Johns Hopkins Engineering

Molecular Biology

A Preview of the Cell

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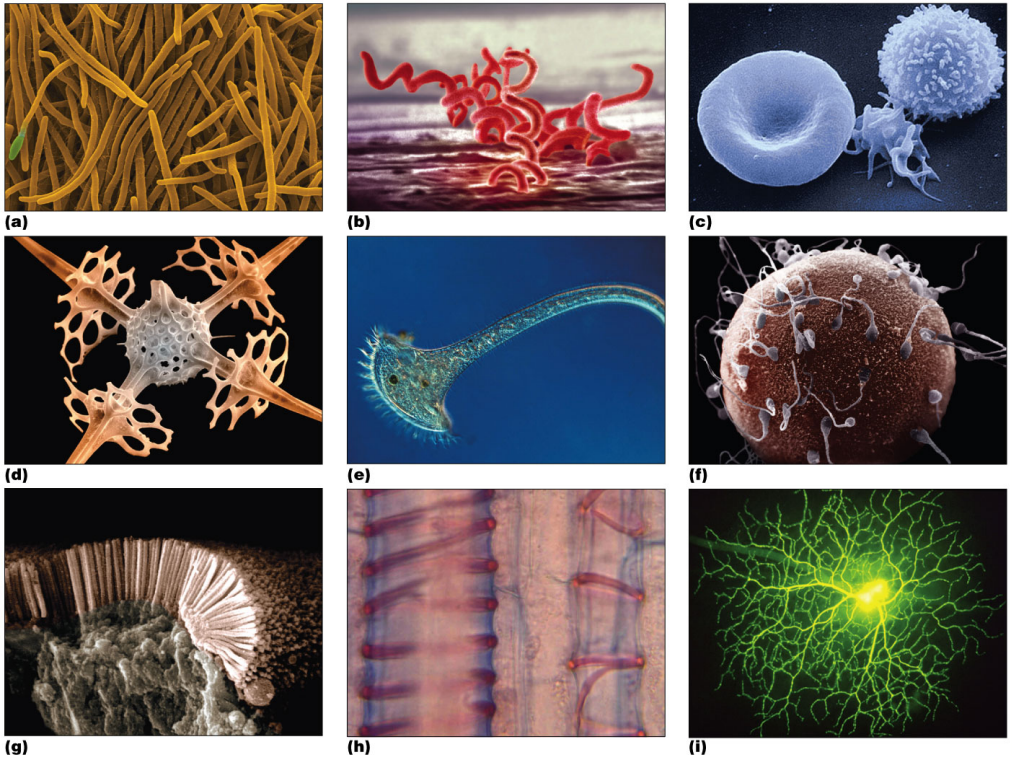
Outline

- Cells
- Microscopy
- Biochemistry
- Genetics

Cells: The building blocks of life

- Cells are the basic units of biology
- Every living organism either consists of cells or is itself a single cell



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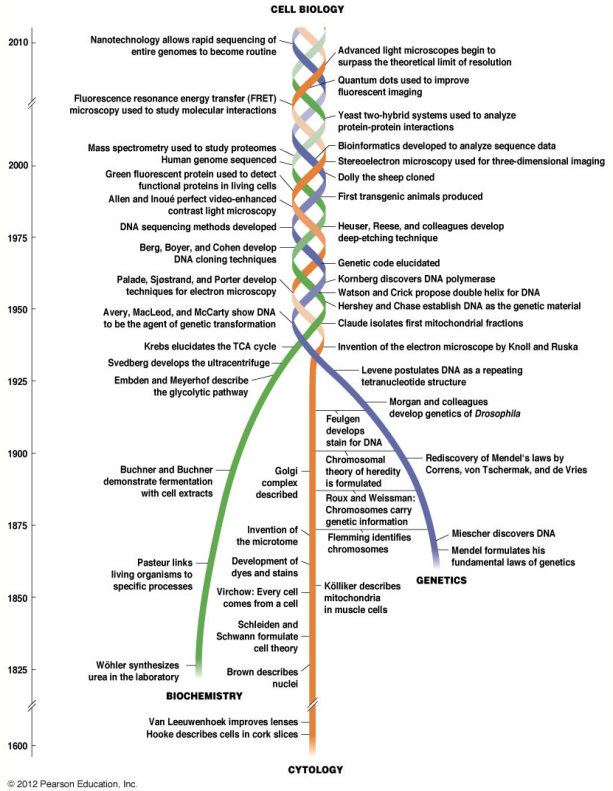
The Emergence of Modern Cell Biology

- Three historical strands weave together into modern cell biology, each with important contributions to understanding cells
- The **cytology** strand focuses mainly on cellular structure, and emphasizes optical techniques
- The **biochemistry** strand focuses on cellular function
- The **genetics** strand focuses on information flow and heredity



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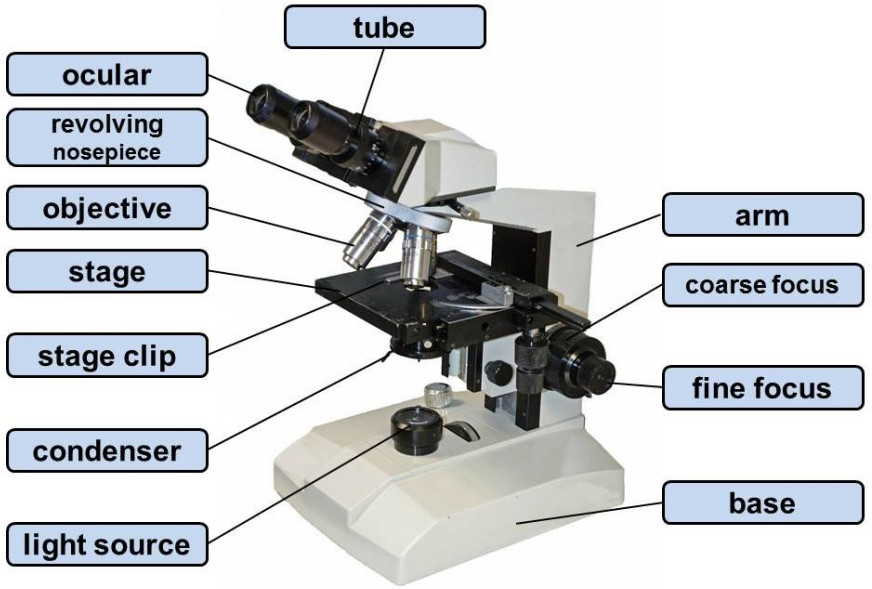
Microscopes: essential tools in early cell biology

- By the 1830s, *compound microscopes* were used (two lenses)
  - Increased magnification and resolution
  - Structures only 1 micrometer in size could be seen
- Using a compound microscope, Robert Brown identified the *nucleus,* a structure inside plant cells

Light Microscopy

- The **light microscope** was the earliest tool of cytologists
- Allowed identification of *organelles* within cells
- Organelles are membrane-bound structures, such as *nuclei*, *mitochondria,* and *chloroplasts*



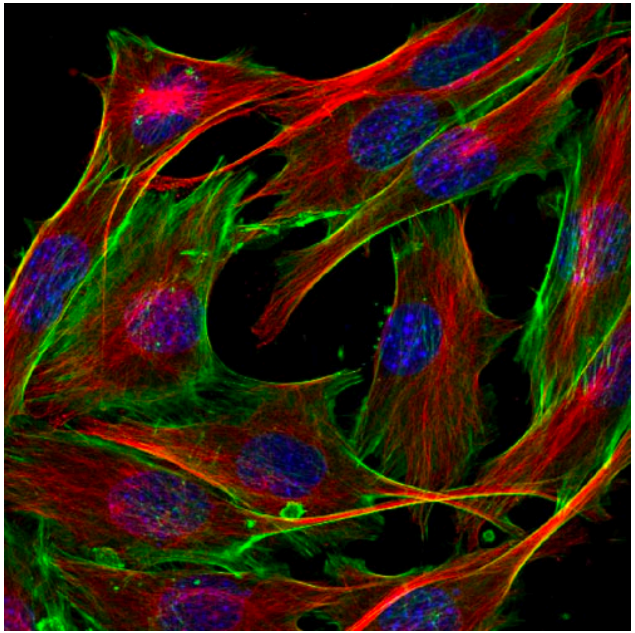
http://light-microscope.net

Useful tools in early microscopy

- The microtome (mid-1800s) allowed preparation of very thin slices of samples
- A variety of dyes for staining cells began to be used around the same time
  - These improved the **limit of resolution** (how far apart objects must be to appear as distinct)
- The smaller the limit of resolution a microscope has, the greater its **resolving power**

Visualizing living cells today

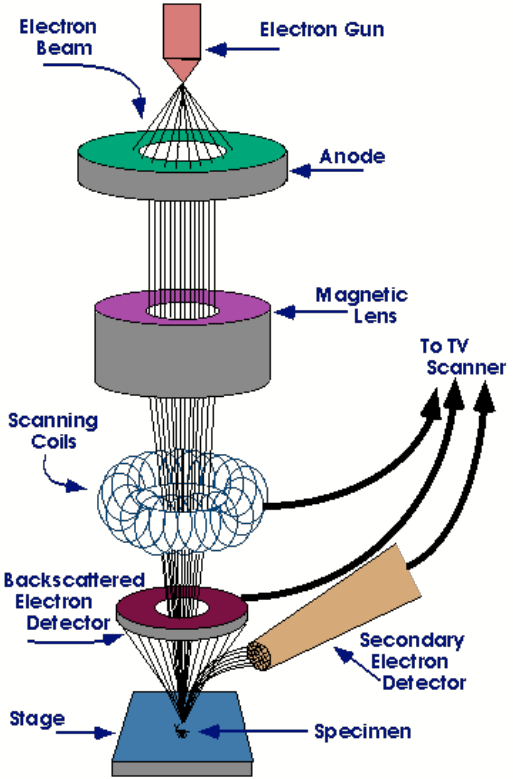
- *Phase contrast/differential interference contrast microscopy* exploit differences in the phase of light passing through a structure with a refractive index different than the surrounding medium
- *Fluorescence microscopy* detects fluorescent dyes, or labels, to show locations of substances in the cell
- *Confocal scanning* uses a laser beam to illuminate a single plane of a fluorescently labeled specimen
- https://microscopy.jhmi.edu/



Mouse embryonic fibroblasts placed on type-I collagen coated glass slide. Nucleus (blue), actin filaments (green), and microtubules (red) were imaged by nikon A1 confocal laser microscope with 60x magnification. Image by Dong-Hwee Kim, PhD. Denis Wirtz Lab, Johns Hopkins PS-OC.

The Electron Microscope

- The **electron microscope**, using a beam of electrons rather than light, was a major breakthrough for cell biology
- The limit of resolution of electron microscopes is around 0.1-0.2 nm
- The magnification is much higher than light microscopes –up to 100,000X



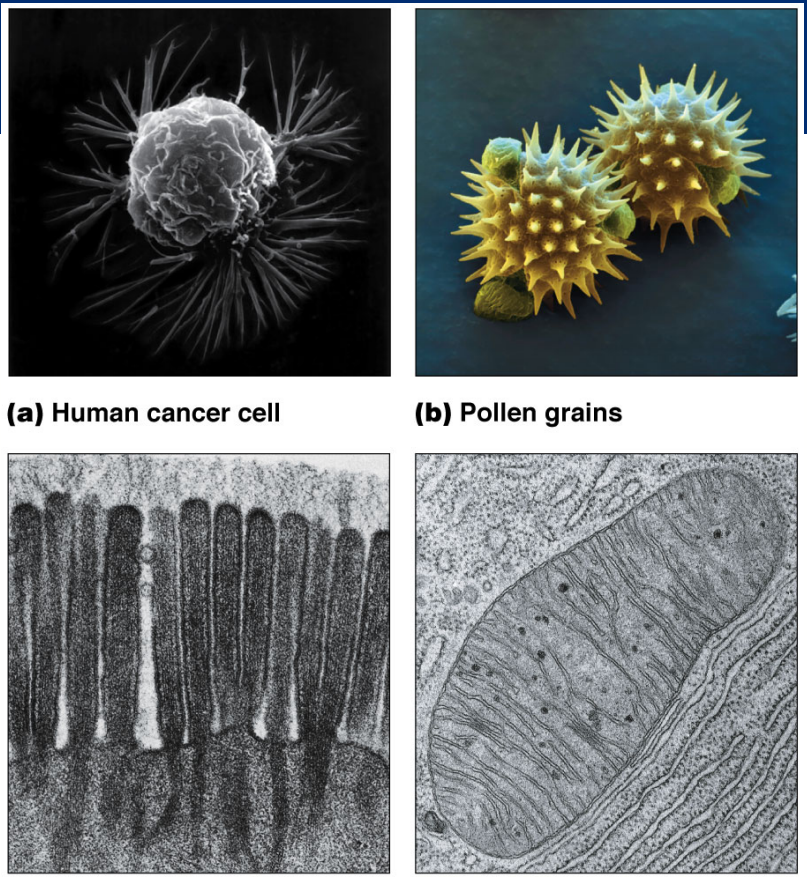
Electron Microscopy

- In **transmission electron microscopy (TEM)**, electrons are transmitted through the specimen
- In **scanning electron microscopy (SEM)**, the surface of a specimen is scanned, by detecting electrons deflected from the outer surface

SEM image of a dust mite
Credit: Wikipedia

SEM

TEM



(a) Human cancer cell

(b) Pollen grains

(c) Intestinal cell

(d) Mitochondrion

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Figure 1-4

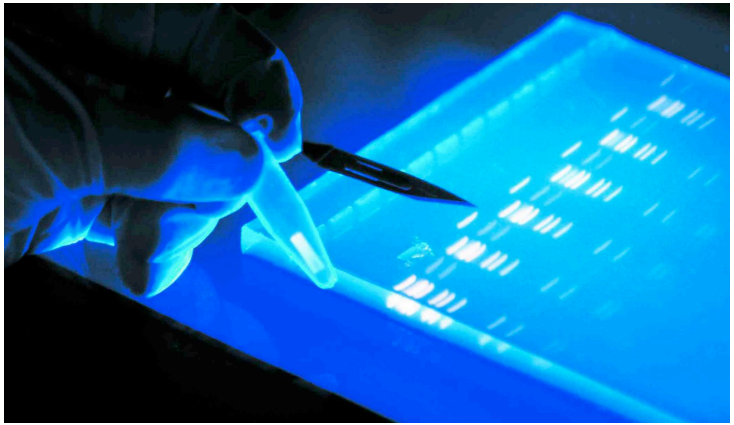
Biochemistry: The Chemistry of Biological Structure & Function

- Around the same time cytologists were studying cells microscopically, others began to explore cellular function
- Louis Pasteur (1860s) showed that yeasts could ferment sugar into alcohol
  - Discovered the principles of fermentation, vaccination, & pasteurization
- The Buchners (1897) showed that yeast extracts could do the same
- Led to the discovery of **enzymes,** biological catalysts

Biochemistry: Important Advances

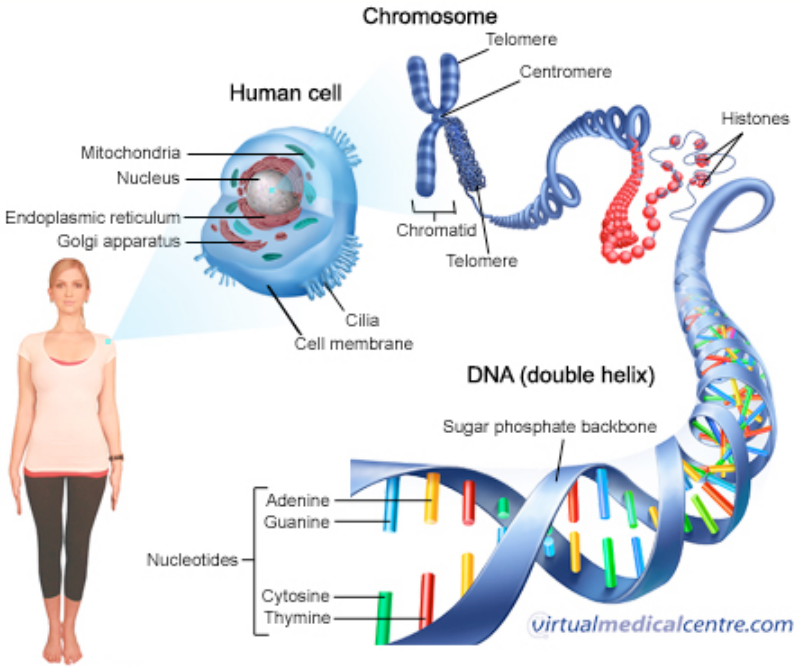
- **Chromatography** - techniques to separate molecules from a solution based on size, charge, or chemical affinity
- **Electrophoresis** - uses an electrical field to move proteins, DNA or RNA molecules through a medium based on size/charge
- **Mass spectrometry** - to determine the size and composition of individual proteins

DNA electrophoresis separates DNA fragments according to size



Genetics: Information flow and inheritance

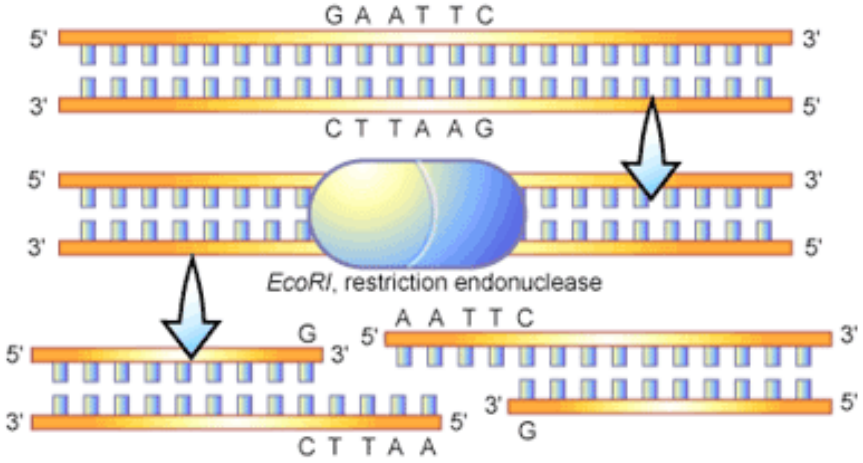
- Three geneticists formulated the **chromosome theory of heredity**, proposing that Mendel's hereditary factors are located on chromosomes
- Morgan, Bridges, and Sturtevant (1920s) were able to connect specific traits to specific chromosomes in the model organism, *Drosophila melanogaster* (the common fruit fly)
- Humans have 23 pairs of chromosomes



Important Techniques in Genetics

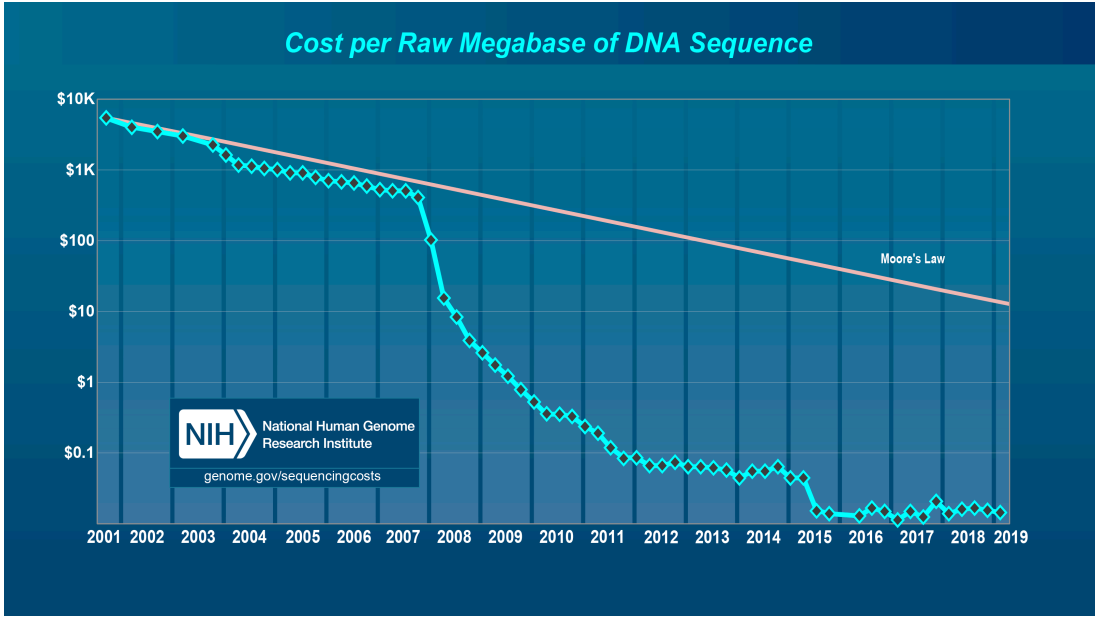
- Ultracentrifugation and electrophoresis, for separating DNA and RNA molecules

- Recombinant DNA technology, *restriction enzymes* cut DNA at specific places allowing scientists to create *recombinant DNA molecules,* with DNA from different sources



Important Techniques in Genetics (continued)

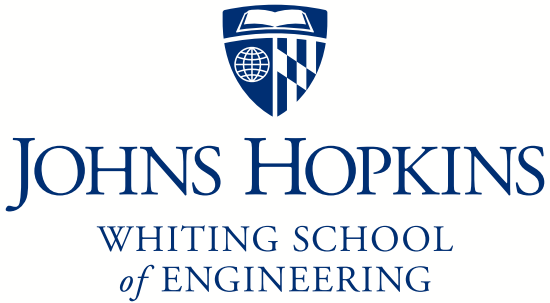
- **DNA sequencing**, methods for rapidly determining the base sequences of DNA molecules
- It is now possible to sequence entire *genomes* (entire DNA content of a cell) and the cost (per base) is continually decreasing
- **Bioinformatics** merges computer science with biology to organize and interpret enormous amounts of sequencing and other data



Credit: NIH, National Human Genome Research Institute

Summary

- Cell Theory
- Light microscopy
  - Advances and limitations
  - Electron microscopy
- Biochemistry and Genetics
  - Key laboratory techniques



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