Lecture 2: Construction plans for cells

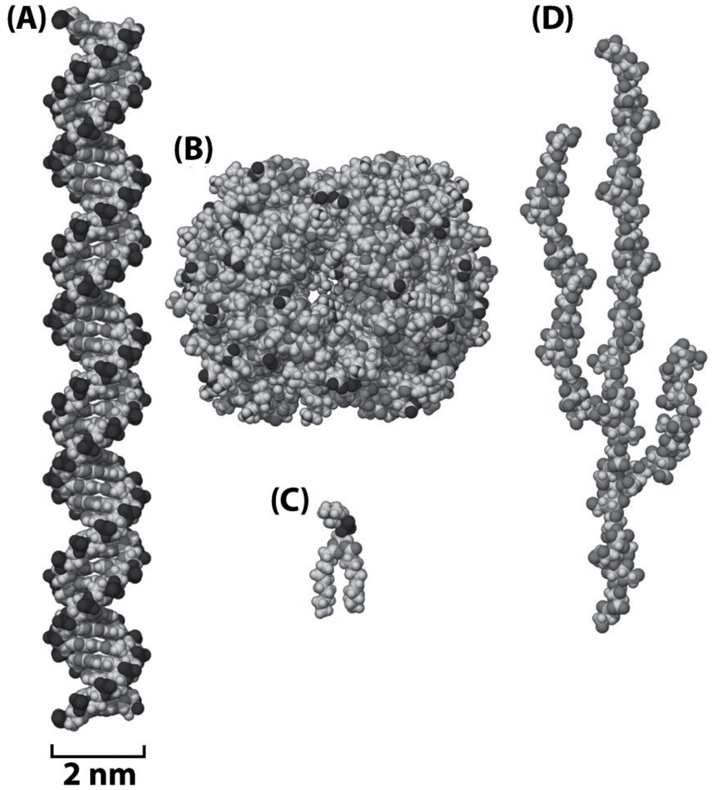
Goal: Size and contents of cells

- An ode to E. coli
- Cells and the structures within them

PBOC Chapter 2.1, 2.2

The stuff of life

Last week: What macromolecules are cells made of?



Advantages:

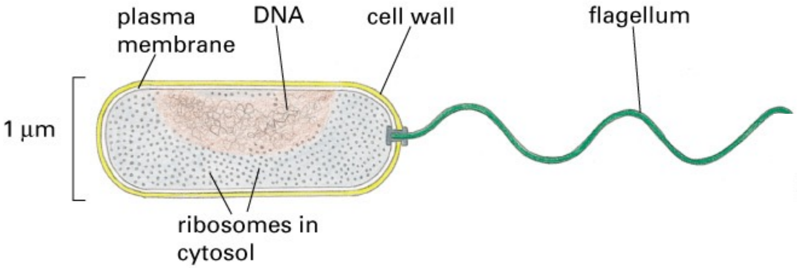
- Each class can be assembled by the cell from a small set of simpler subunits
- Combinatorial assembly gives rise to diversity
- Limited repertoire of chemical reactions needed
- Facilitates existence of food chain

Lecture 2

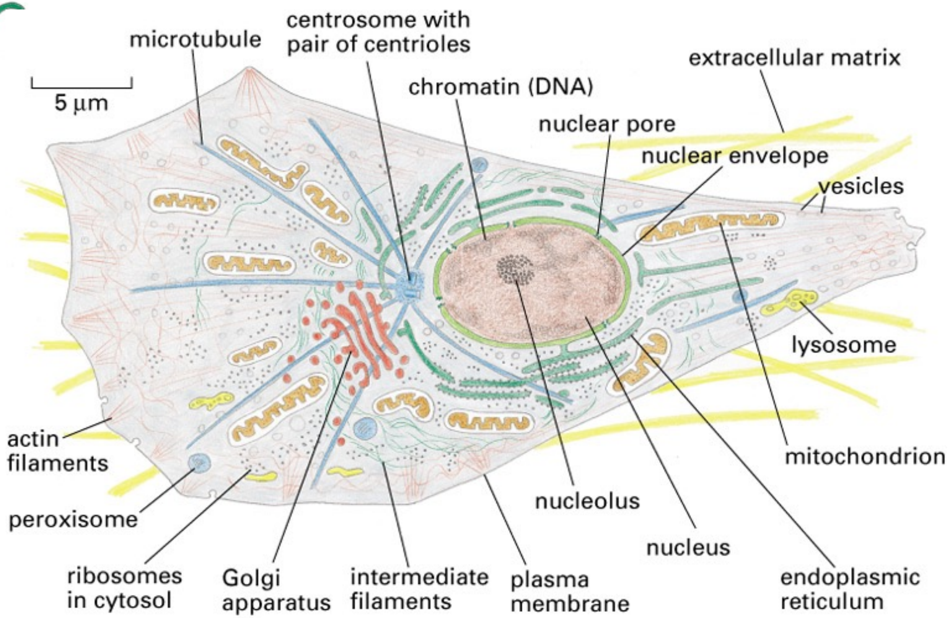
What is the anatomy of a cell?

Basic facts about cells

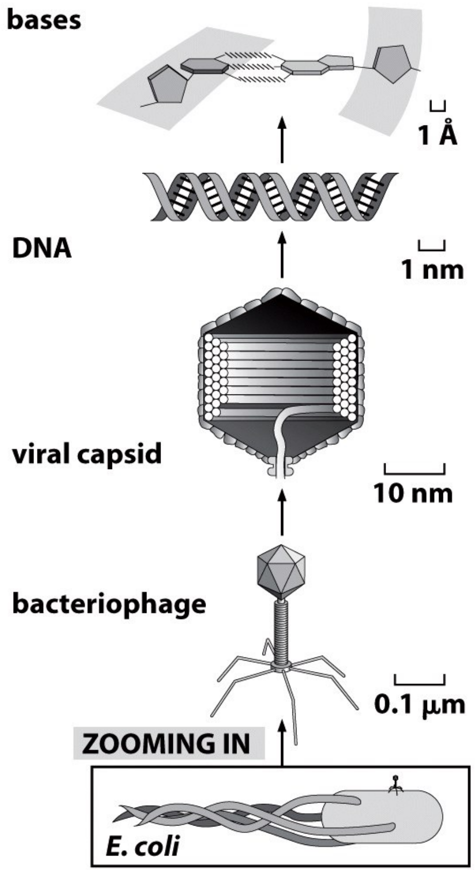
Prokaryotes and Eukaryotes

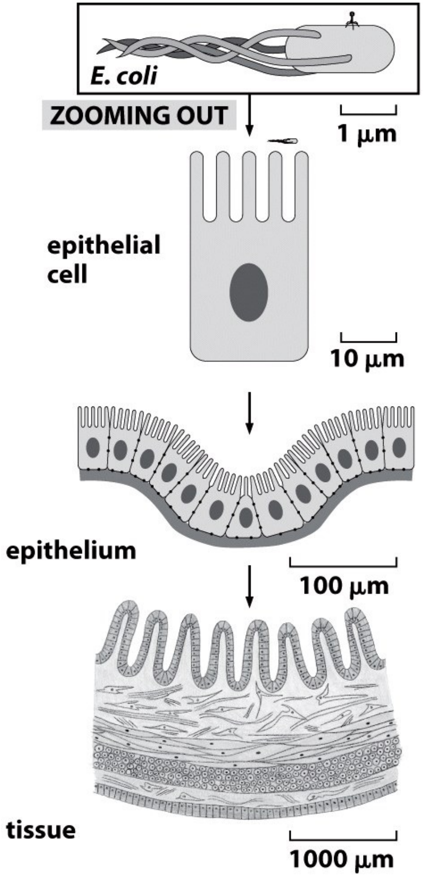


All cells share molecular components:



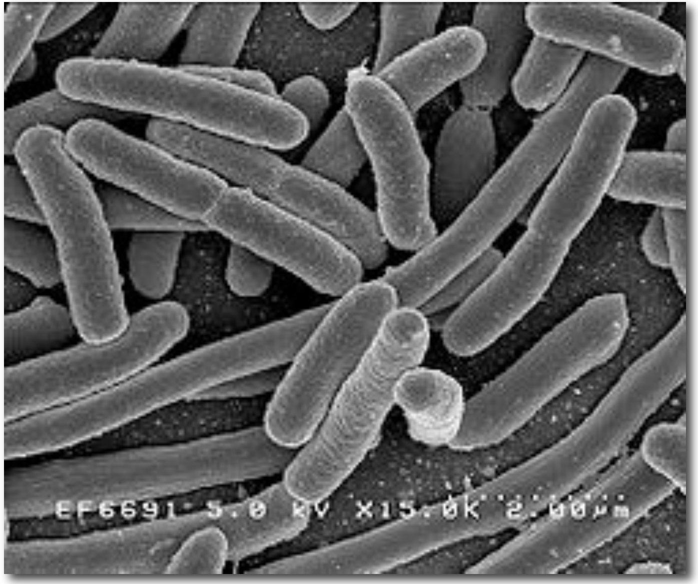
Basic facts about cells





An ode to E. coli

Why study bacteria?



Bacteria E.coli: human intestinal inhabitant

- easy to isolate
- is able to grow well in the presence of O_2 (unlike most other gut bacteria)
- replicates rapidly in vitro, easily adjusts to changes in its environment
- Genetics! easy to produce mutants
- Feedback: the more is known, the more it is studied

An ode to E. coli

Why study bacteria?

E. coli in the news

Beware of Raw Cookie Dough

E. Coli Ban in Ground Beef to Be Expanded

How Do Farmers Clean the Soil After E. Coli?

Tips for Parents to Ensure Safety of a Packed School Lunch

Coriander Oil Is Found to Kill E. Coli, Salmonella and MRSA

An ode to E. coli

Why study bacteria?

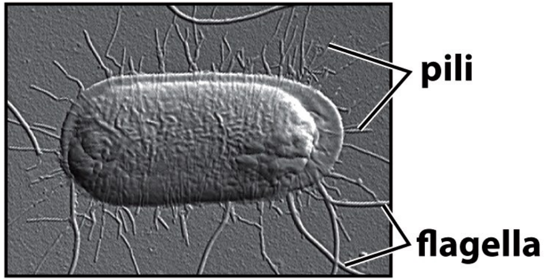
The human microbiome

> “We’re not individuals, we’re colonies of creatures.”— Bruce Birren, co-director, Genome Sequencing and Analysis Program

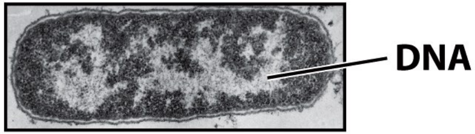
The human body is home to an enormous number and diversity of microbes. Within the body of a healthy adult, microbial cells are estimated to be ~ the same number as human cells. And the combined genetic contributions of these microbes — in excess of 100,000 protein-coding genes — may provide essential traits not encoded in our own genome yet required for normal development, physiology, immunity, and nutrition.

An ode to E. coli

The bacterial standard ruler



AFM image



electron microscopy image

shape model

An ode to E. coli

Molecular census

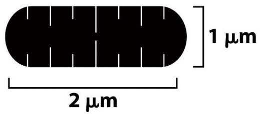
Why?
To model, need to understand:

- large number (concentration) vs small number (stochasticity)
- crowded, constrained vs dilute, free

An ode to E. coli

Molecular census

Given:
- dimensions



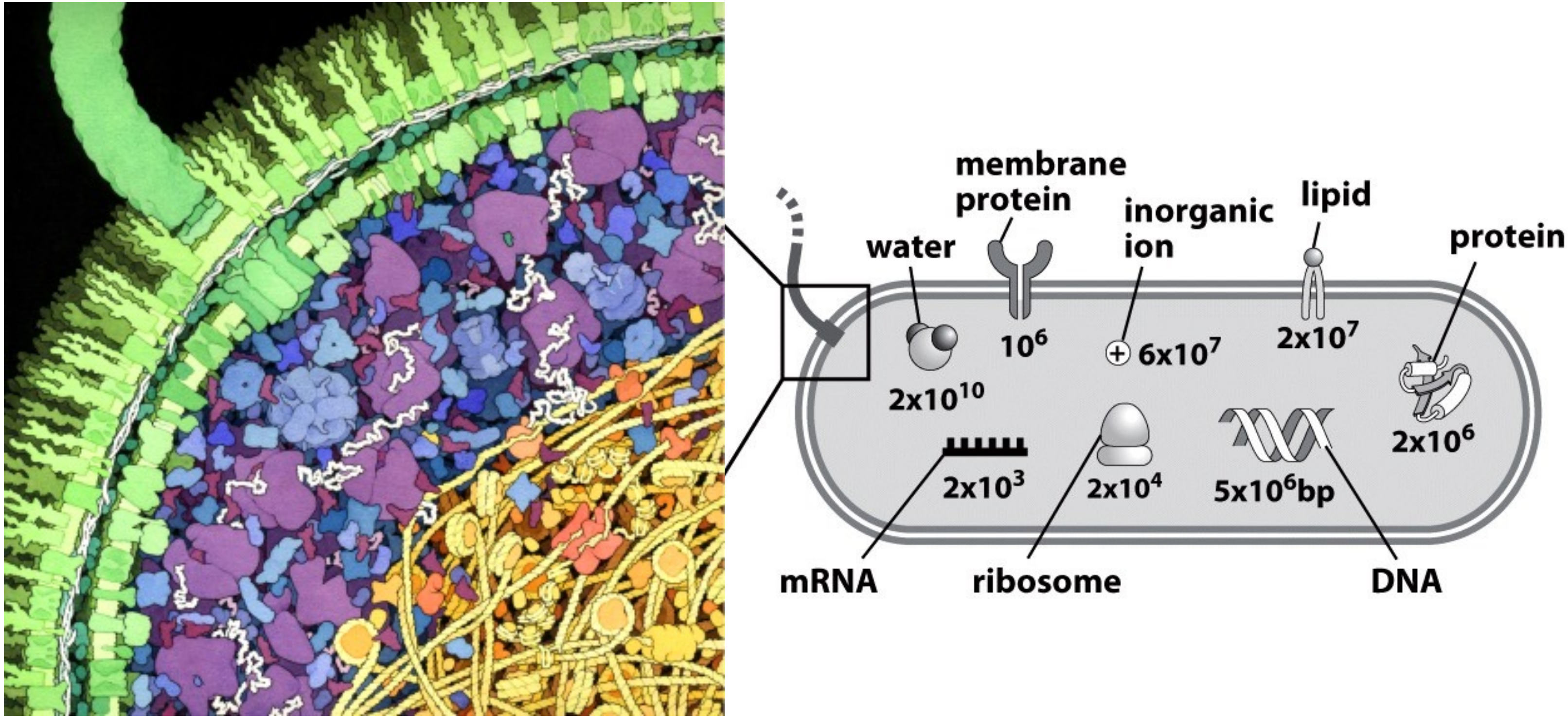
- total cell mass = 1 pg
- total protein mass (15% of cell mass)
- proteins in the membrane (30%)
- mean protein size = 300 amino acids
- mean amino acid mass = 100 Da

Units:
1 Da = 1.6×10^{-24} g

Estimate:
- Number of proteins in a cell
- Number of membrane proteins
- Mean spacing between proteins in cell
- Mean spacing between proteins on membrane

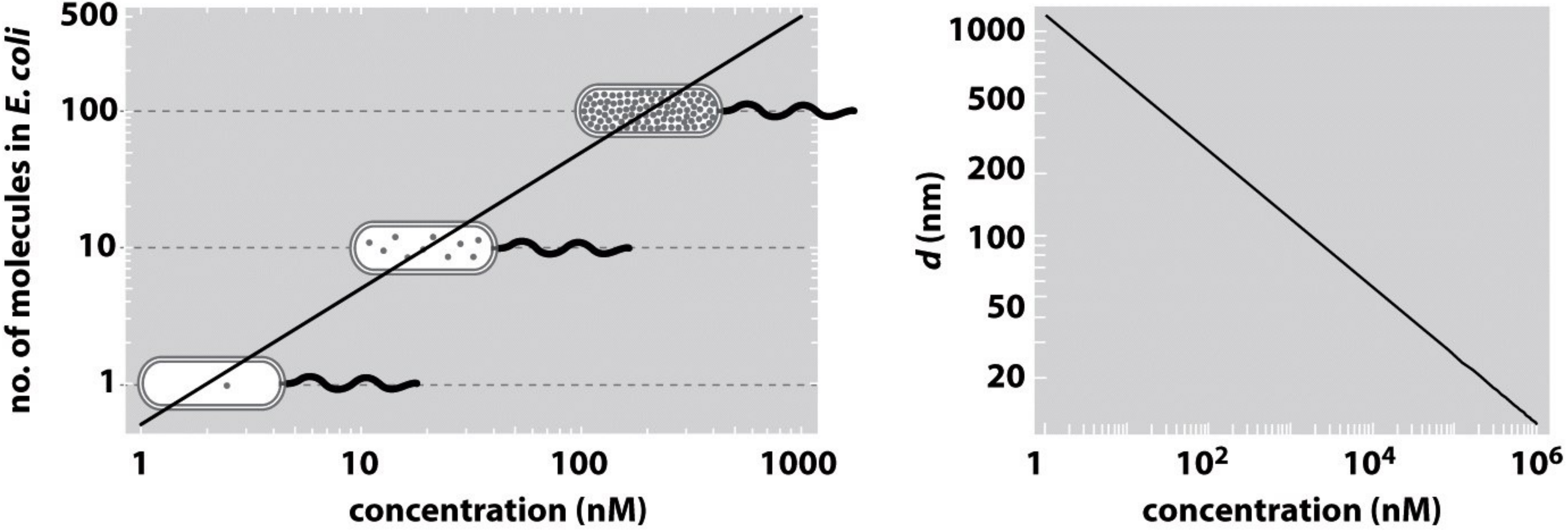
An ode to E. coli

Molecular census



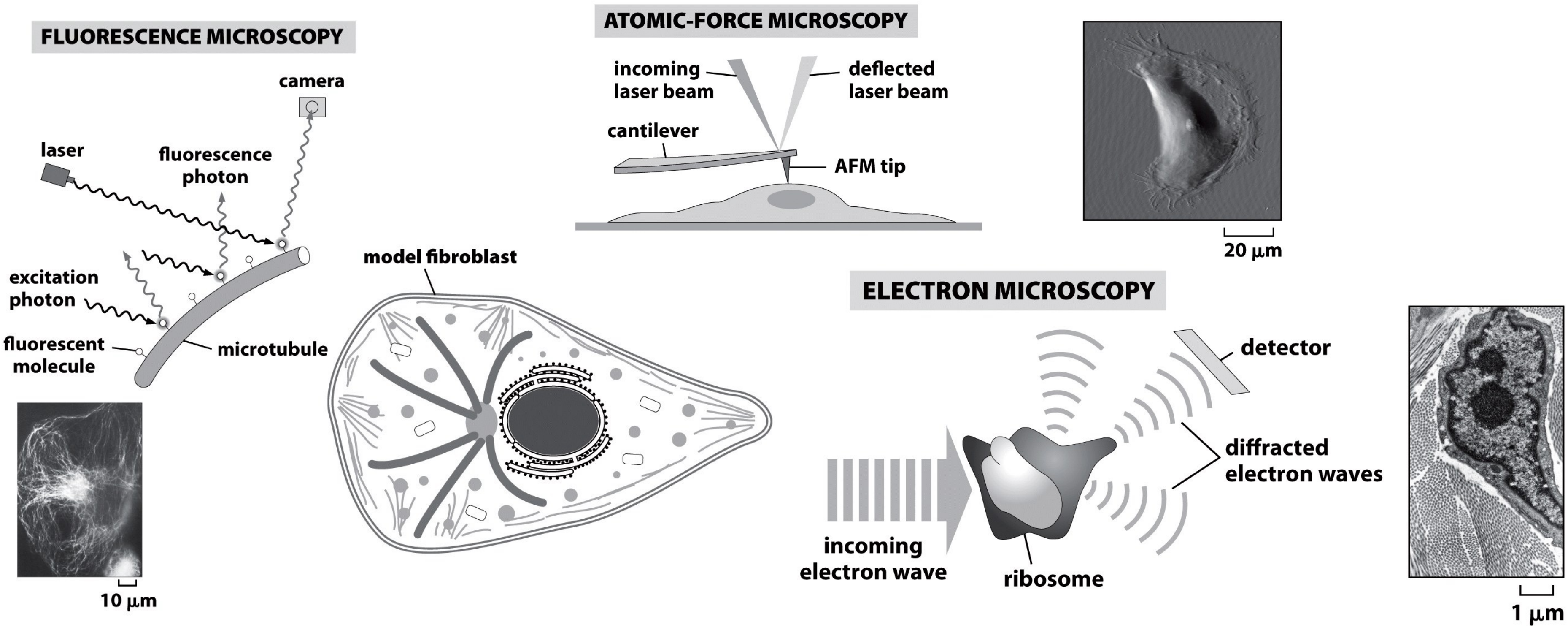
An ode to E. coli

Molecular census



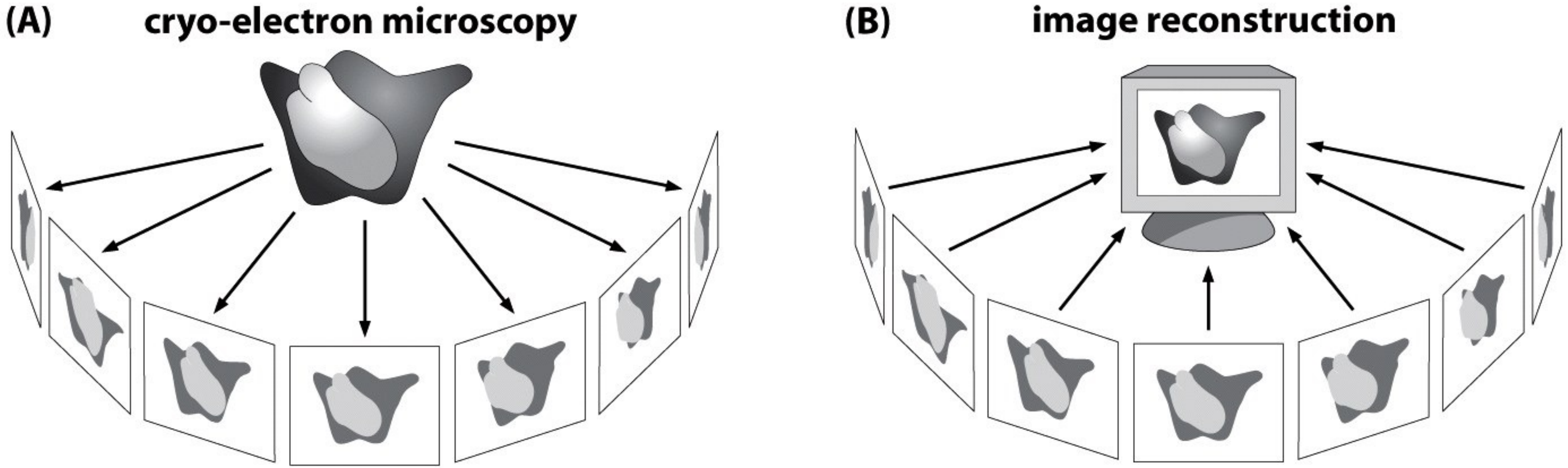
Cells and the structures within them

How do we know? Cellular organization

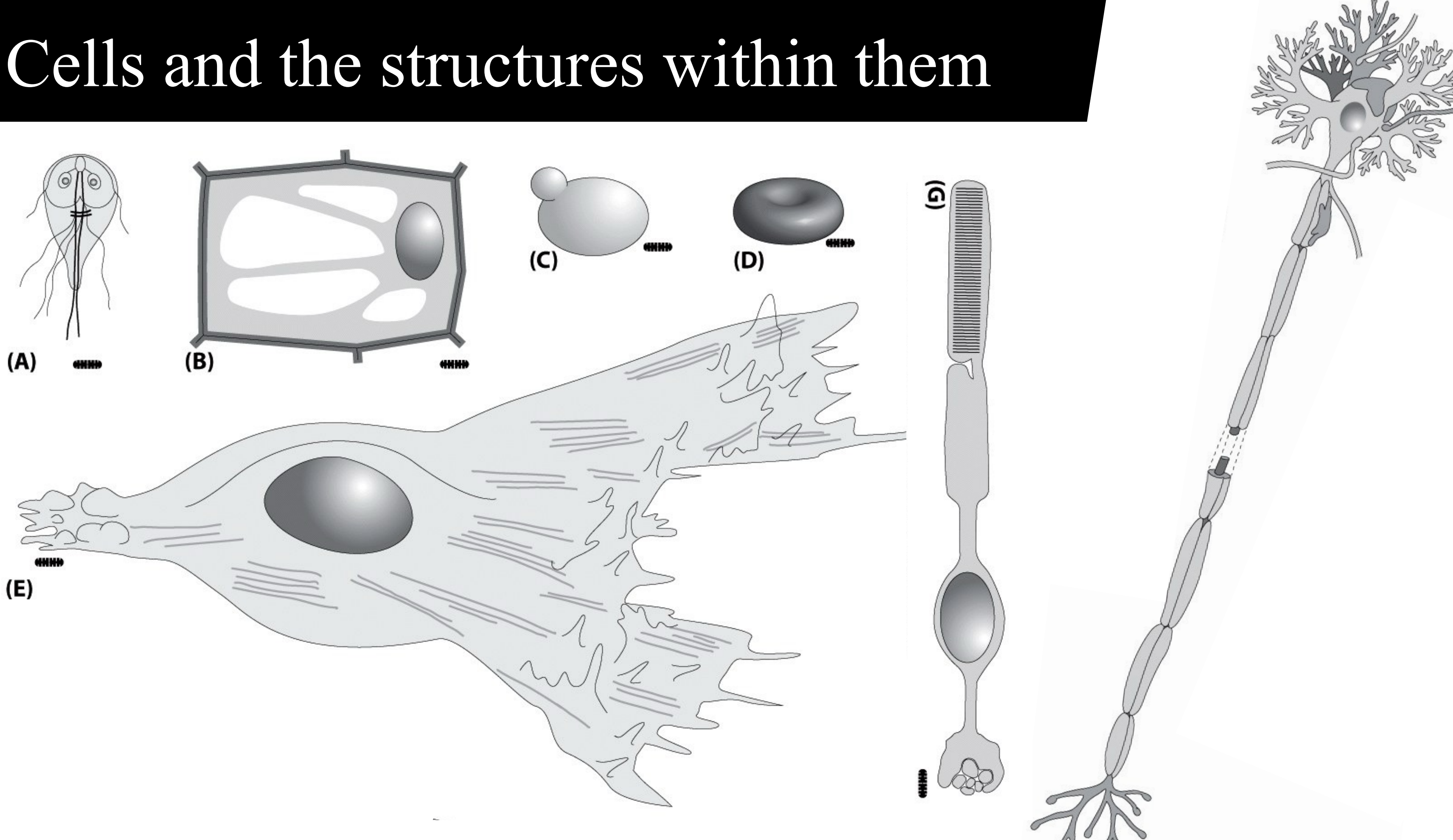


Cells and the structures within them

How do we know? Molecular structure

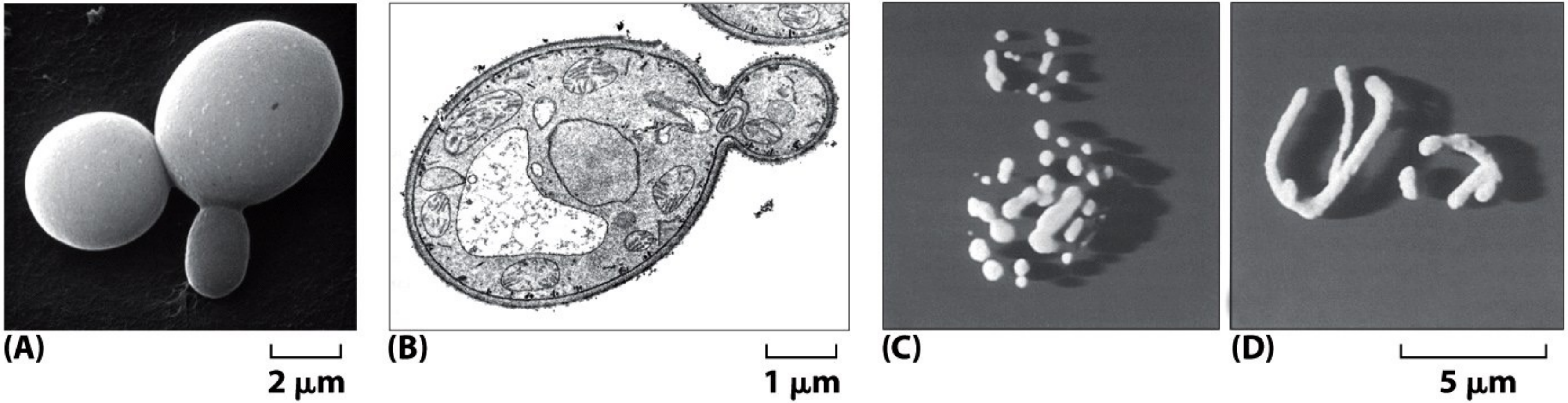


Cells and the structures within them



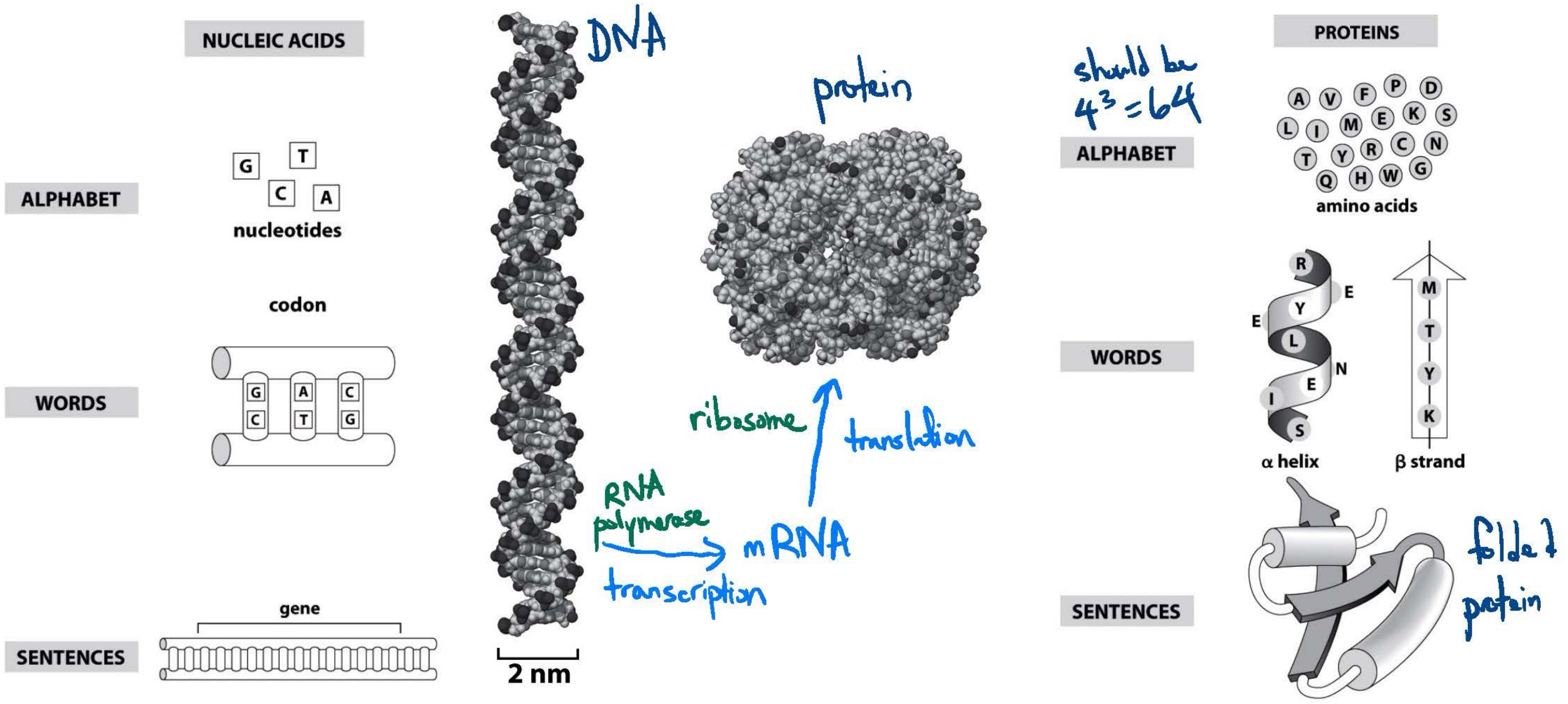
Cells and the structures within them

Yeast: Single-celled eukaryote



The stuff of life

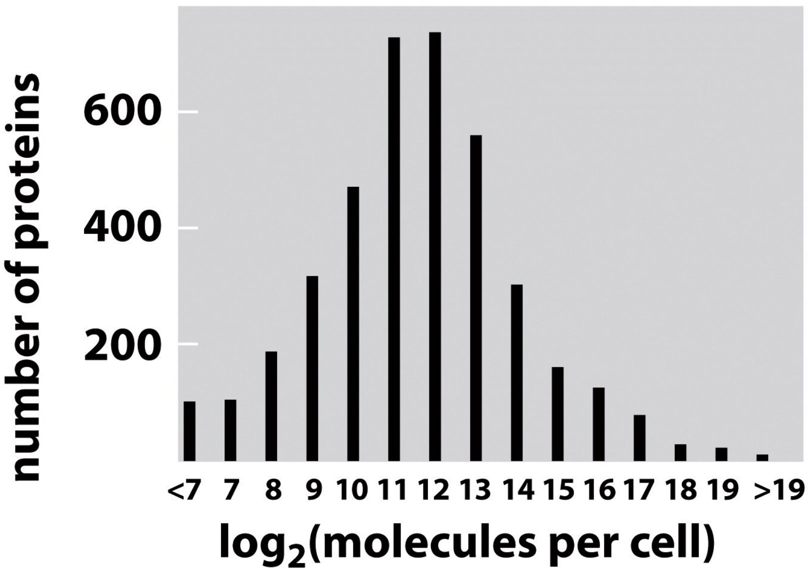
Last week: Nucleic acids and proteins are polymer languages

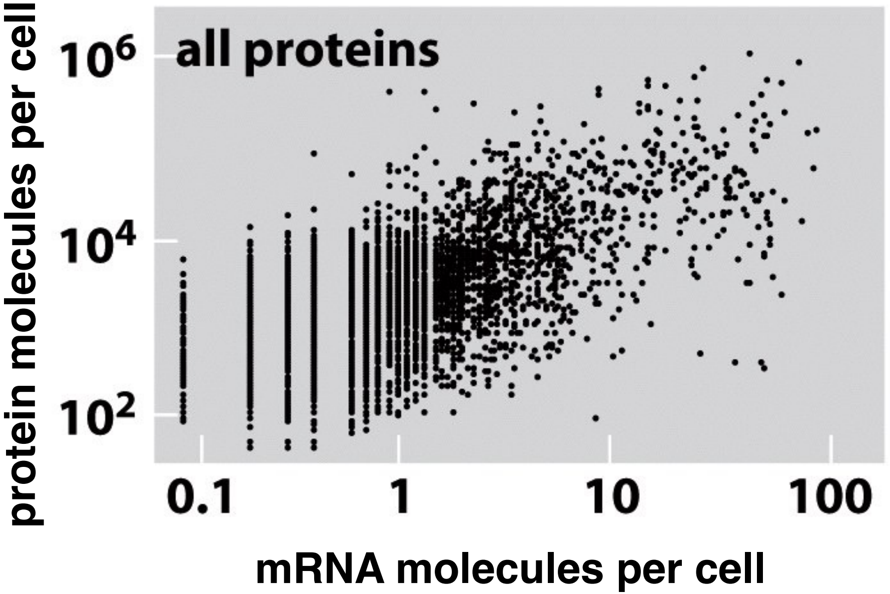


Cells and the structures within them

Yeast: Single-celled eukaryote

~6000 protein-coding genes

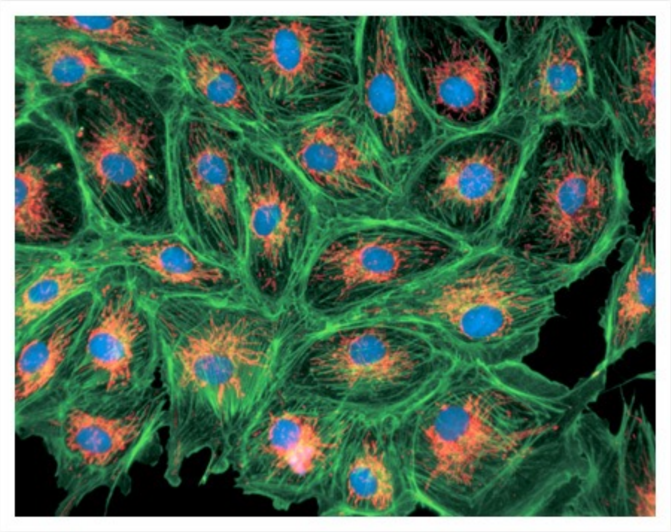


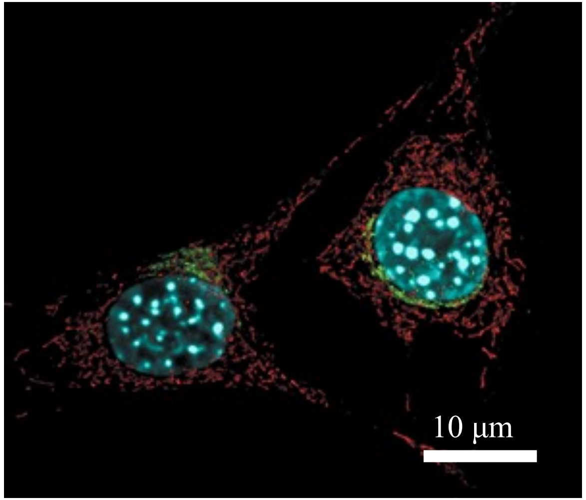


Cells and the structures within them

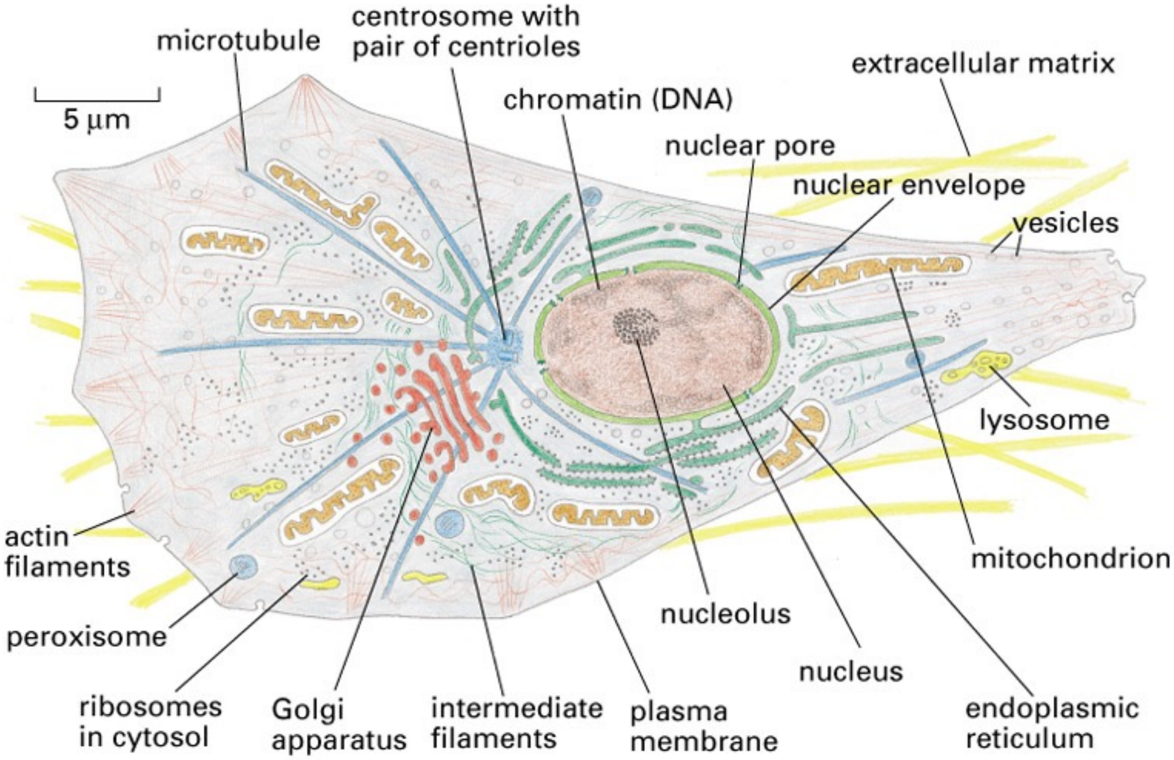
Why study mammalian cells?

- Best cellular models for human diseases
- No simpler analogue captures mechanisms of gene regulation
- Also true of other cellular mechanisms …





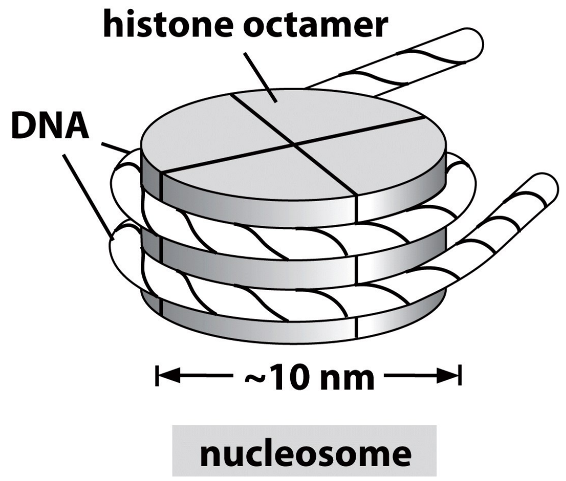
Cells and the structures within them

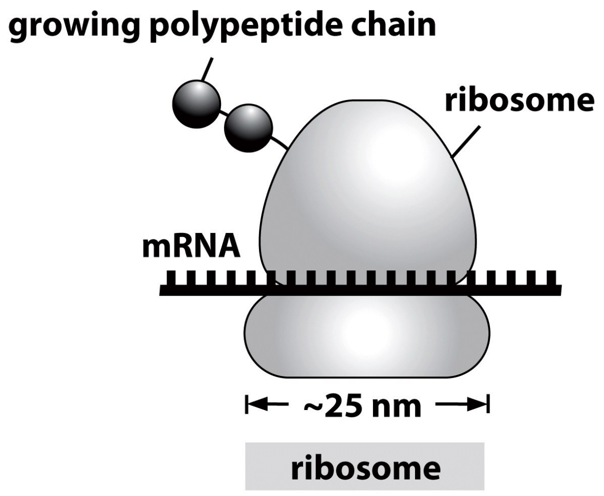


organelles

- specialized subcompartments of the cell
- different protein, lipid, and ion compositions
- provide environment for particular cellular tasks

Cells and the structures within them

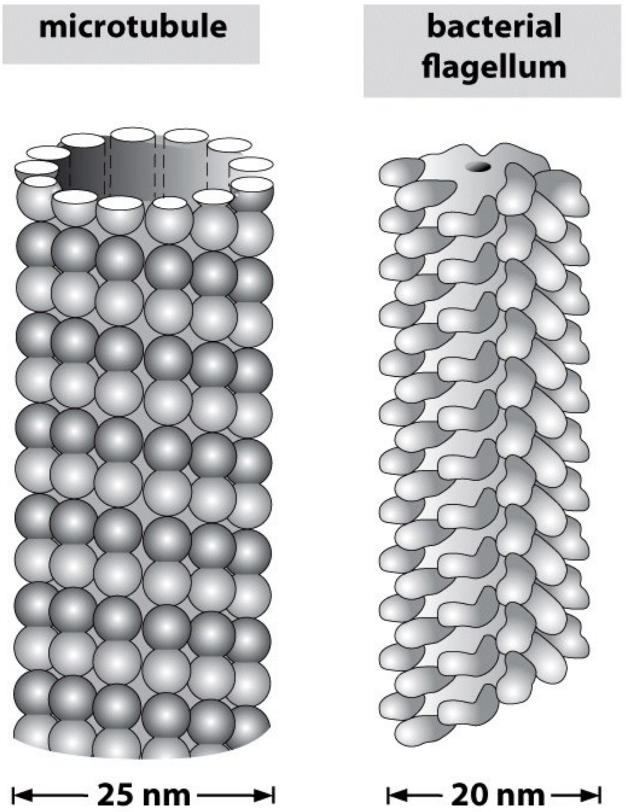




protein complexes

- act as molecular machines
- perform particular cellular functions

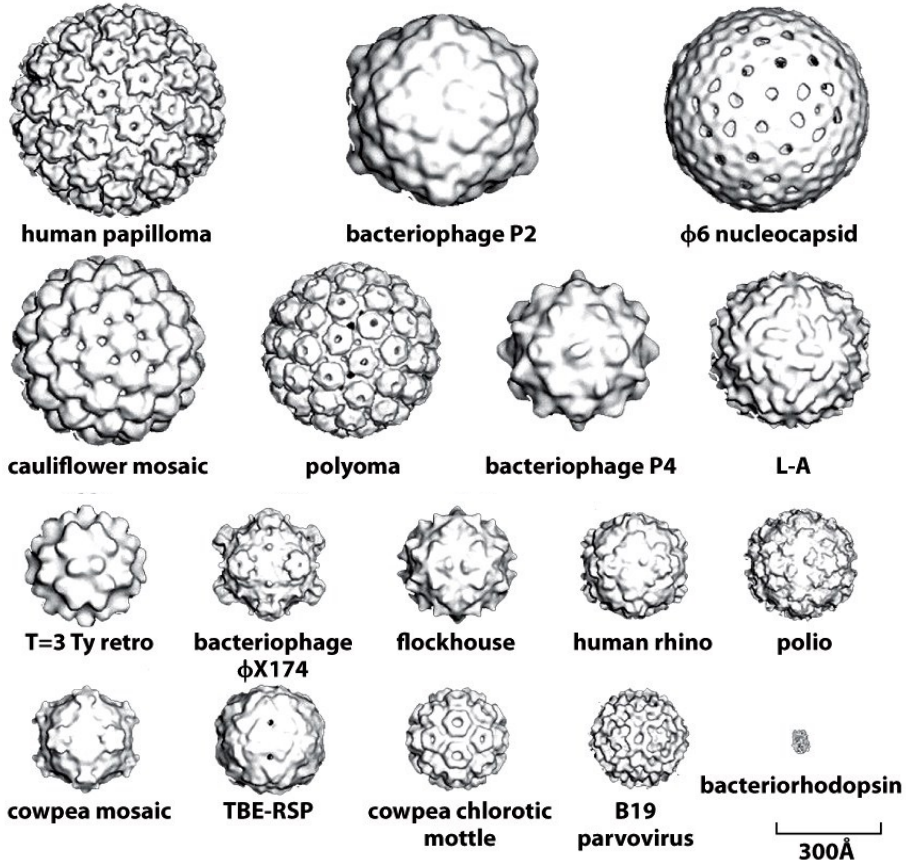
Cells and the structures within them

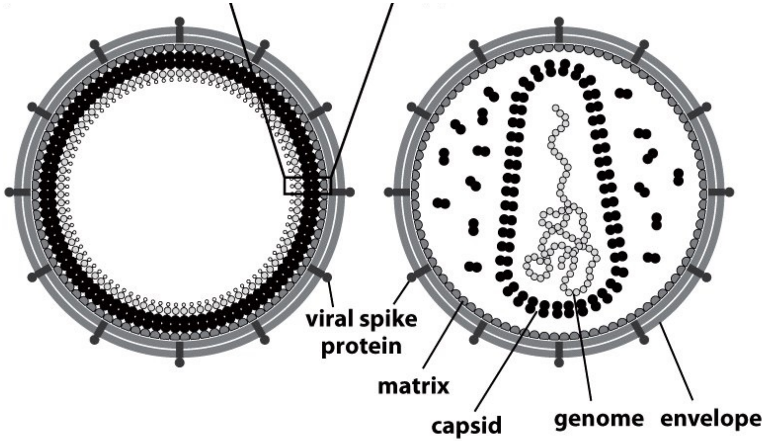


protein polymers

- provide mechanical rigidity
- cell shape
- cell motility
- sensing flow

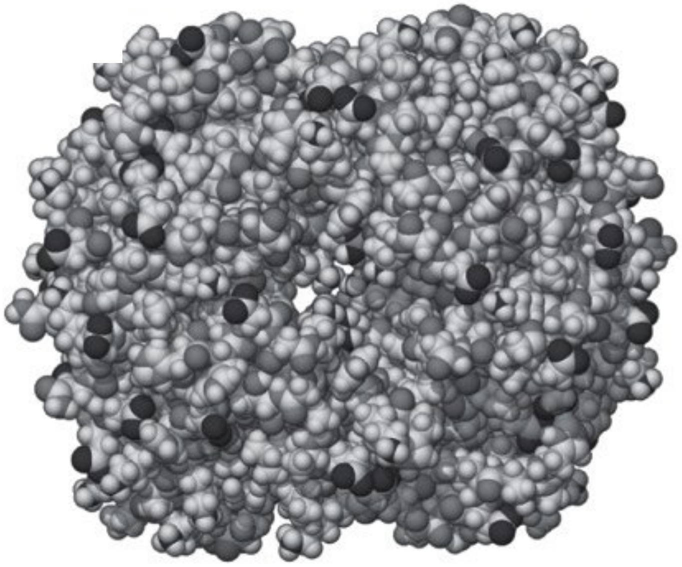
Cells and the structures within them





Alive or dead?

Cells and the structures within them



proteins

- fold into a 3D shape
- atomic coordinates $\mathbf{r}_i(t) = x_i(t)\mathbf{i} + y_i(t)\mathbf{j} + z_i(t)\mathbf{k}$
- enzymatic activity
- binding pockets
- physical and chemical properties of amino acids determine folded structure and reactivity

Lecture 2: Construction plans for cells

- Different kinds of cells
  - bacteria
  - variety of eukaryotes
- Molecular census
  - sizes of things
  - how many proteins, etc.
- Subcellular organization
  - organelles
  - protein assemblies
  - protein structure

Lecture 3: Mechanical and chemical equilibrium

Goal: Energy in the cell

- Biological systems as minimizers
- Entropy and hydrophobicity

PBOC Chapter 5.2, 5.5.1