ME 411 / ME 511

Biological Frameworks for Engineers

Welcome

- Introductions
  - Prof. Nate Sniadecki, nsniadec@uw.edu
- http://faculty.washington.edu/nsniadec/ME411/A14
- Course Mission and Overview
- Administration and Logistics

ME 411 / ME 511

Functions of Life

Scale of Life

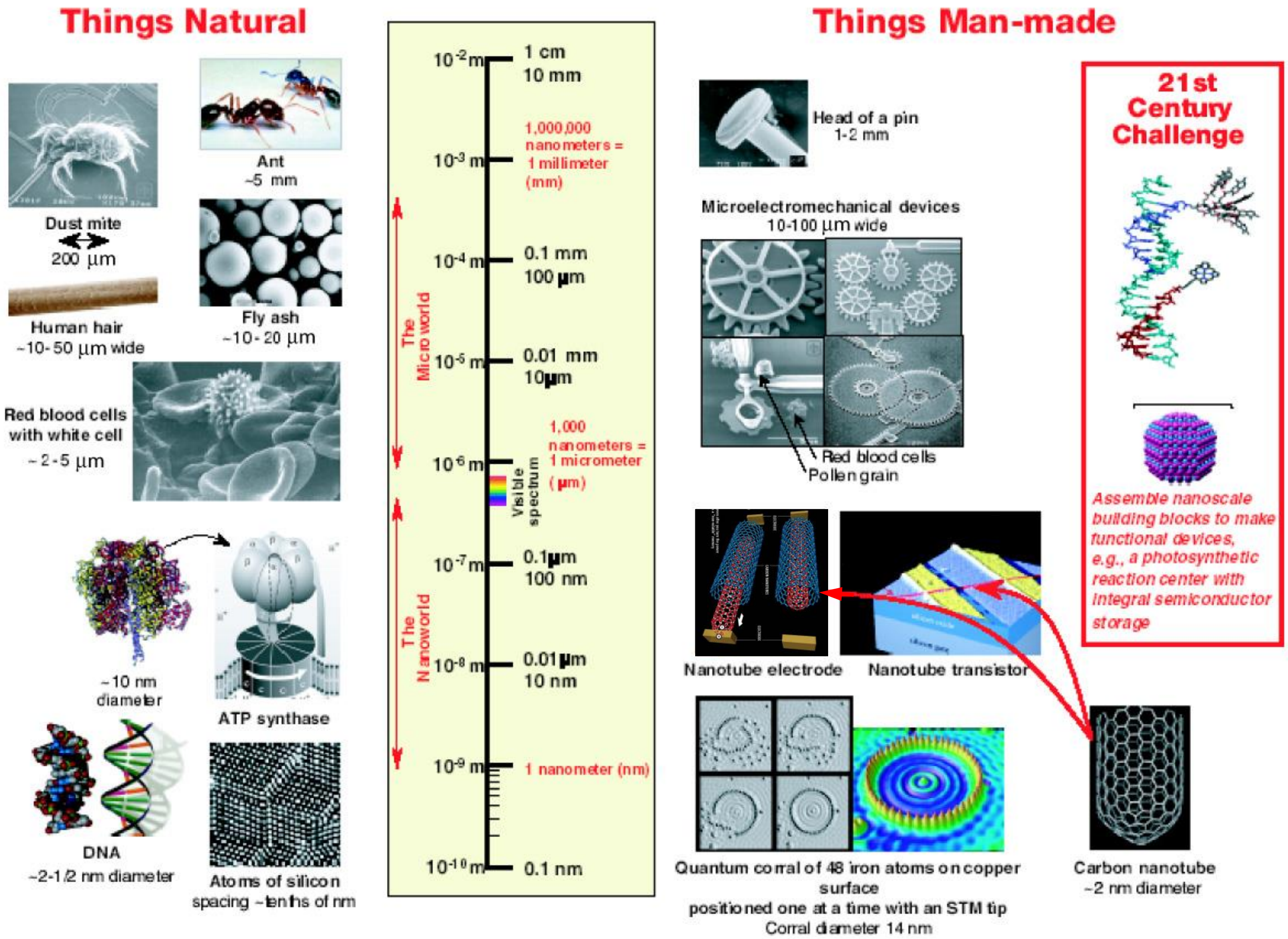


Table 1.1: Rules of thumb for biological estimates.

	Quantity of interest	Symbol	Rule of thumb
E. coli			
	Cell volume	$V_{E.\,coli}$	$\approx 1\ \mu m^3$
	Cell mass	$m_{E.\,coli}$	≈ 1 pg
	Cell cycle time	$t_{E.\,coli}$	≈ 3000 s
	Cell surface area	$A_{E.\,coli}$	$\approx 6\ \mu m^2$
	Macromolecule concentration in cytoplasm	$c^{\text{macromol}}_{E.\,coli}$	≈ 300 mg/mL
	Genome length	$N^{E.\,coli}_{\text{bp}}$	$\approx 5 \times 10^6$ bp
	Swimming speed	$v_{E.\,coli}$	$\approx 20\ \mu m/s$
Yeast			
	Volume of cell	V_{yeast}	$\approx 60\ \mu m^3$
	Mass of cell	m_{yeast}	≈ 60 pg
	Diameter of cell	d_{yeast}	$\approx 5\ \mu m$
	Cell cycle time	t_{yeast}	≈ 200 min
	Genome length	$N^{\text{yeast}}_{\text{bp}}$	$\approx 10^7$ bp
Organelles			
	Diameter of nucleus	d_{nucleus}	$\approx 5\ \mu m$
	Length of mitochondrion	l_{mito}	$\approx 2\ \mu m$
	Diameter of transport vesicles	d_{vesicle}	≈ 50 nm
Water			
	Volume of molecule	V_{H_2O}	$\approx 10^{-2}\ nm^3$
	Density of water	ρ	$1\ g/cm^3$
	Viscosity of water	η	≈ 1 centipoise (10^{-2} g/(cm s))
	Hydrophobic embedding energy	$\approx E_{\text{hydr}}$	2500 cal/(mol nm^2)

Table 1.1 (part 1 of 2) Physical Biology of the Cell, 2ed. (© Garland Science 2013)

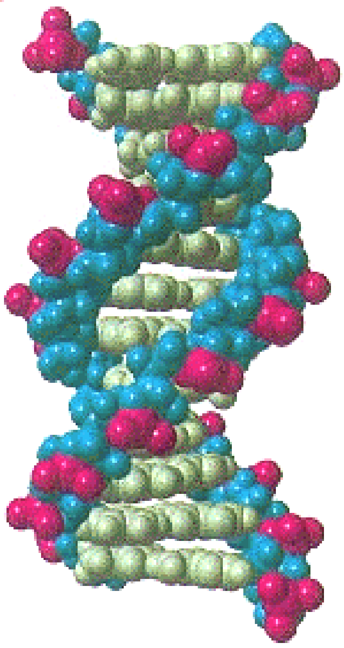
Table 1.1: Rules of thumb for biological estimates.

	Quantity of interest	Symbol	Rule of thumb
DNA			
	Length per base pair	l_{bp}	$\approx 1/3$ nm
	Volume per base pair	V_{bp}	$\approx 1\ \text{nm}^3$
	Charge density	λ_{DNA}	$2\ e/0.34$ nm
	Persistence length	ξ_p	50 nm
Amino acids and proteins			
	Radius of "average" protein	$r_{protein}$	≈ 2 nm
	Volume of "average" protein	$V_{protein}$	$\approx 25\ \text{nm}^3$
	Mass of "average" amino acid	M_{aa}	≈ 100 Da
	Mass of "average" protein	$M_{protein}$	$\approx 30{,}000$ Da
	Protein concentration in cytoplasm	$c_{protein}$	≈ 150 mg/mL
	Characteristic force of protein motor	F_{motor}	≈ 5 pN
	Characteristic speed of protein motor	v_{motor}	≈ 200 nm/s
	Diffusion constant of "average" protein in cytoplasm	$D_{protein}$	$\approx 10\ \mu\text{m}^2/\text{s}$
Lipid bilayers			
	Thickness of lipid bilayer	d	≈ 5 nm
	Area per molecule	A_{lipid}	$\approx \frac{1}{2}\ \text{nm}^2$
	Mass of lipid molecule	m_{lipid}	≈ 800 Da

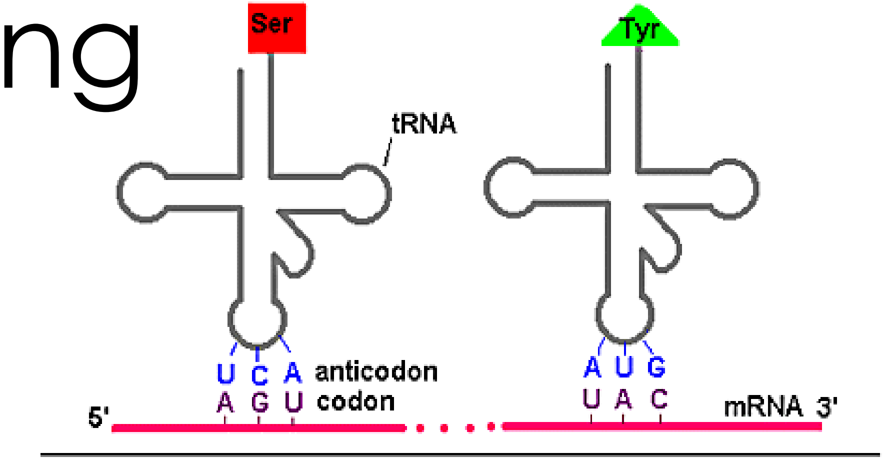
Table 1.1 (part 2 of 2) Physical Biology of the Cell, 2ed. (© Garland Science 2013)

Motivation…

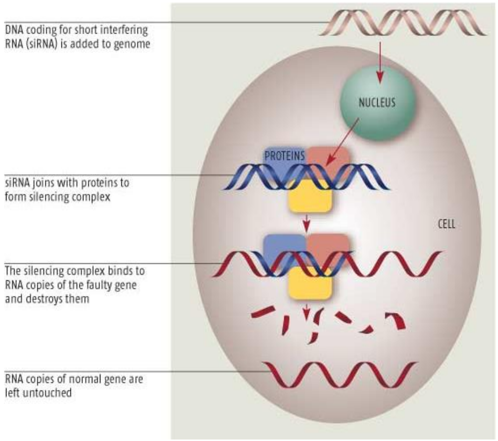
… to empower you to work at the interface between medicine and (mechanical) engineering



Coding



(5')G G A T A G C A T G A A A C C A G C A T A A (3')



Gene Therapy

NanoDesign

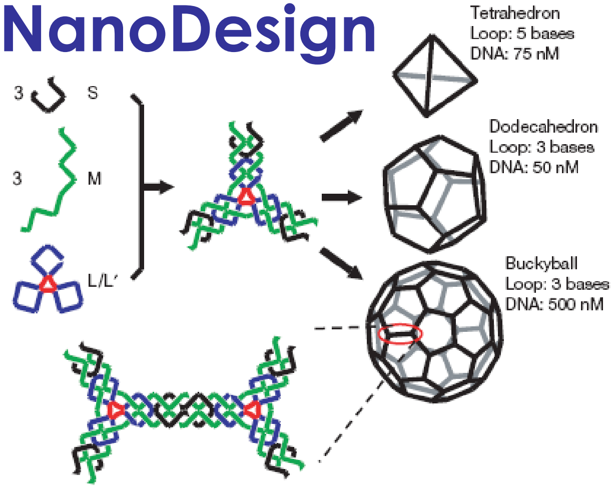
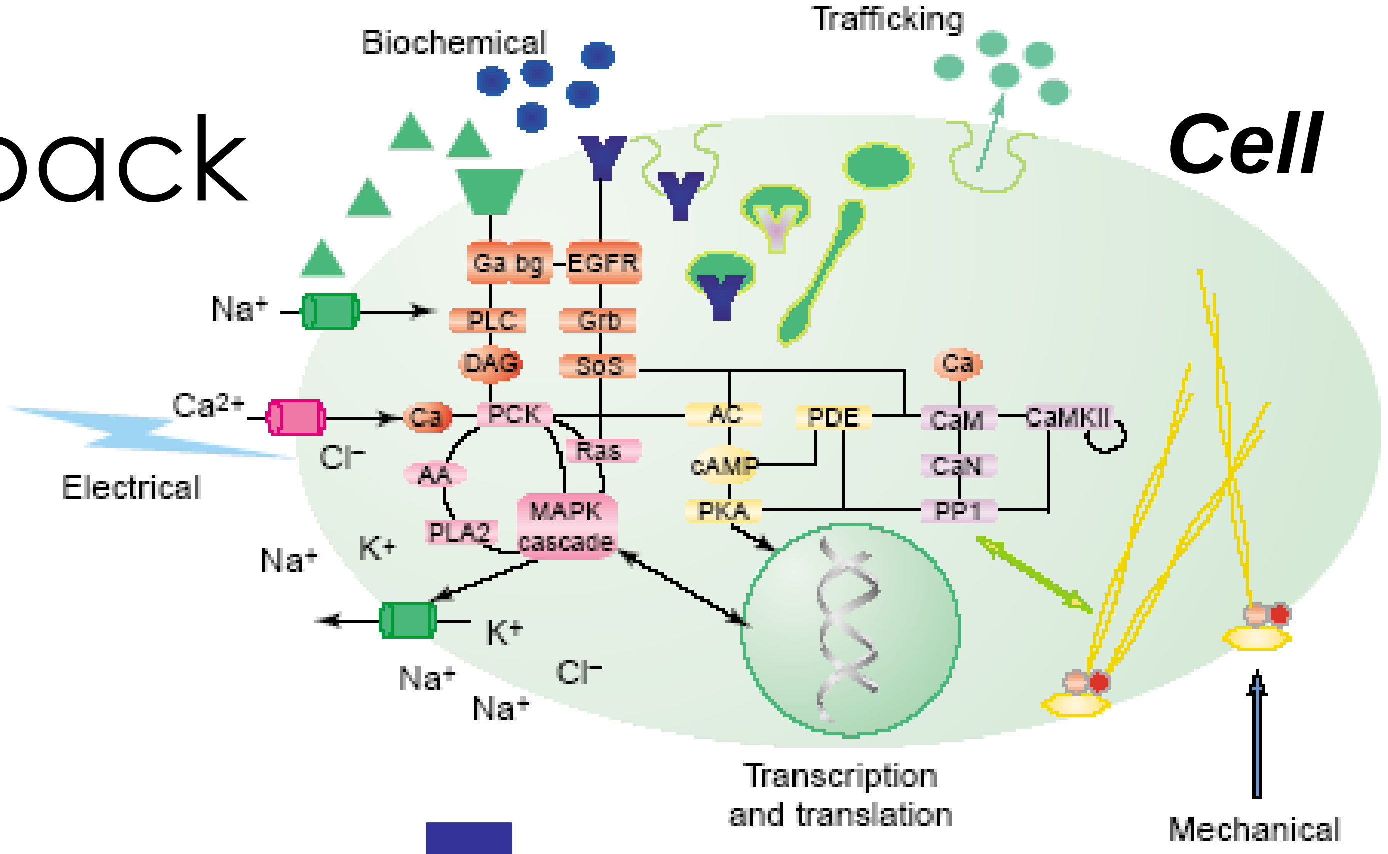
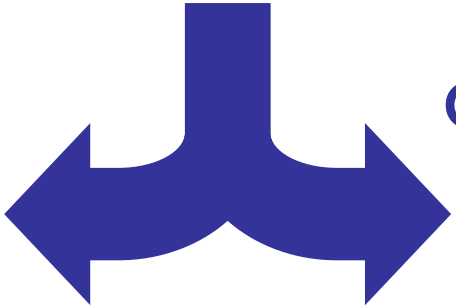


Figure 1 | Self-assembly of DNA polyhedra. Three different types of DNA single strands stepwise assemble into symmetric three-point-star motifs (tiles) and then into polyhedra in a one-pot process. There are three single-stranded loops (coloured red) in the centre of the complex. The final structures (polyhedra) are determined by the loop length (3 or 5 bases long) and the DNA concentration.

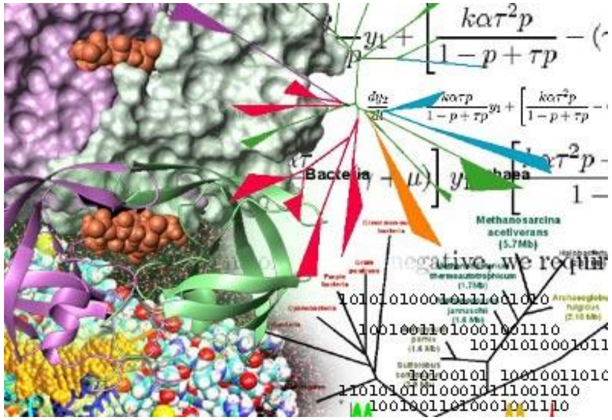
Feedback



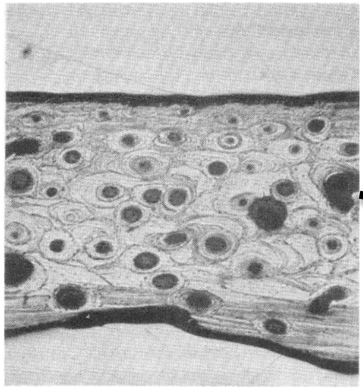
Stem Cell Therapy



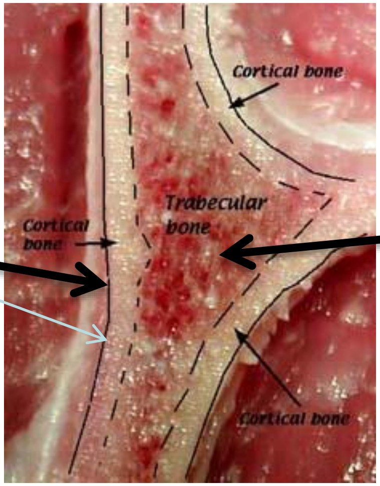
Computational Biology



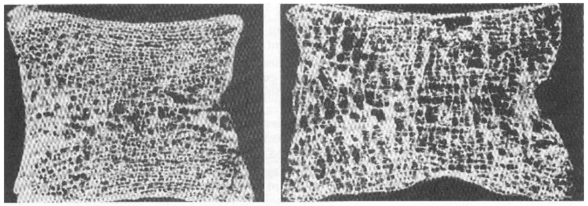
Integration



Cortical
(plywood)

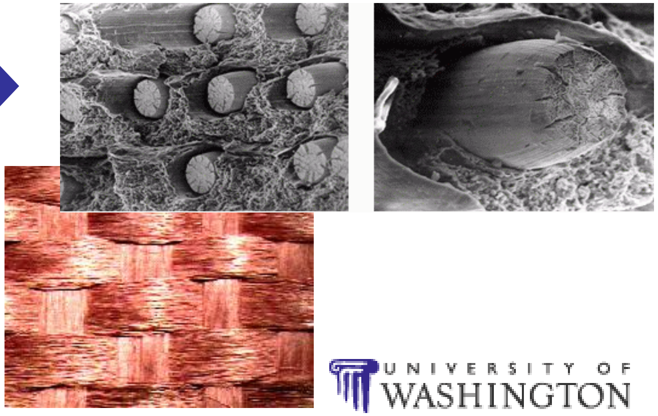


Trabecular
(foam)



Osteoporosis Prevention

Composite Design



Functions of Life?

Environmental Limits to Life?

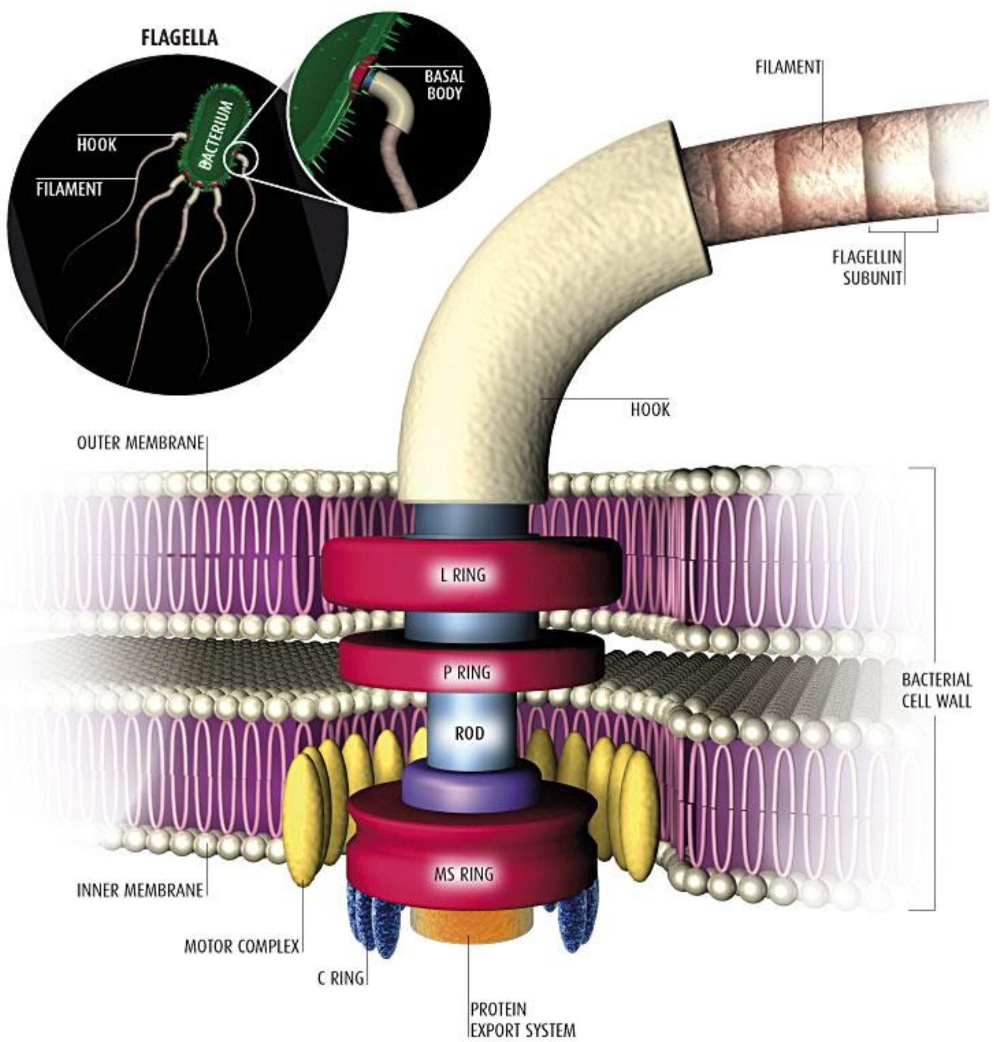
Fundamental Themes

- Molecular Machines
- Integrated Systems
- Structure – Function
- Response and Adaptation

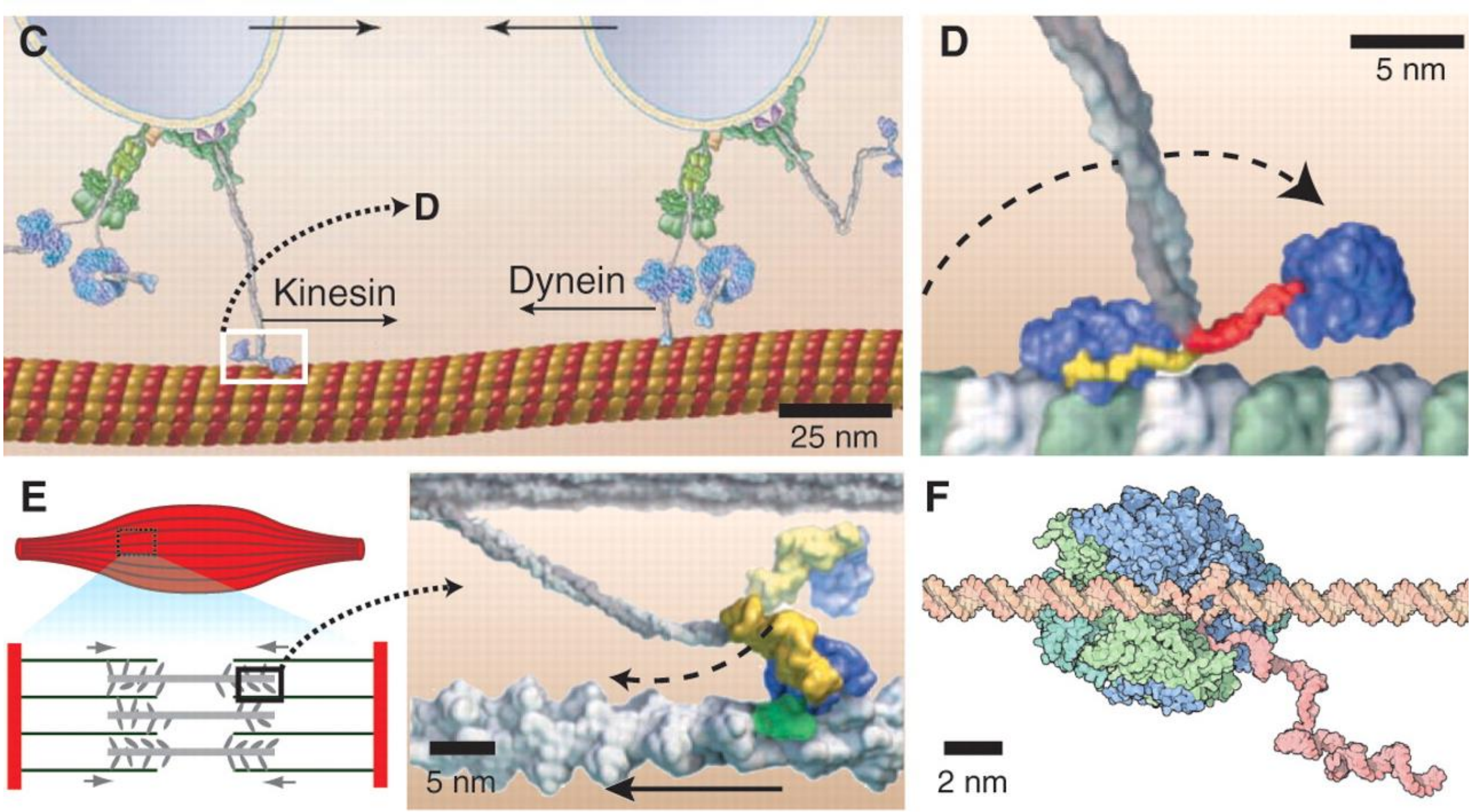
Molecular Machines

NATURE'S OUTBOARD MOTOR

Despite the intricacies of the bacterial flagellum, biologists are unravelling its workings and making great headway in understanding how the nanoscale appendage evolved

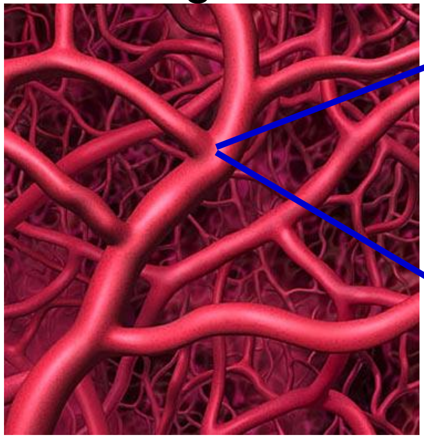


Molecular Machines

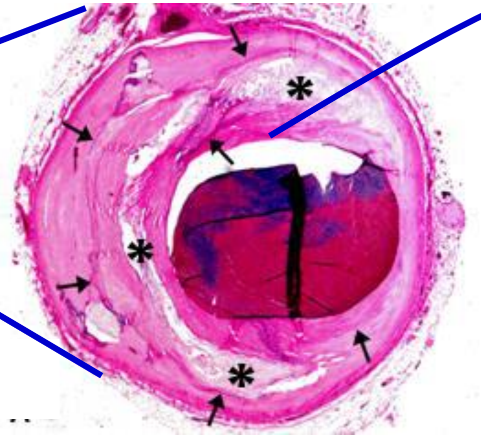


Integrated Systems

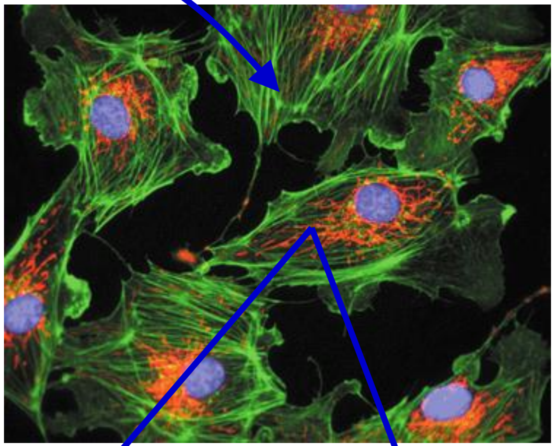
Organ



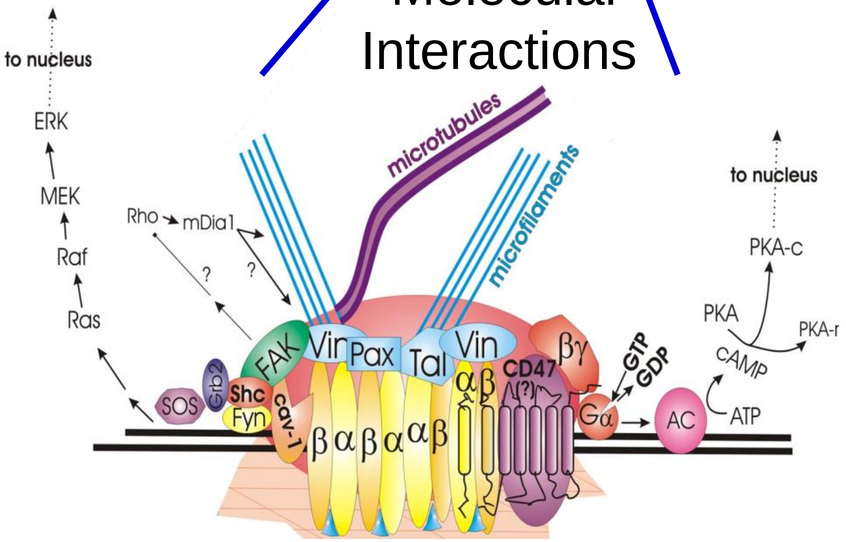
Tissue



Cell



Molecular Interactions



Biological scale:
Molecular → Cellular → Tissue → Organ → Organism → Ecosystem → Biosphere

Length Scale:
nm → µm → mm → cm → m → km

Structure - Function

- Form follows function

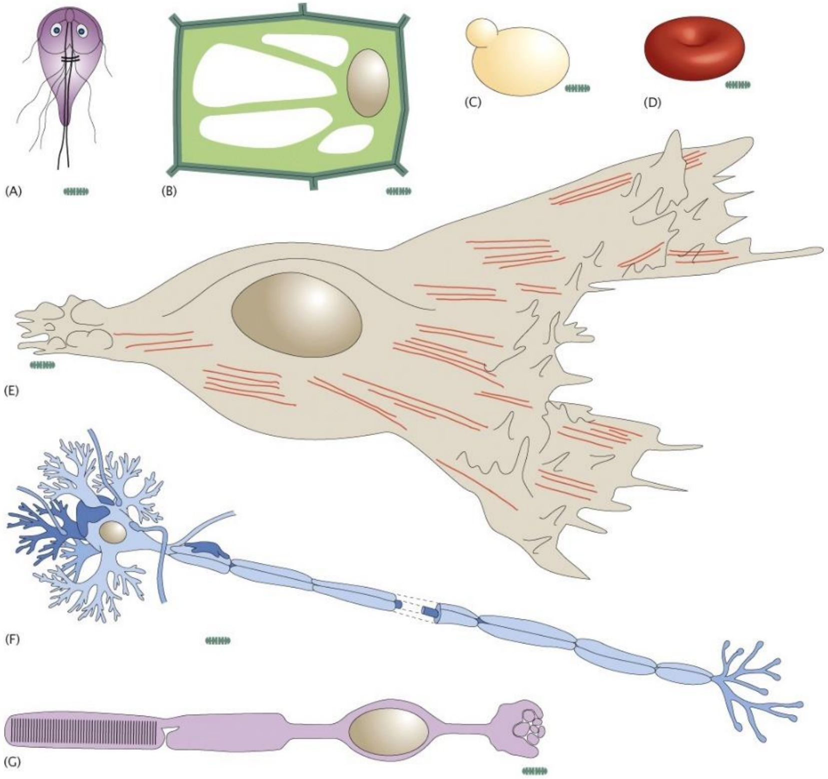
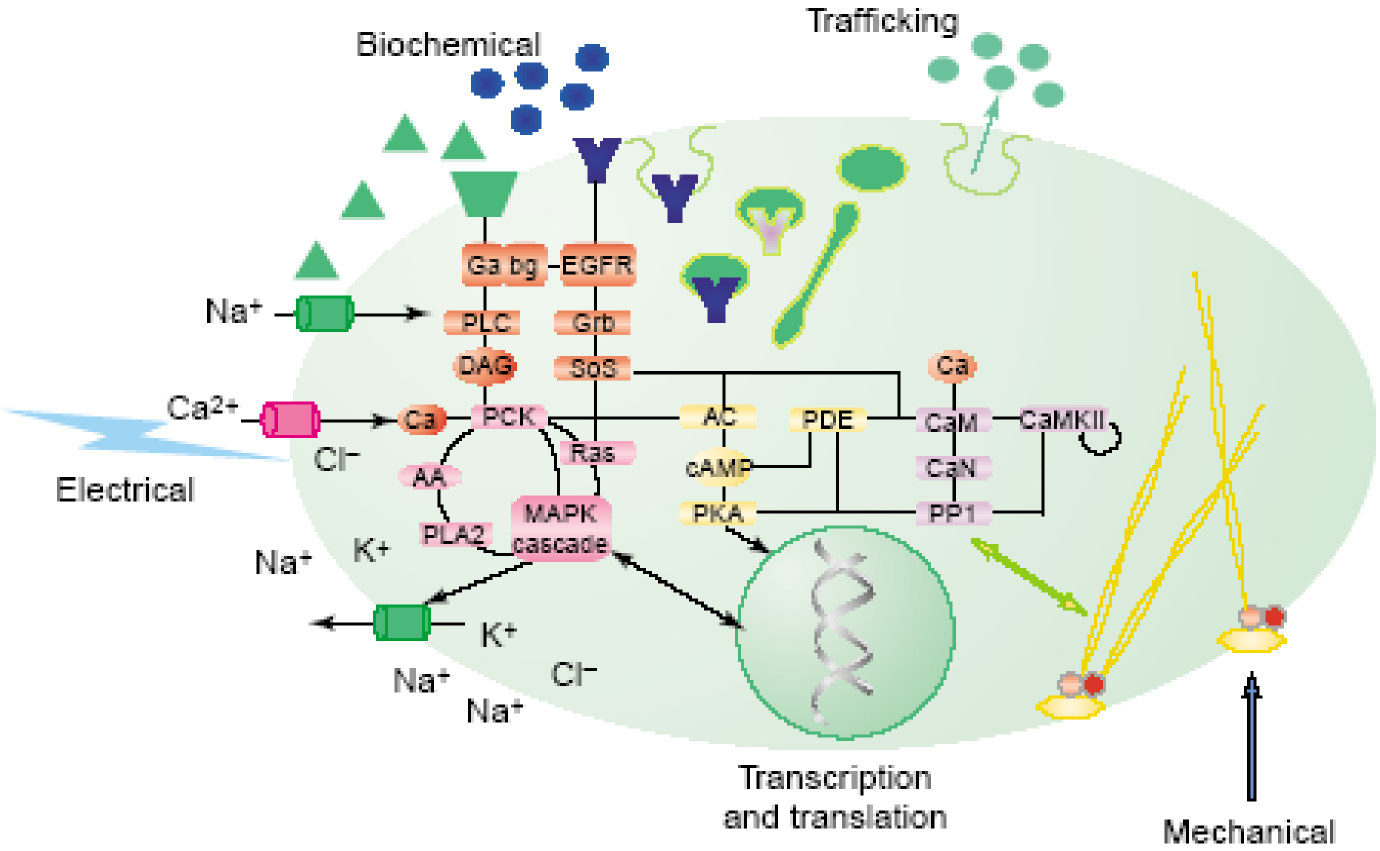


Figure 2.16 Physical Biology of the Cell, 2ed. (© Garland Science 2013)

How to Design Students

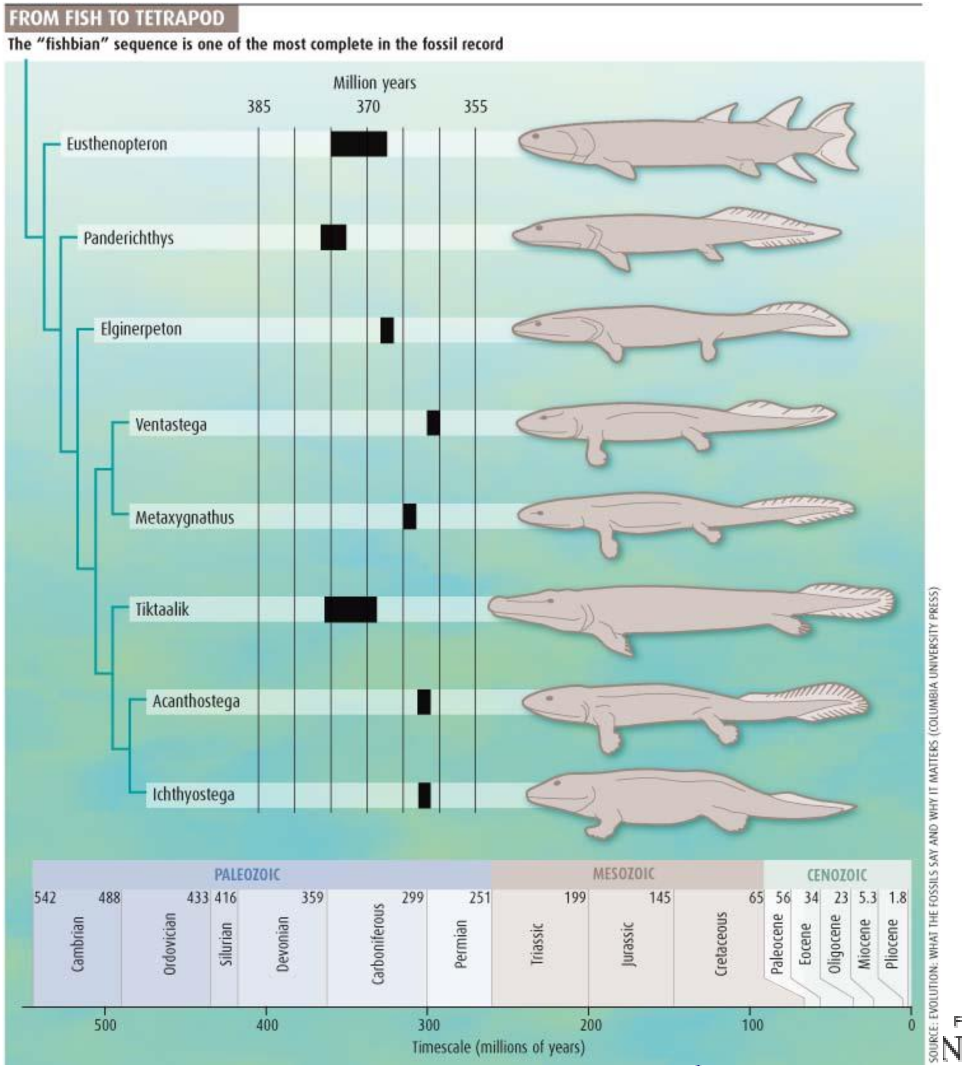
Adaptation

- Short-term



Adaptation

- Long-term (evolution)



FROM FISH TO TETRAPOD

The "fishbian" sequence is one of the most complete in the fossil record

SOURCE: EVOLUTION: WHAT THE FOSSILS SAY AND WHY IT MATTERS (COLUMBIA UNIVERSITY PRESS)

Questions?

Bring your laptop…