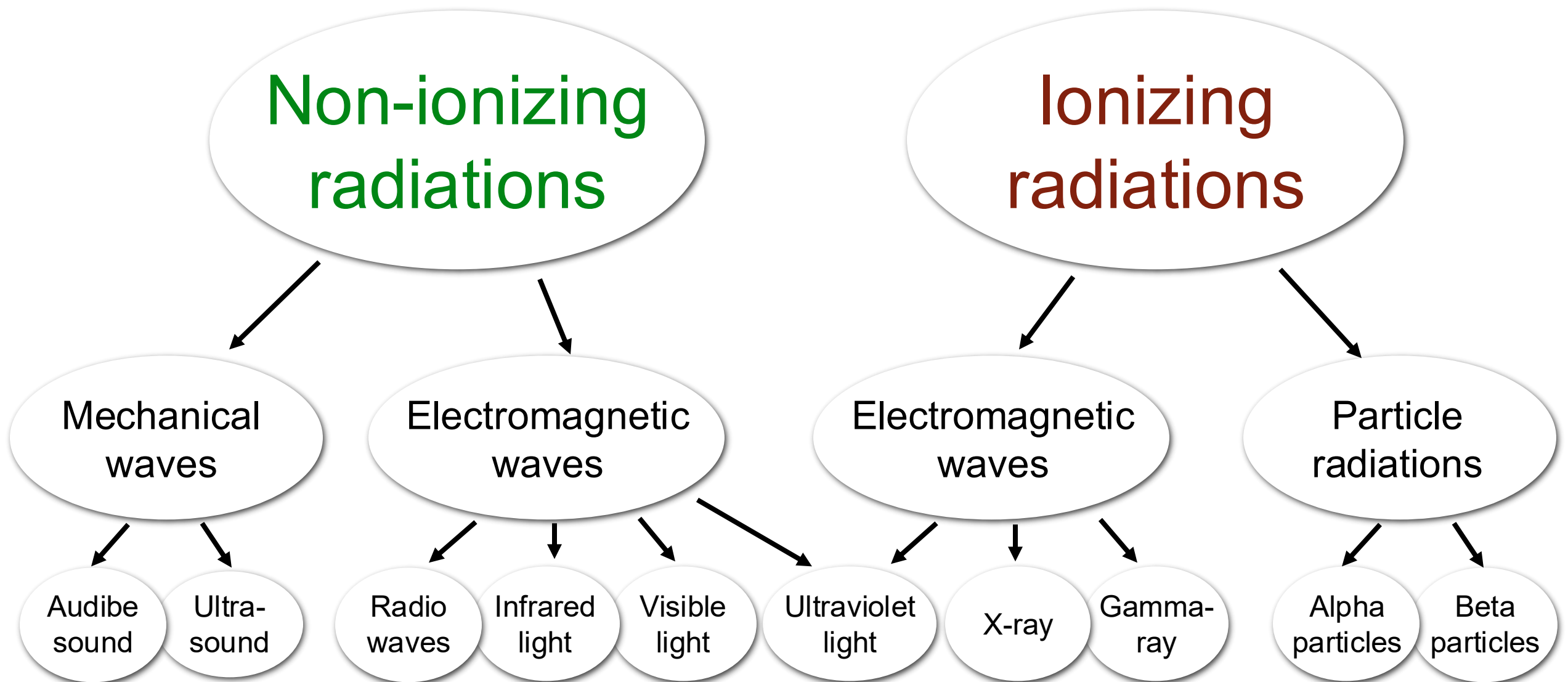
Radiation



Irradiated object



# Types of radiation



# Radiation = propagating *energy*

In the form of waves, or subatomic particles emitted by an atom or body as it changes from a high energy state to a lower energy state.

Energy,  $E$ :

$$[E] = \text{J (Joule)}$$

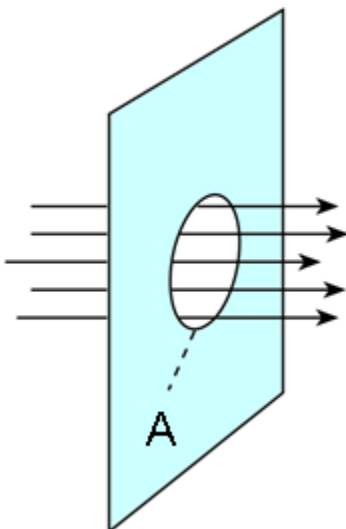
Radiant flux; radiant power:

$$P = \frac{\Delta E}{\Delta t}$$

$$[P] = \text{W (Watt)}$$

$\Delta E$ : energy carried during  $\Delta t$  time

Radiant intensity



$$J = \frac{P}{A} = \frac{1}{A} \frac{\Delta E}{\Delta t}$$

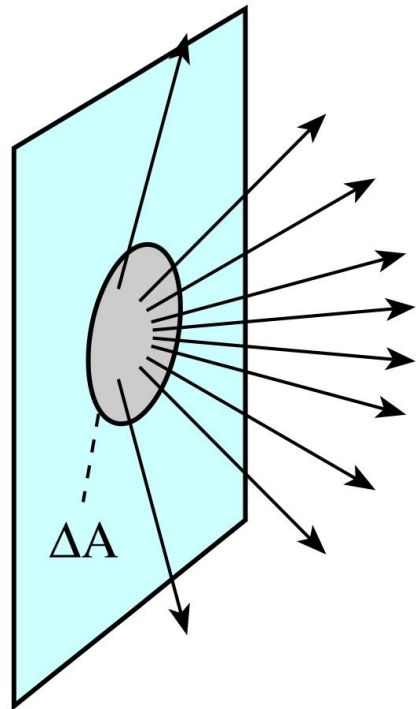
$$[J] = \text{W/m}^2$$

$A$ : area (perpendicular to the direction of energy propagation)

# Parameters of radiometry

Radiance

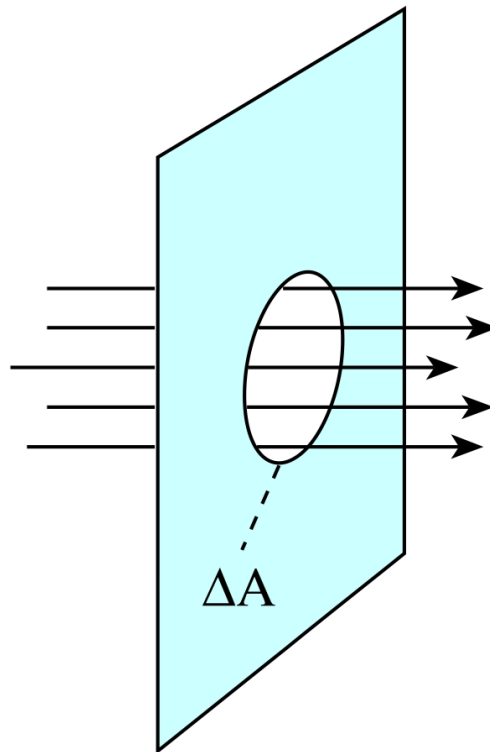
$$M = \frac{\Delta P}{\Delta A} \left[ \frac{\text{W}}{\text{m}^2} \right]$$



Power radiated by unit area into a solid angle of  $2\pi$ .

Radiation intensity

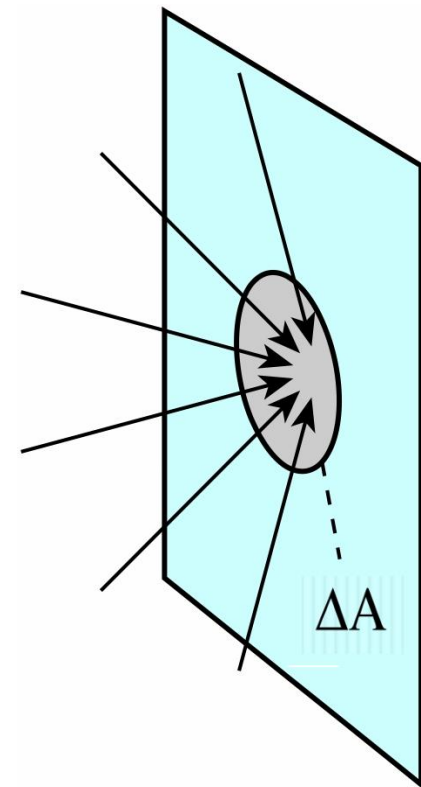
$$J_E = \frac{\Delta I_E}{\Delta A} \left[ \frac{\text{W}}{\text{m}^2} \right]$$



Power propagating through unit area.

Irradiance

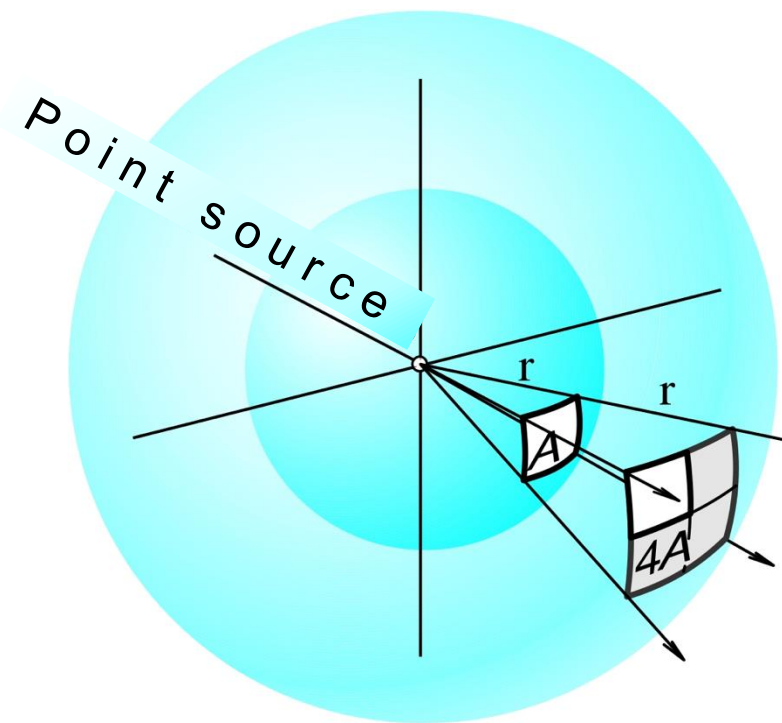
$$\varepsilon = \frac{\Delta P}{\Delta A} \left[ \frac{\text{W}}{\text{m}^2} \right]$$



Power incident on a surface of unit area (radiation may arrive from all directions). (other symbol  $E_{inc}$ )

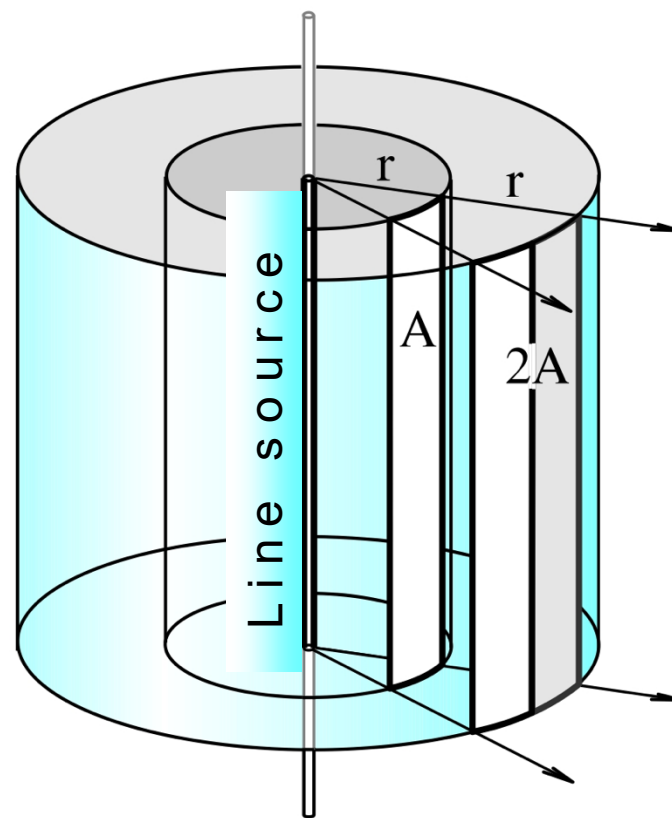
# Radiant intensity as a function of the geometry of radiation source

Radiation is distributed on an imaginary surface ( $A$ ) around the radiation source



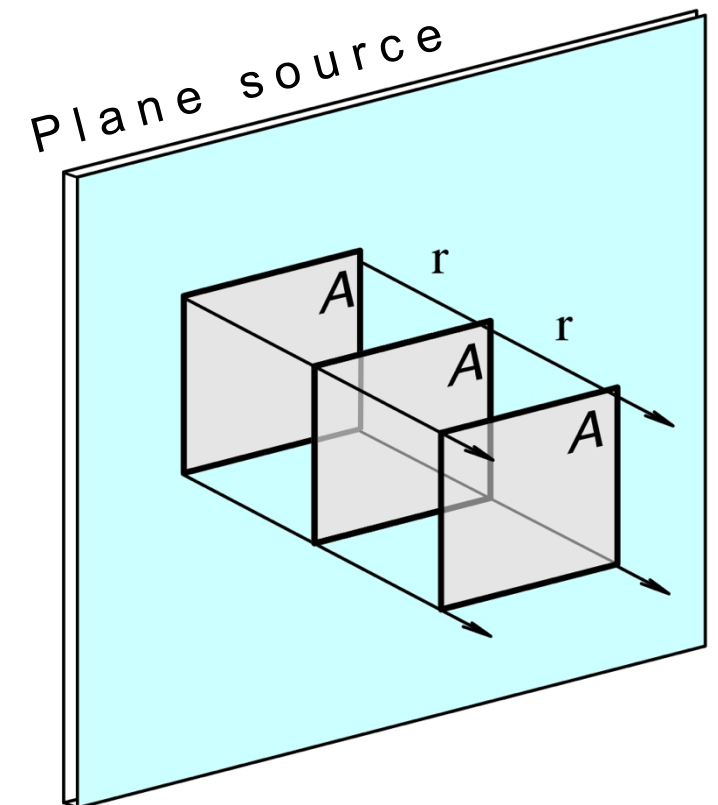
$$A_{\text{sphere}} \sim r^2$$

$$E_{\text{inc}} \sim 1/r^2$$



$$A_{\text{cylinder}} \sim r$$

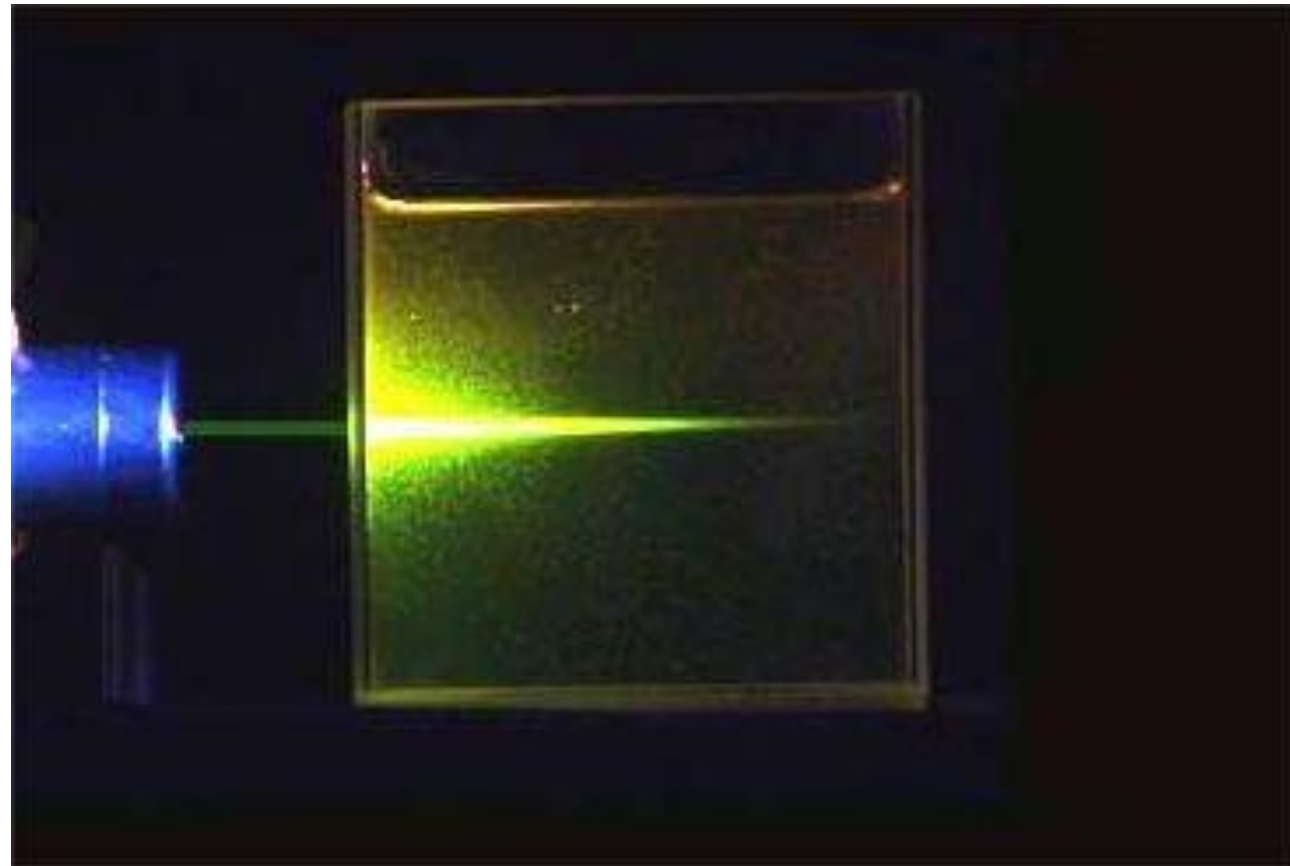
$$E_{\text{inc}} \sim 1/r$$



$$A = \text{constant}$$

$$E_{\text{inc}} = \text{constant}$$

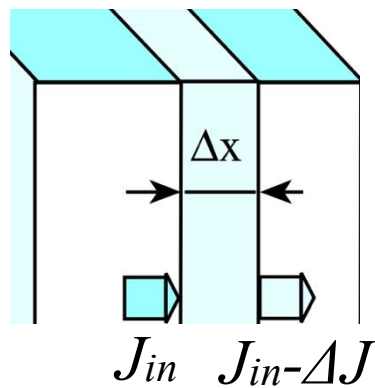
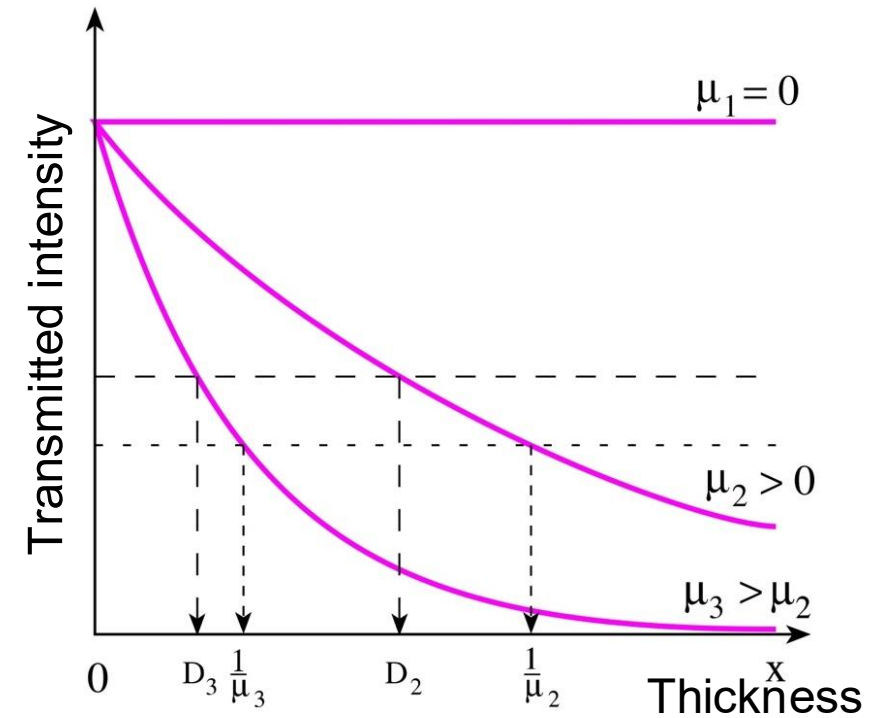
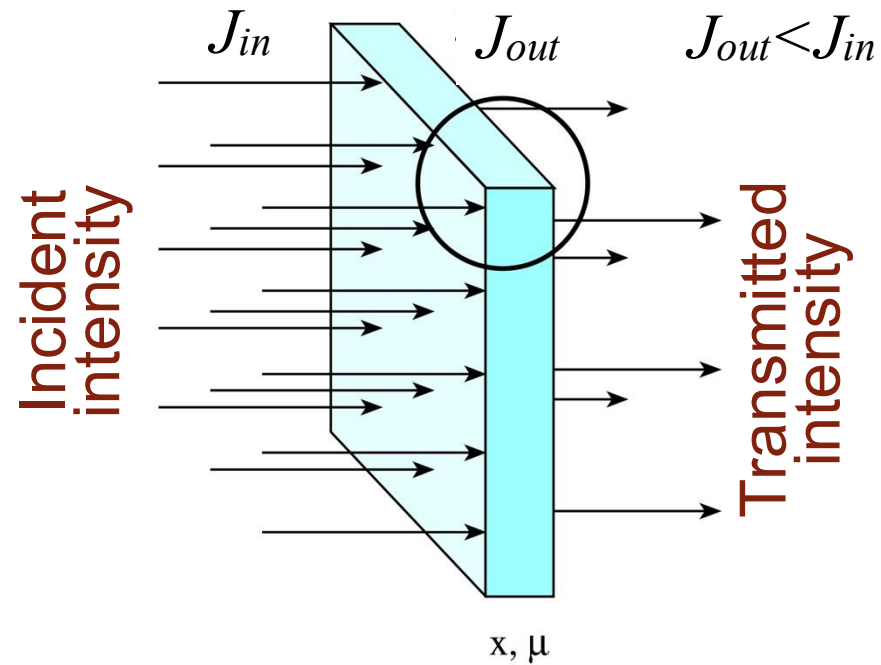
# As radiation travels through matter, its intensity decreases



(Radiation that exits is weaker than the one that enters)

Is there a simple, general law to describe this phenomenon?

# General radiation attenuation law



A given quantity ( $J$ ) and its change ( $\Delta J$ ) are proportional:

$$\Delta J = -\mu \Delta x J_{in}$$



Exponential function:

$$J_{out} = J_{in} e^{-\mu x}$$

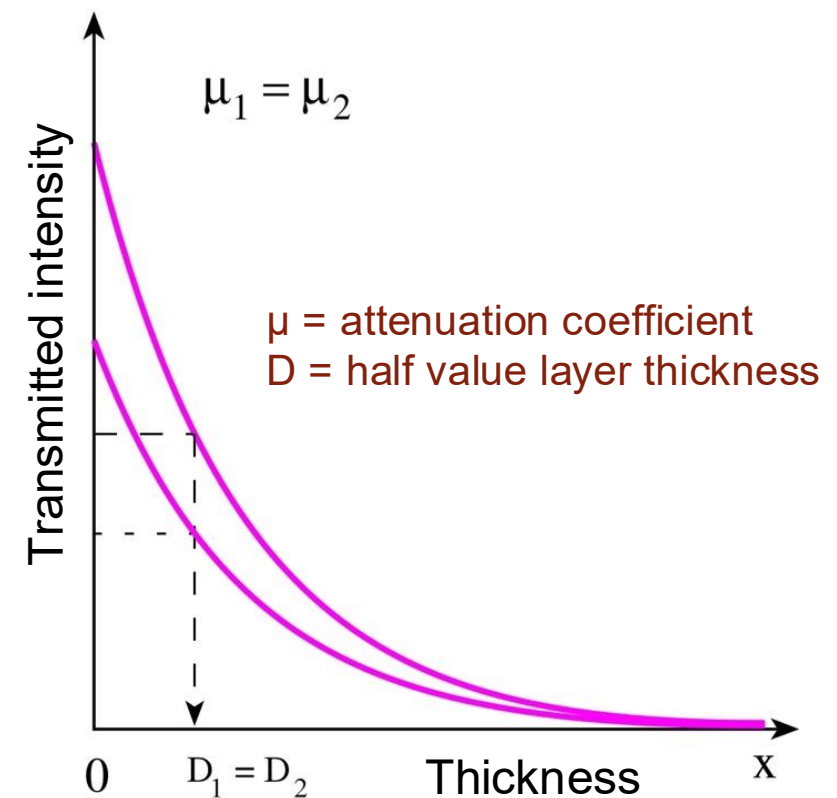
$$J = J_0 e^{-\mu x}$$

Properties of  $\Delta J$ :

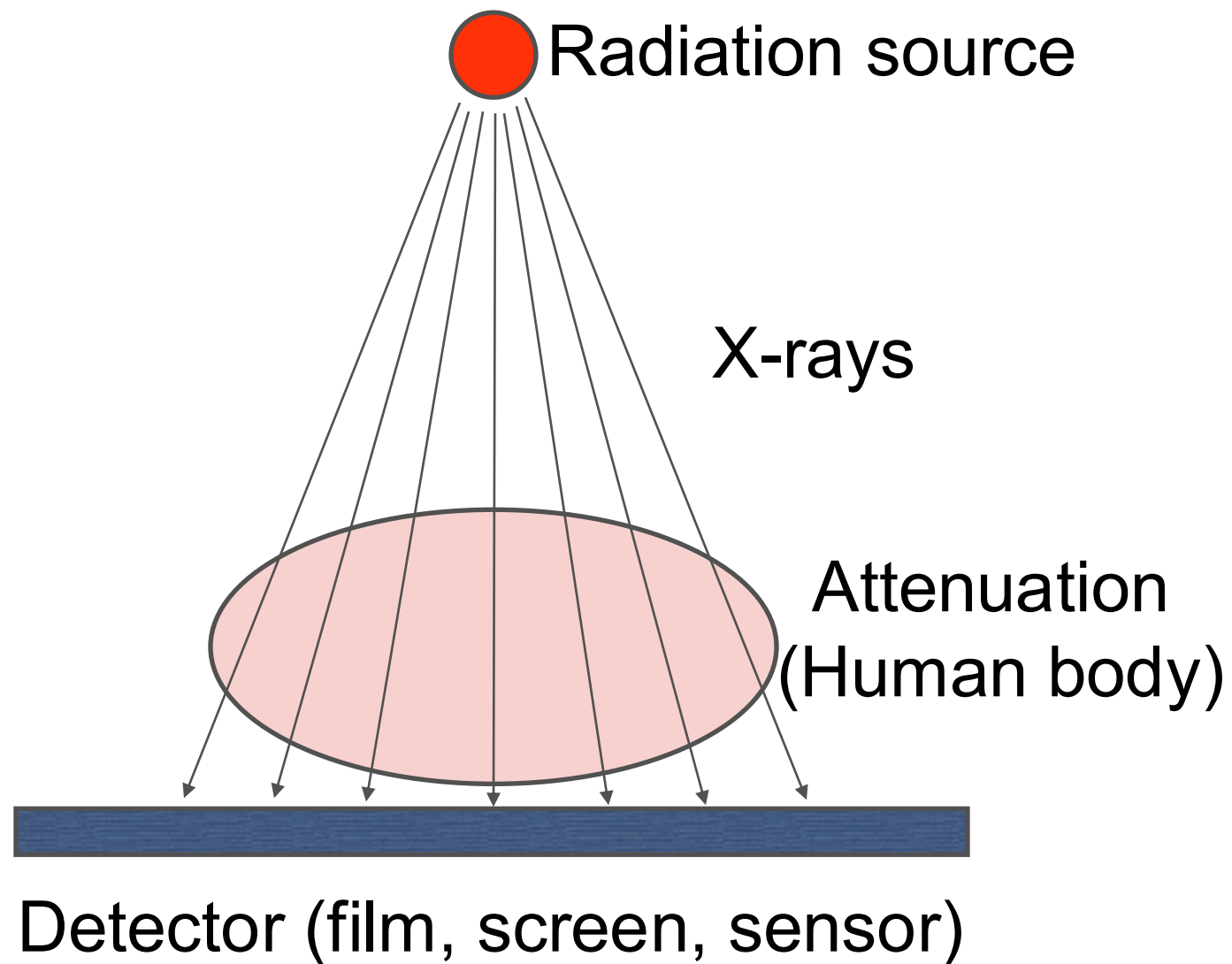
$$\Delta J \sim J_{in}$$

$$\Delta J \sim \Delta x$$

$$\Delta J \sim \mu$$



# Medical relevance



Chest x-ray

# Feedback



<https://feedback.semmelweis.hu/feedback/index.php?feedback-qr=FBPK2BCPVX2QHB9K>