Medical Biophysics

Introduction. Radiations.

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Objectives and methods of medical biophysics

Objectives:

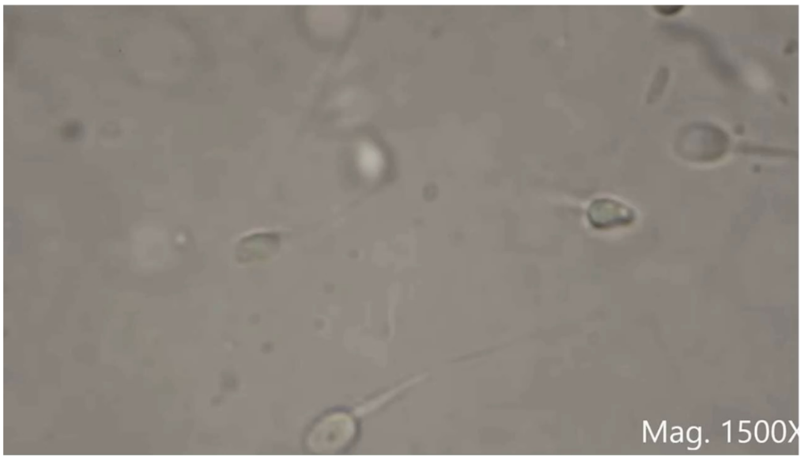
1. Provide a *physical* “description” of biomedical phenomena
2. Discuss and understand *physics*-based medical techniques

Methods:

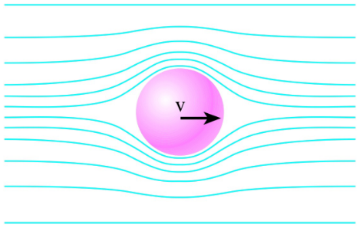
Biomedical phenomena and processes are

1. quantified
2. simplified

Physical description of a biological phenomenon



Stokes' law:



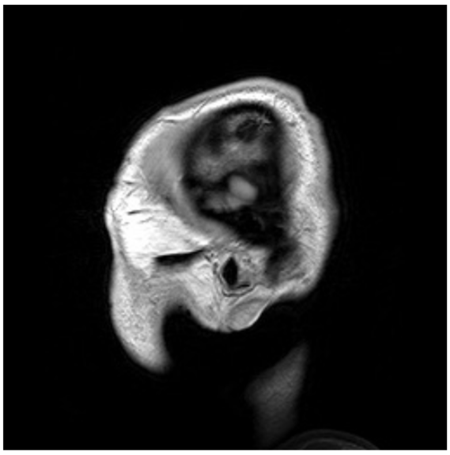
$$F=6r\pi\eta v$$

Questions we might ask:

1. How much force (F) is necessary for a spermatocyte 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)

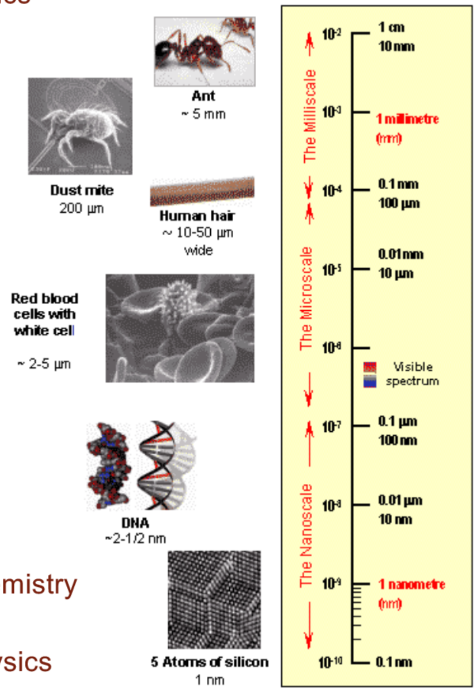
Quantify
Dimensions of Living Systems

Thermodynamics — 10^{23} Atoms

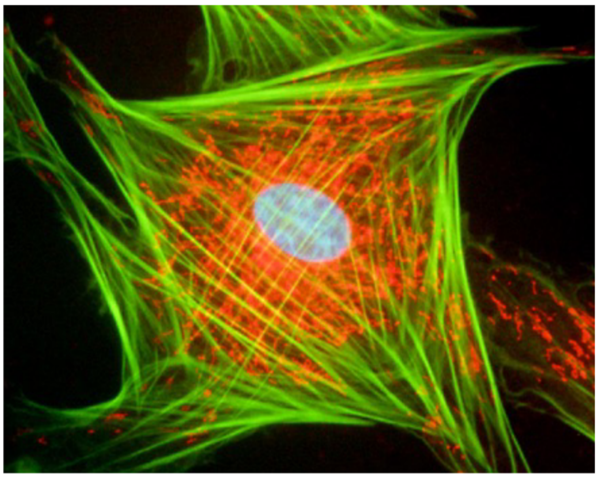
Mesoscale — 10^{10} Atoms — 10^{3} Atoms

Quantum chemistry — 10^{1} Atoms

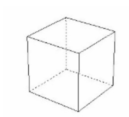
Quantum physics — 10^{0} Atom



Simplify
Model of the cell and of a molecule

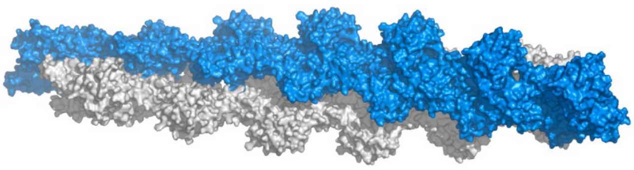


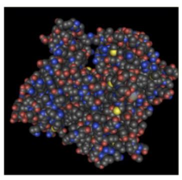
Simplified cell model: cube



	Cell: cube with 20 µm edge	Analogue - **Lecture hall:** 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)

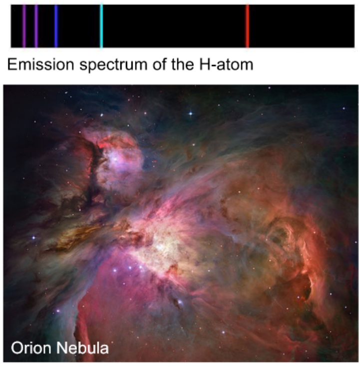




Actin monomer (globular or G-actin) (d=5 nm, cc~100 µM)

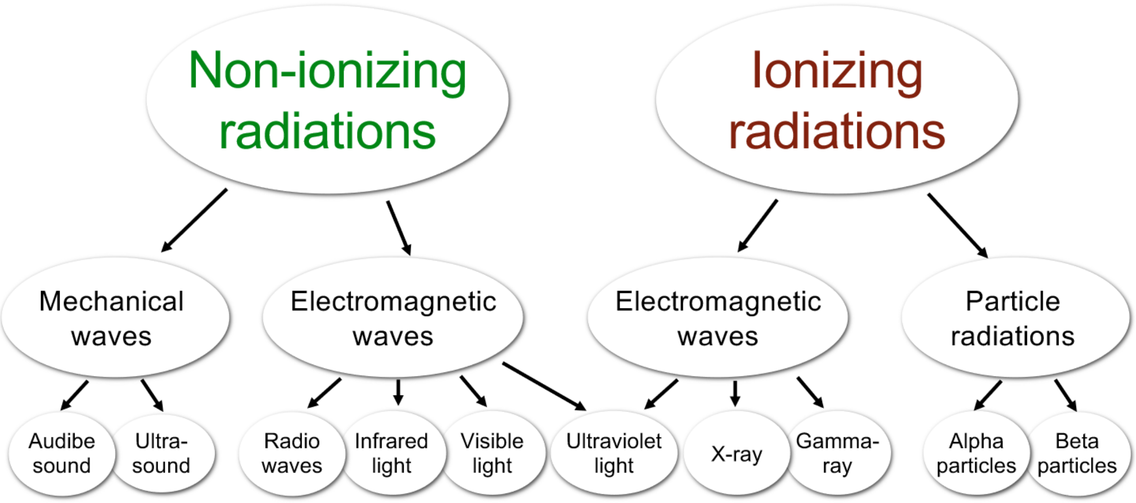
Deficiencies of the model: in reality the concentrations vary locally, and dynamics and collisions also take place.

Radiation is everywhere



Source ⟶ Radiation ⟶ Irradiated object

Types of radiation



Radiation = propagating ***energy***

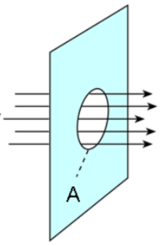
In the form of waves, or subatomic particles emitted by an atom or body as it changes from a high energy state to a lower energy state.

Energy, E: $[E]$ = J (Joule)

Radiant flux; radiant power: $$P = \frac{\Delta E}{\Delta t}$$ $[P]$ = W (Watt)

ΔE: energy carried during Δt time

Radiant intensity



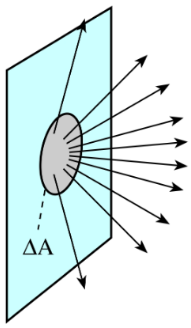
$$J = \frac{P}{A} = \frac{1}{A}\frac{\Delta E}{\Delta t}$$ $[J] = W/m^2$

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

Parameters of radiometry

Radiance

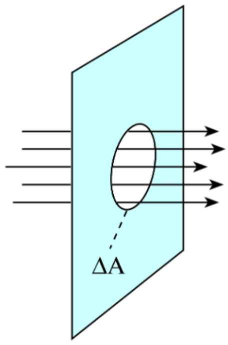
$$M = \frac{\Delta P}{\Delta A} \quad \left[\frac{W}{m^2}\right]$$



Power radiated by unit area into a solid angle of 2π.

Radiation intensity

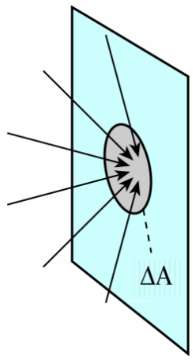
$$J_E = \frac{\Delta I_E}{\Delta A} \quad \left[\frac{W}{m^2}\right]$$



Power propagating through unit area.

Irradiance

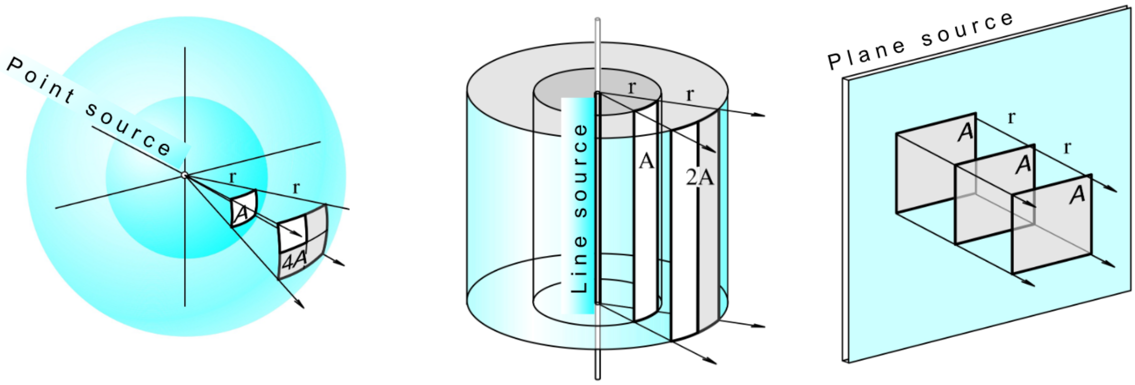
$$\varepsilon = \frac{\Delta P}{\Delta A} \quad \left[\frac{W}{m^2}\right]$$



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

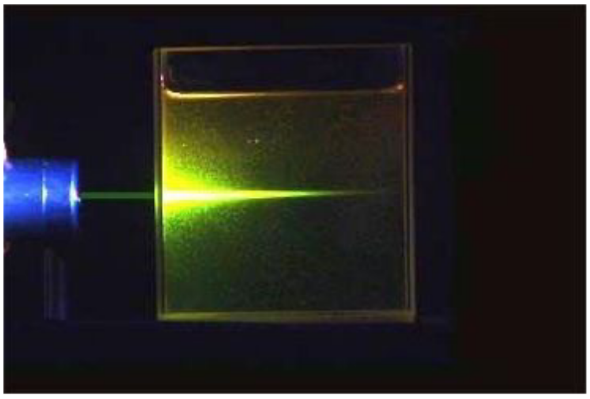
Radiant intensity as a function of the geometry of radiation source

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



$A_{sphere} \sim r^2$	$A_{cylinder} \sim r$	$A = constant$
$E_{inc} \sim 1/r^2$	$E_{inc} \sim 1/r$	$E_{inc} = constant$

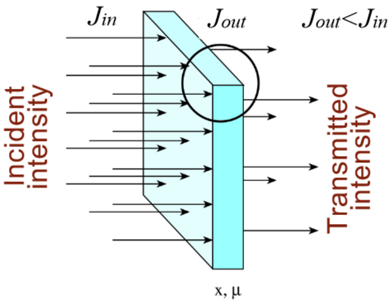
As radiation travels through matter, its intensity decreases

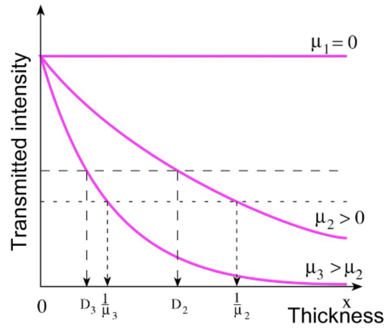


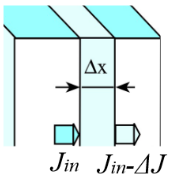
(Radiation that exits is weaker than the one that enters)

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

General radiation attenuation law







Properties of ΔJ:

$\Delta J \sim J_{in}$

$\Delta J \sim \Delta x$

$\Delta J \sim \mu$

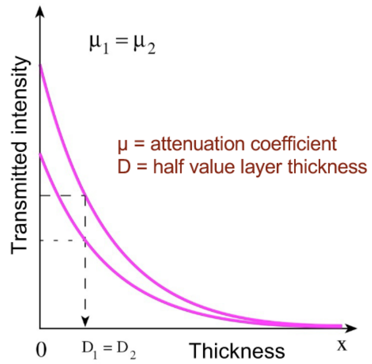
A given quantity (J) and its change (ΔJ) are proportional:

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

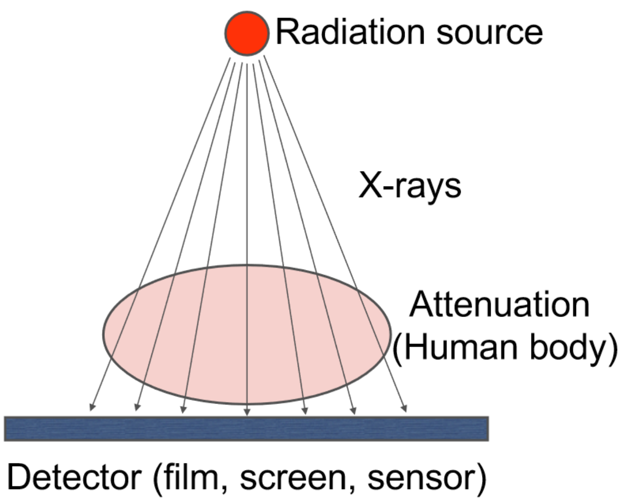
Exponential function:

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

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



Medical relevance



Chest x-ray

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