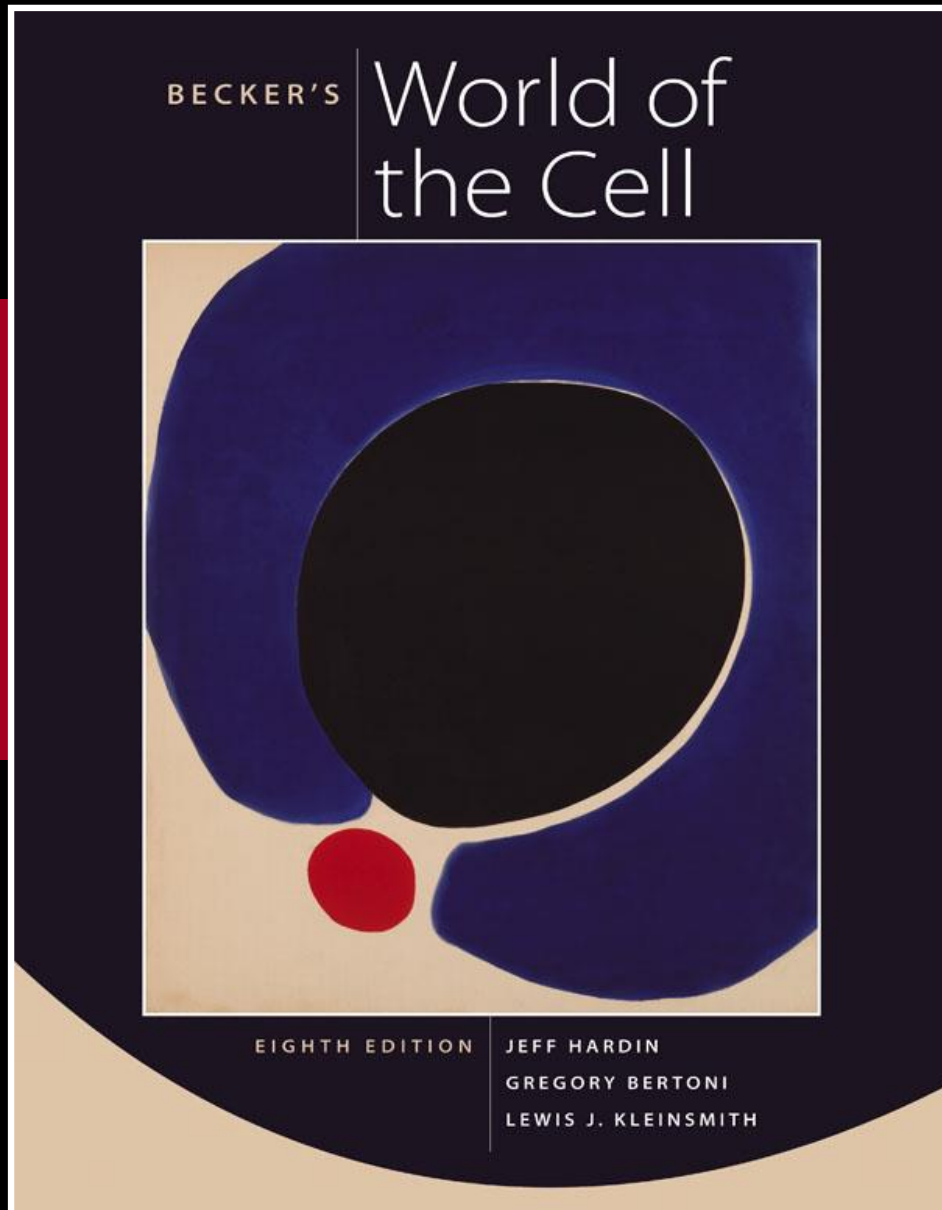


Chapter 1

A Preview of the Cell



Lectures by
Kathleen Fitzpatrick
Simon Fraser University

The Cell Theory: A Brief History

- **Robert Hooke** (1665) observed compartments in cork, under a microscope, and first named **cells** (the basic unit of biology)
- His observations were limited by the low *magnification power* (30X enlargement) of his microscope
- **Antonie van Leeuwenhoek**, a few years later, produced better lenses that magnified up to 300X

Early progress in cell biology was slow

- Two factors restricted progress in early cell biology
 - Microscopes had limited *resolution* (ability to see fine detail)
 - The descriptive nature of cell biology; the focus was on observation, with little emphasis on explanation

Microscopes: essential tools in early cell biology

- By the 1830s, *compound microscopes* were used (two lenses)
 - Increased magnification and better resolution
 - Structures only 1 micrometer in size could be seen
- Using a compound microscope, **Robert Brown** identified the *nucleus*, a structure inside plant cells
- **Matthias Schleiden** concluded that all plant tissues are composed of cells, and **Thomas Schwann** made the same conclusion for animals

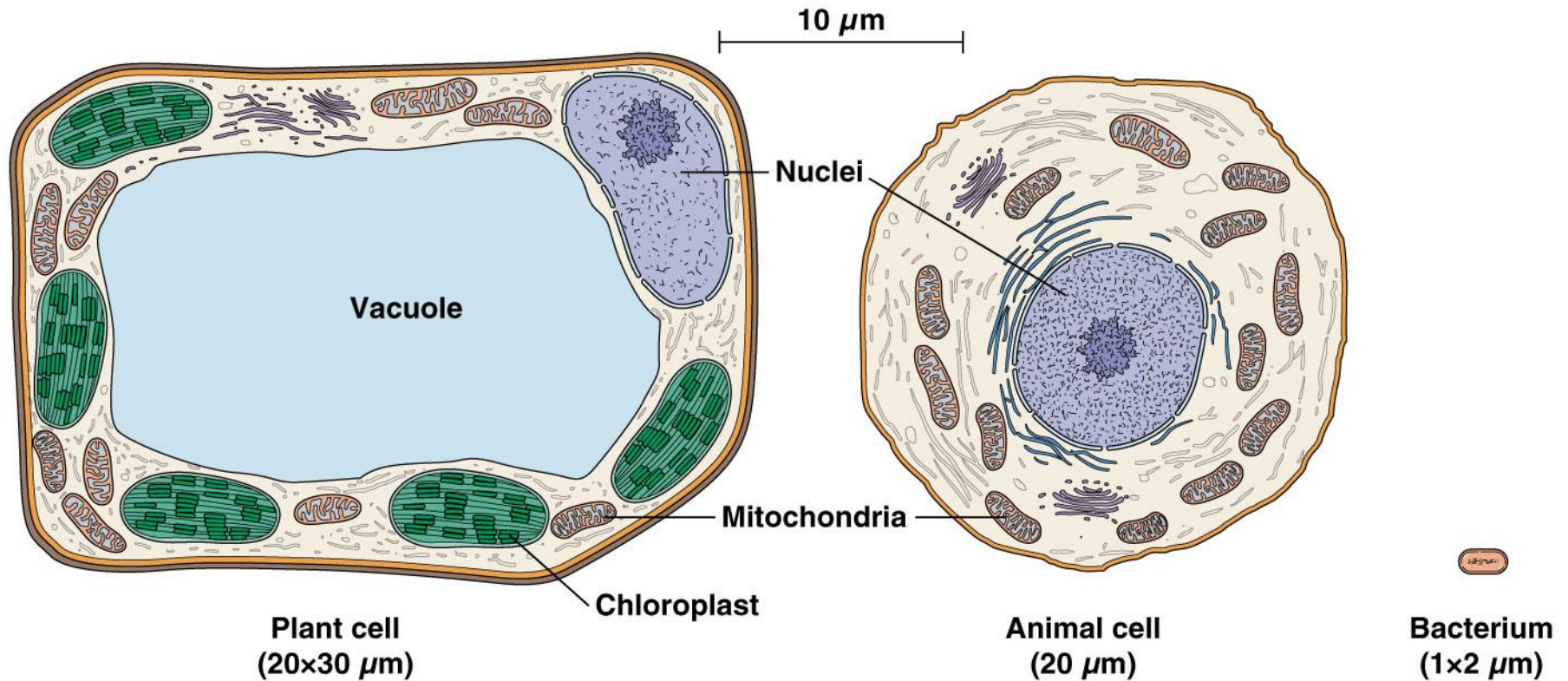
The cell theory

- In 1839, Schwann postulated the **cell theory**
 - 1. All organisms consist of one or more cells
 - 2. The cell is the basic unit of structure for all organisms
- Later, **Virchow** (1855) added
 - 3. All cells arise only from preexisting cells
(Meaning: the cell is the basic unit of reproduction)

Units of Measurements in Cell Biology

- Most cells are too small → cannot be seen by the naked eye
- Cell size can be expressed by the unit of *micrometer* or *micron* (μm)
- $1\ \mu\text{m} = 1 \times 10^{-6}\ \text{m} = 1 \times 10^{-3}\ \text{mm}$

Figure 1-3A



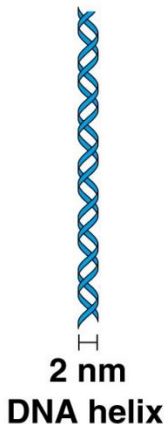
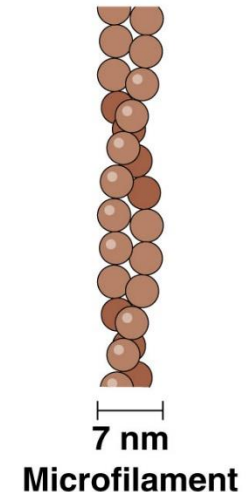
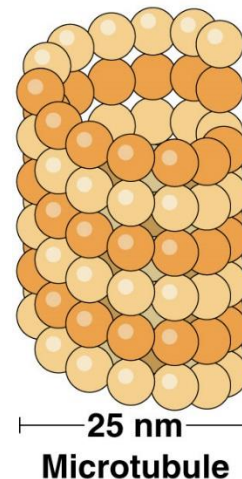
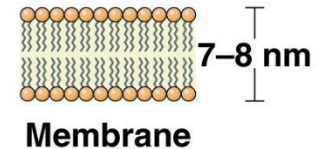
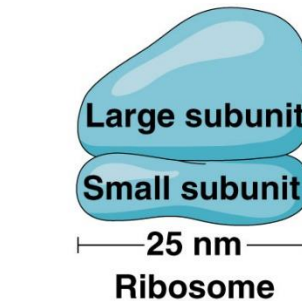
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Organelles, e.g. chloroplasts and mitochondria are few μm ; comparable size to a bacterium.

If you see it in a light microscope, its dimensions can be expressed in μm

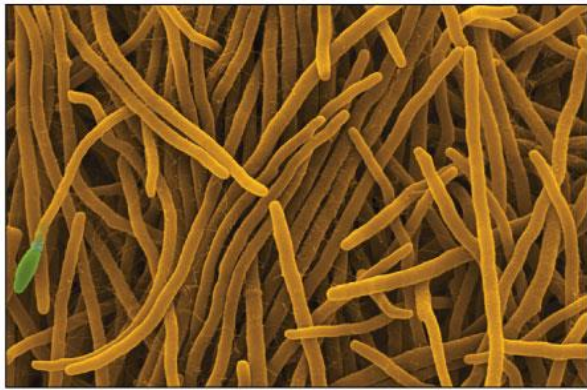
Subcellular Structure Sizes

- Subcellular structures (structures within the cell) and molecules can be expressed by the unit of **nanometer (nm)**
- $1 \text{ nm} = 1 \times 10^{-9} \text{ m} = 1 \times 10^{-6} \text{ mm}$
 $\text{mm} = 1 \times 10^{-3} \text{ }\mu\text{m}$



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Diversity of the Cellular World



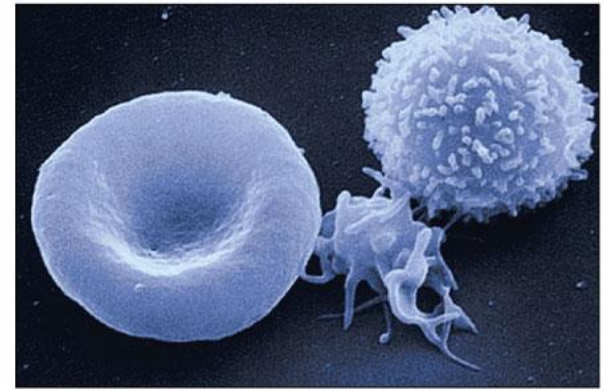
(a)

Filamentous fungal cells



(b)

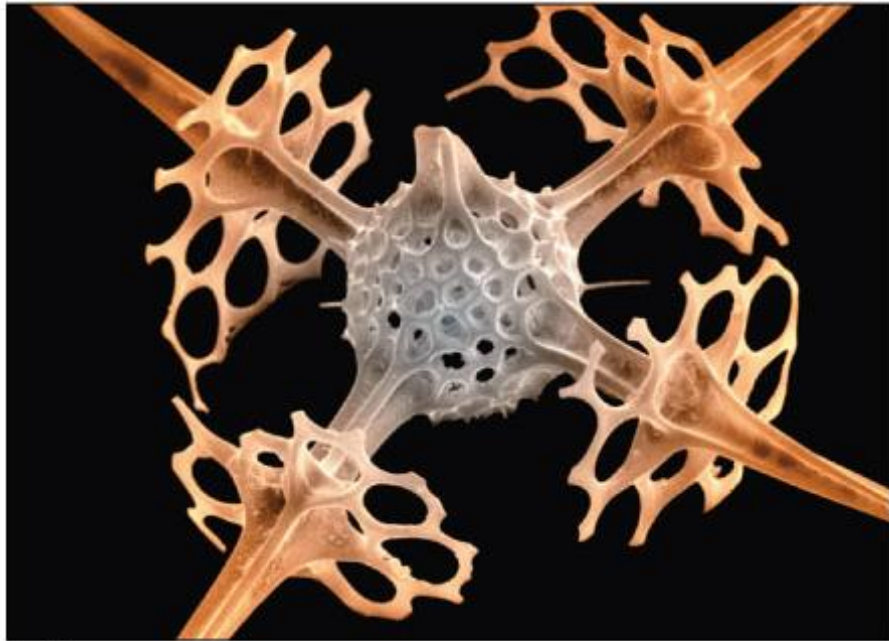
Treponema bacteria



(c)

Human RBC, platelet, WBC

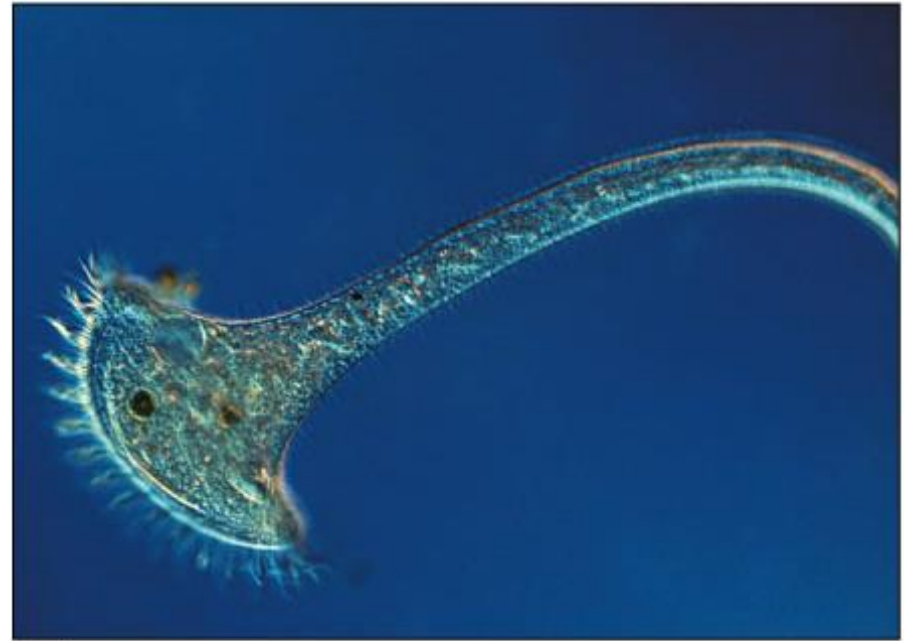
Diversity of the Cellular World



(d)

Radiolarian

شعاعيات



(e)

Protozoan

Diversity of the Cellular World

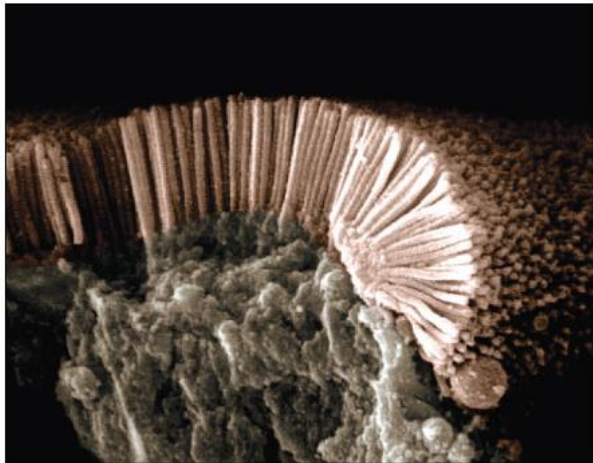


(f)

Human egg and sperms

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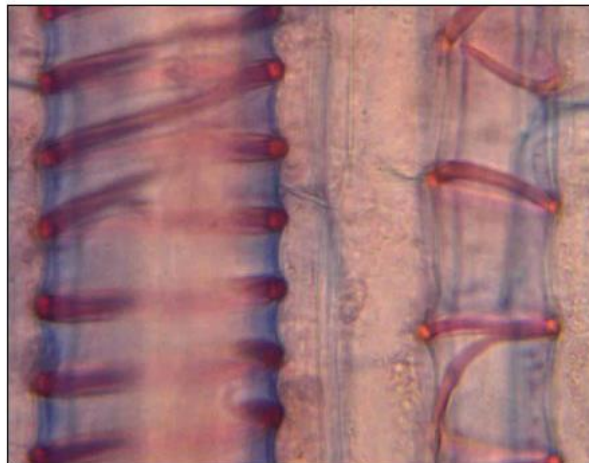
Diversity of the Cellular World



(g)

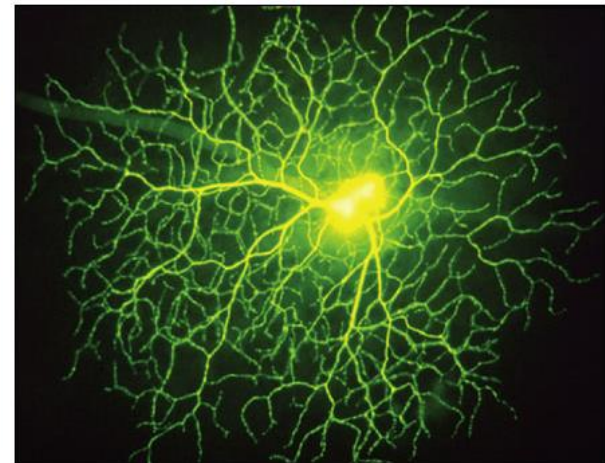
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Intestinal cells



(h)

Xylem cells



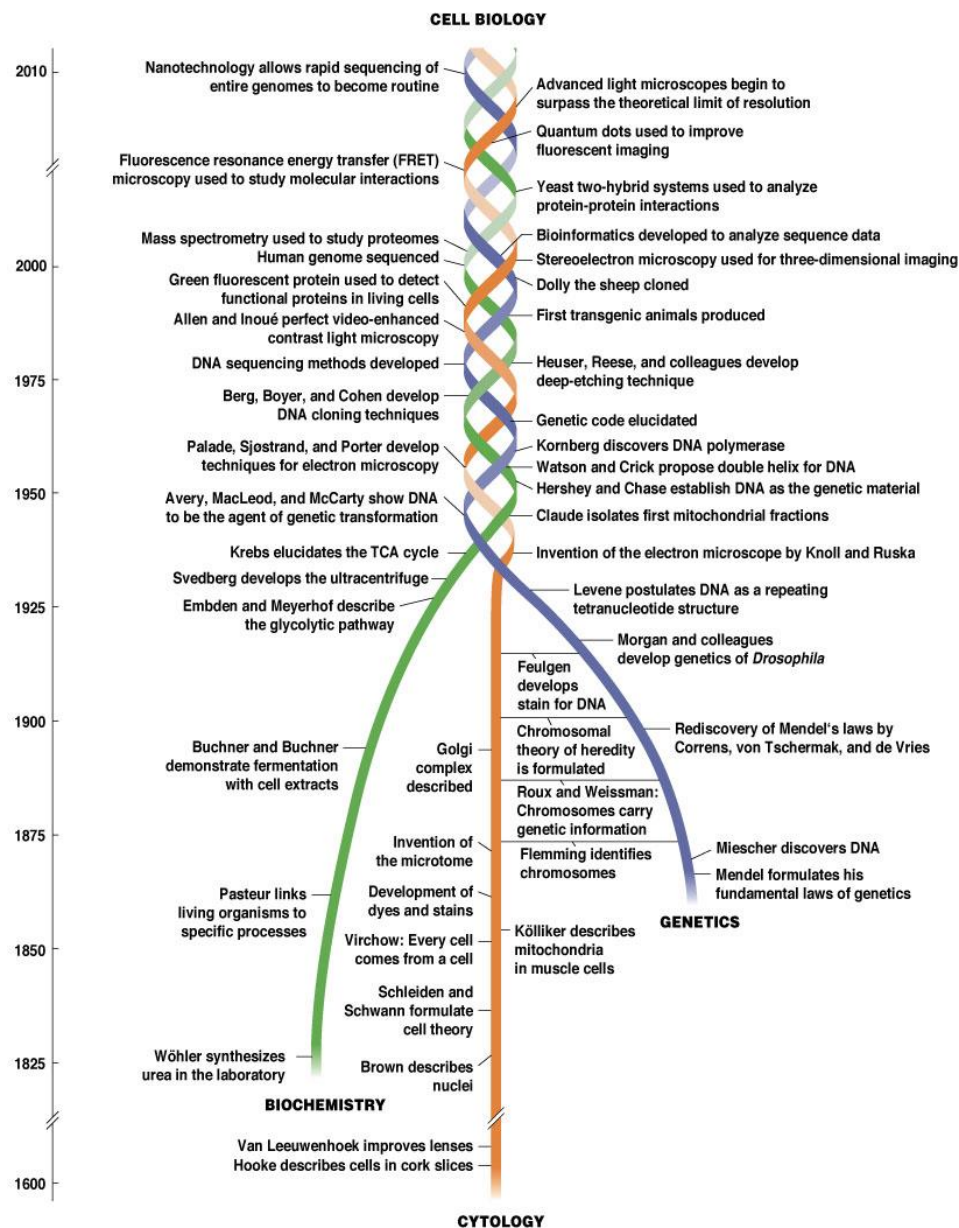
(i)

Retinal neuron

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

Figure 1-2



The Cytological Strand Deals with Cellular Structure

- Historically, cytology deals primarily with cell structure and observation using optical techniques

The Light Microscope

- 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*

Useful tools in early microscopy

- A variety of dyes for staining cells began to be used
- 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**

Visualization of Cells

- The light microscopy so far described is called *brightfield* microscopy, as white light is passed through a specimen
- Some preparations (fixing, staining, embedding in plastic) may distort tissues
- Various types of microscopy have been developed to allow observation of living cells

Visualizing living cells

- *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

Table 1-1

Table 1-1 Different Types of Light Microscopy: A Comparison

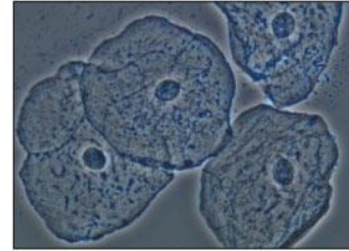
Type of Microscopy

Light Micrographs of Human Cheek Epithelial Cells

Type of Microscopy

Brightfield (unstained specimen):

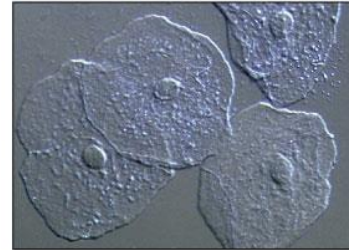
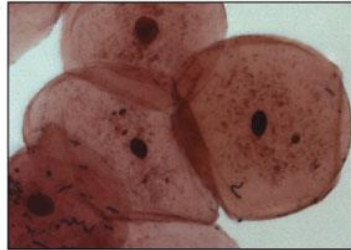
Passes light directly through specimen; unless cell is naturally pigmented or artificially stained, image has little contrast.



Phase contrast: Enhances contrast in unstained cells by amplifying variations in refractive index within specimen; especially useful for examining living, unpigmented cells.

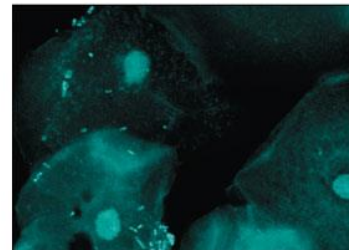
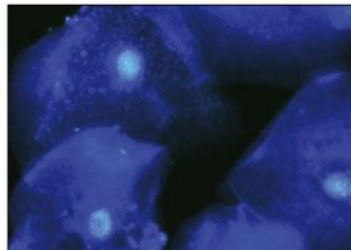
Brightfield (stained specimen):

Staining with various dyes enhances contrast, but most staining procedures require that cells be fixed (preserved).



Differential interference contrast: Also uses optical modifications to exaggerate differences in refractive index.

Fluorescence: Shows the locations of specific molecules in the cell. Fluorescent substances absorb ultraviolet radiation and emit visible light. The fluorescing molecules may occur naturally in the specimen but more often are made by tagging the molecules of interest with fluorescent dyes or antibodies.



Confocal: Uses lasers and special optics to focus illuminating beam on a single plane within the specimen. Only those regions within a narrow depth of focus are imaged. Regions above and below the selected plane of view appear black rather than blurry.

20 μm

Source: Adapted from Campbell and Reece, *Biology*, 6th ed. (San Francisco: Benjamin Cummings, 2002), p. 110.

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The Electron Microscope

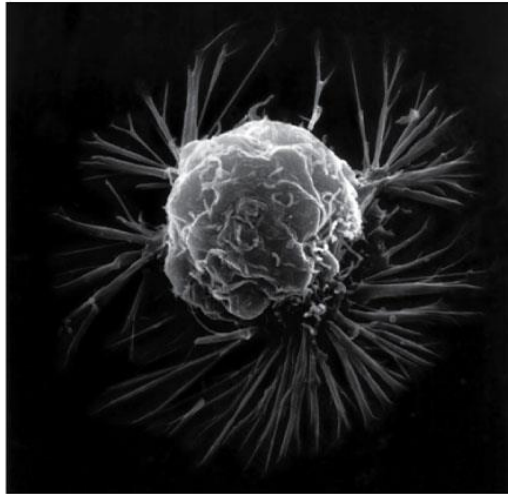
- The **electron microscope**, using a beam of electrons rather than light, was a major breakthrough for cell biology
- The limit of resolution of electron microscopes is around 0.1-0.2 nm
- The magnification is much higher than light microscopes – up to 100,000X

Electron microscopy

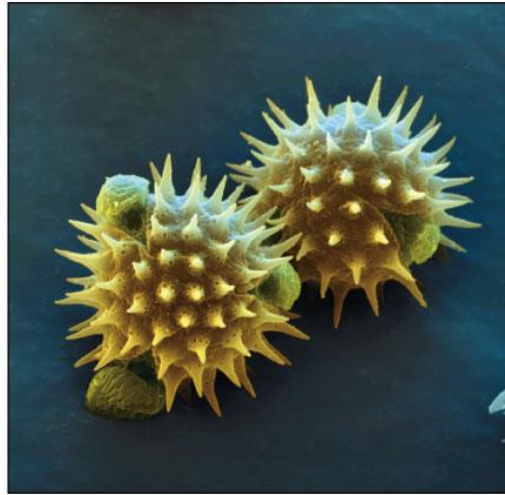
- In **transmission electron microscopy (TEM)**, electrons are transmitted through the specimen
- In **scanning electron microscopy (SEM)**, the surface of a specimen is scanned, by detecting electrons deflected from the outer surface
- Specialized approaches in electron microscopy allow for visualization of specimens in three dimensions, and one allows visualization of individual atoms

Figure 1-5

SEM

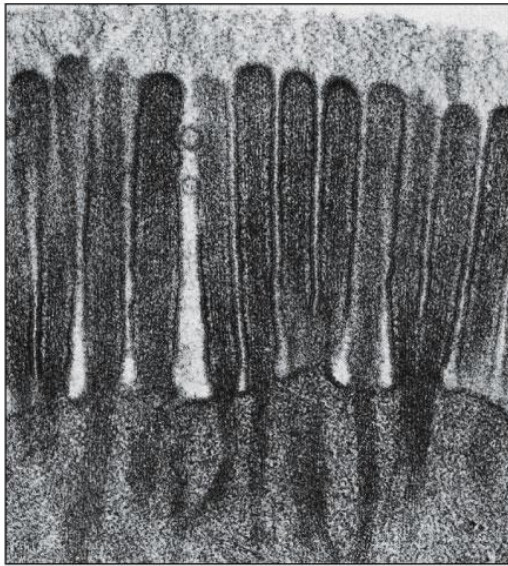


(a) Human cancer cell

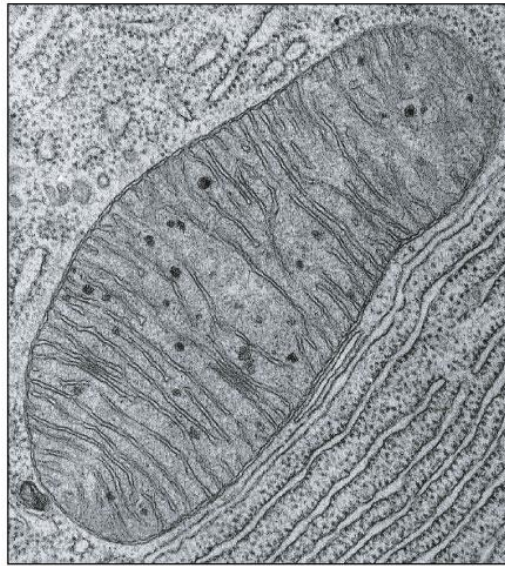


(b) Pollen grains

TEM



(c) Intestinal cell



(d) Mitochondrion

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The Biochemical Strand Covers the Chemistry of Biological Structure and Function

- Around the same time cytologists were studying cells microscopically, others began to explore cellular function
- Much of biochemistry dates from the work of **Fredrich Wöhler** (1828), who showed that a compound made in a living organism could be synthesized in the lab

Developments in early biochemistry

- **Louis Pasteur** (1860s) showed that yeasts could ferment sugar into alcohol
- The **Buchners** (1897) showed that yeast extracts could do the same
- Led to the discovery of **enzymes**, biological catalysts

Important advances in biochemistry

- **Subcellular fractionation** - such as *centrifugation* to separate/isolate different structures and macromolecules
- *Ultracentrifuges* - capable of very high speeds (over 100,000 revolutions per minute)

Important advances in biochemistry (continued):

- **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

The Genetic Strand Focuses on Information Flow

- The genetic strand has important roots in the nineteenth century
- **Gregor Mendel**'s experiments with peas (1866) laid the foundation for understanding the passage of “hereditary factors” from parents to offspring
- The hereditary factors are now known to be **genes**

Chromosomes and the genetic material

- **Walther Flemming** (1880) saw threadlike bodies in the nucleus called **chromosomes**
- He called the process of cell division *mitosis*

DNA is the genetic material

- Experiments with bacteria and viruses in the 1940s began to implicate DNA as the genetic material

*****HOMEWORK***** “AT LEAST 500 WORDS”

- 1953 - **Watson and Crick**, with assistance from **Rosalind Franklin**, proposed the *double helix model* for DNA structure
- 1960s - many advances toward understanding DNA replication, RNA production, and the genetic code

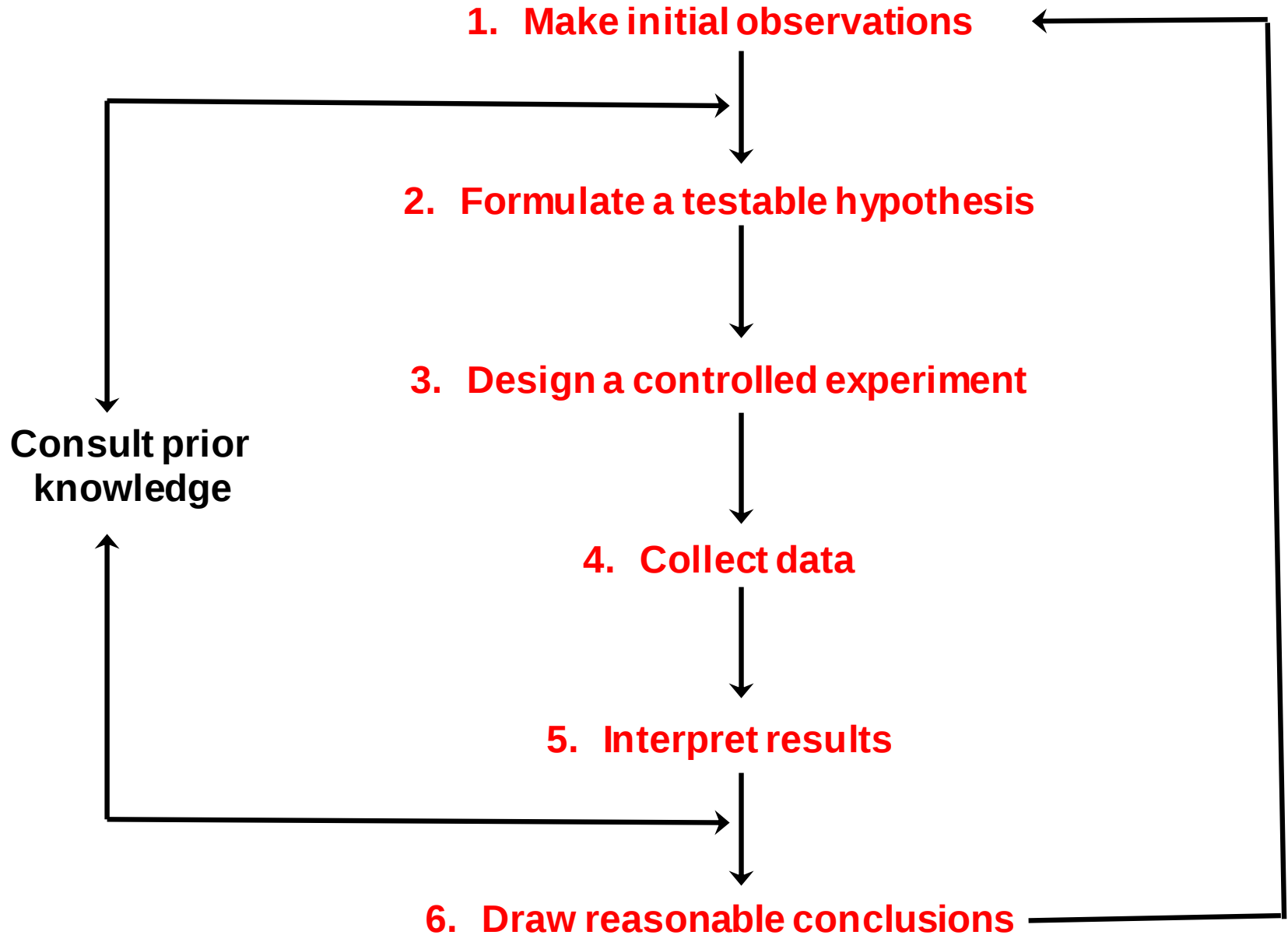
“Facts” and the Scientific Method

- In science, “facts” are tenuous and dynamic
- The *scientific method* is used to assess new information
 - Scientists formulate a *hypothesis* (tentative explanation or model that can be tested)
 - Data are collected and interpreted and the model is accepted or rejected
 - *Occam’s razor* states that the simplest explanation consistent with the observations is most likely to be correct

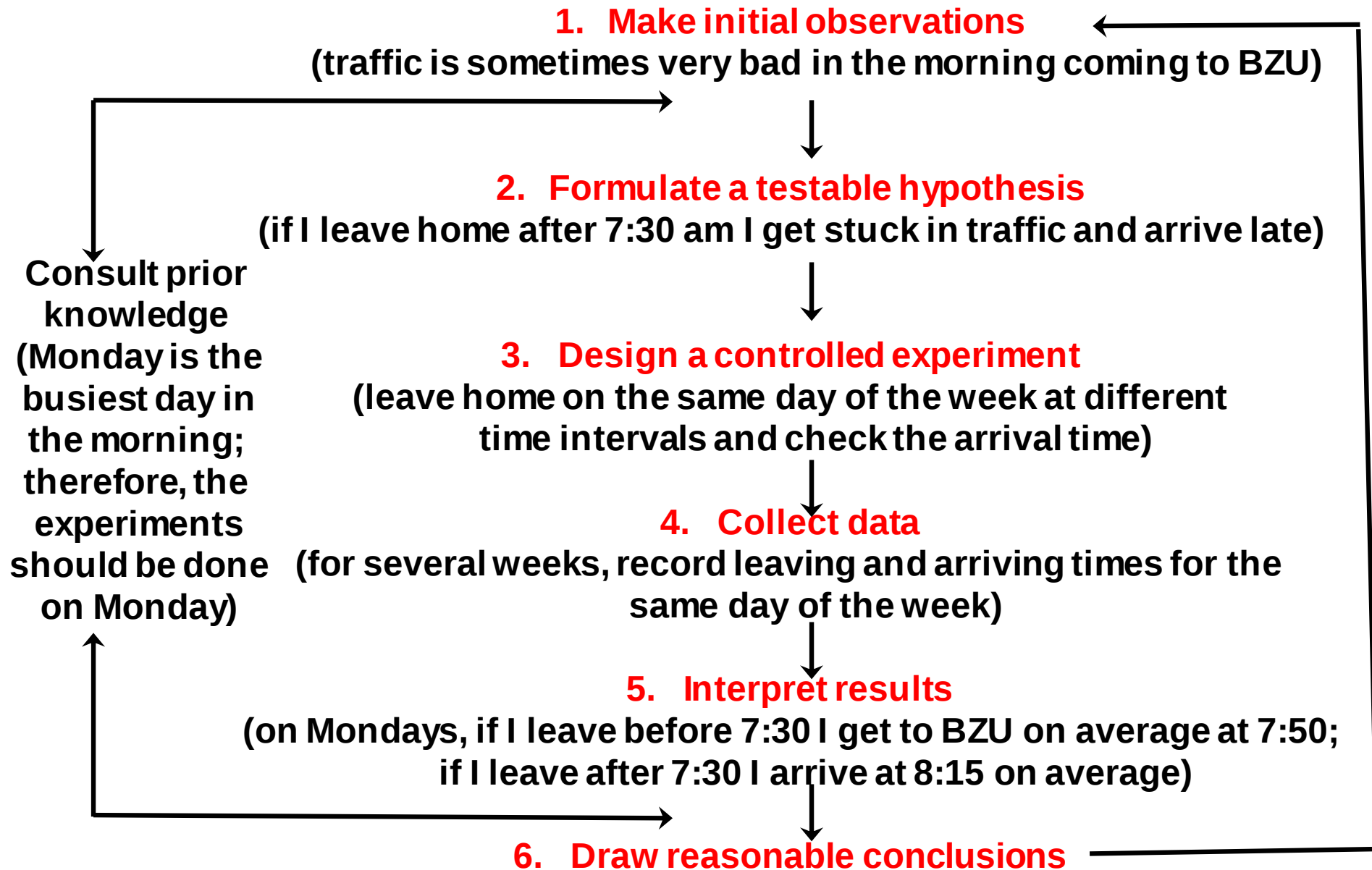
How we explain observations

- **Hypothesis** - statement consistent with most of the data, may take the form of a *model* (an explanation that appears to account for the data); must be testable
- **Theory** - a hypothesis that has been extensively tested by many investigators, using different approaches, widely accepted
- **Law** - a theory that has been tested and confirmed over a long period of time with virtually no doubt of its validity

The Scientific Method



The Scientific Method: Example



Research approaches in cell biology

- Research in laboratories may be
 - *In vitro*, using purified chemicals and cellular components
 - *In vivo*, using live cells or organisms
 - *In silico*, using computer analysis of large amounts of data