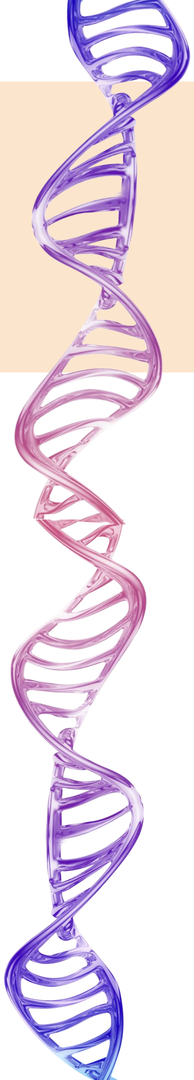


Molecular Biology

Course Overview

Instructor: Dr. Luu Phuc Loi, PhD

The course is divided into four main theoretical parts:

Part 0: Prokaryotic vs. Eukaryotic Cells

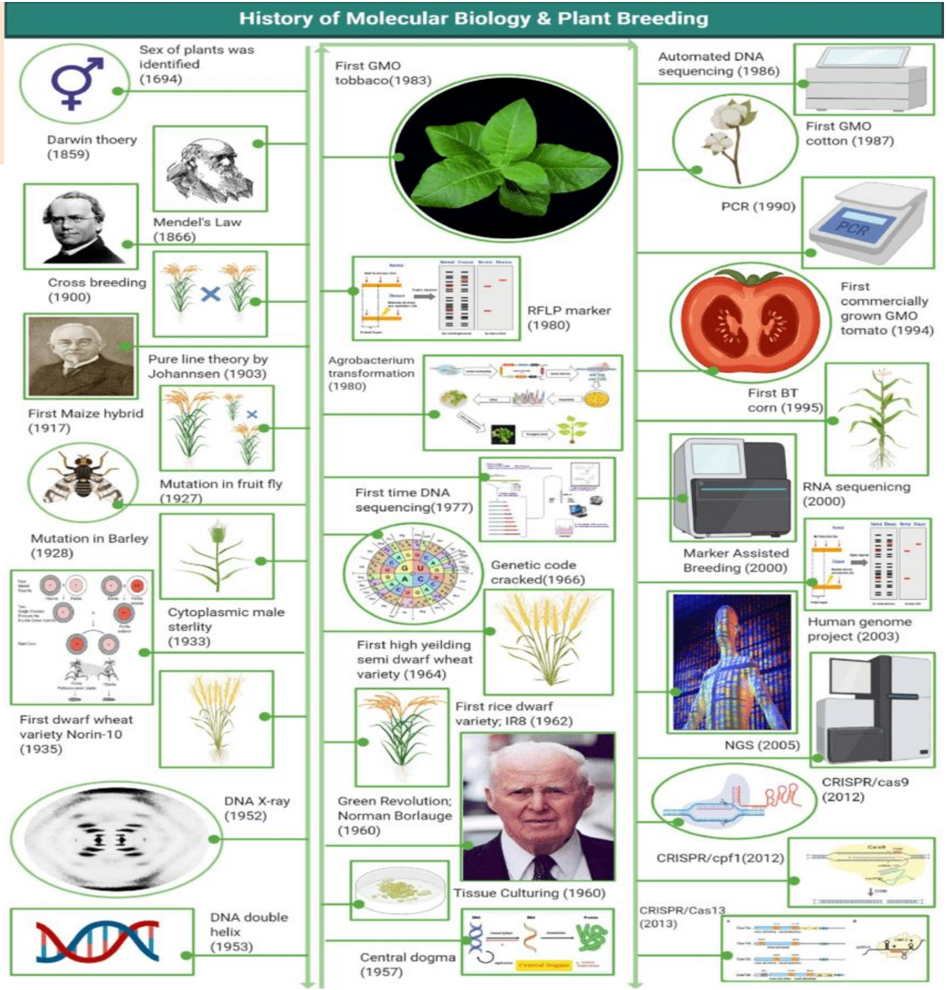
Part 1: DNA Replication and Repair

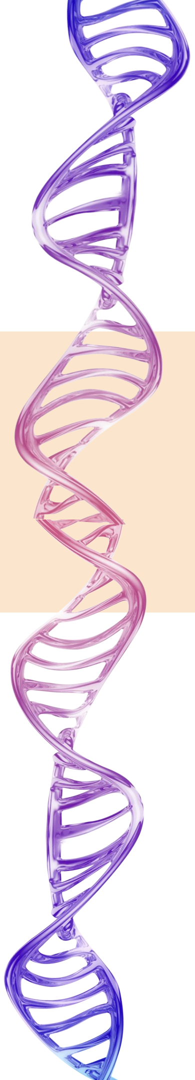
Part 2: Transcription and Transposition

Part 3: Translation – From Genome to Protein

Molecular Biology

- Molecular biology is a science that deal with the study of biology at a molecular level.
- Molecular biology the study of gene structure and functions at a molecular level to understand the molecular basis of heredity, genetics variation and the expression of gene.





Introduction to Cells

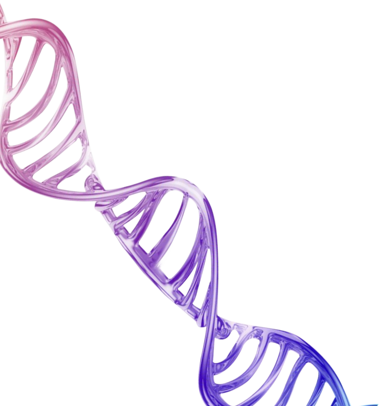
The fundamental unit of life

25 Jan 2026

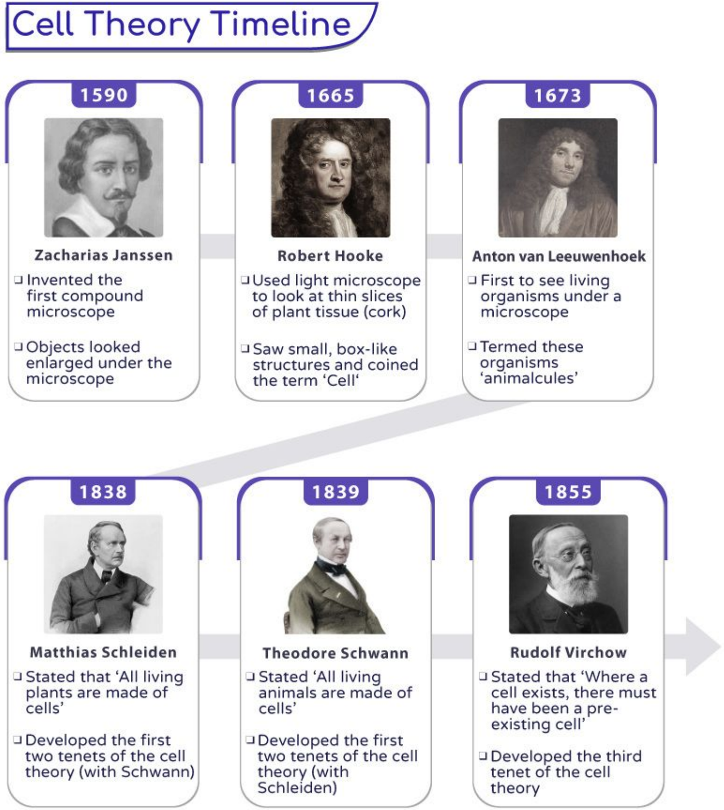
phD Luu Phuc Loi

Teaching assistants: Phuong Thao & Hoang Kim

Table of contents



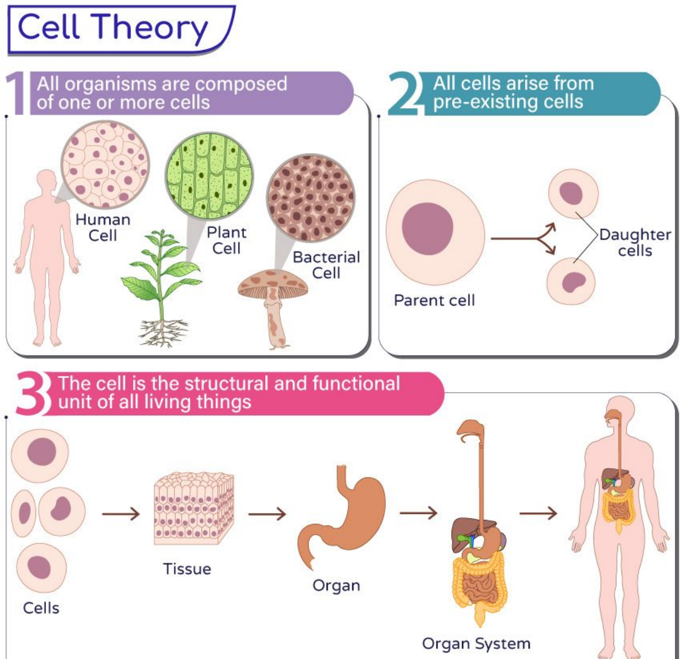
The brief history of The Cell theory



- The invention of light microscope led to the discovery of Cells.

The Cell Theory

- All organisms are composed one or more cells
- All cells come from pre-existing cells.
- The cell is the structural and functional unit of all living things.



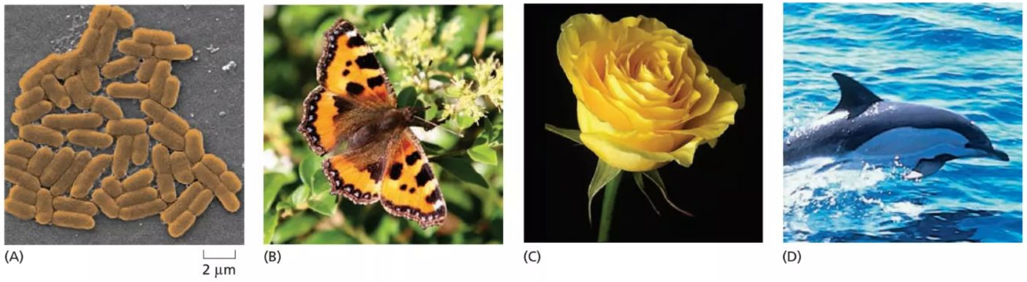


Figure 1–3 All living organisms are constructed from cells. (A) A colony of bacteria, (B) a butterfly, (C) a rose, and (D) a dolphin are all made of cells that have a fundamentally similar chemistry and operate according to the same basic principles. (A, courtesy of Janice Carr; D, courtesy of Jonathan Gordon, IFAW.)

Diversity of Cells: Cells vary enormously in appearance and function

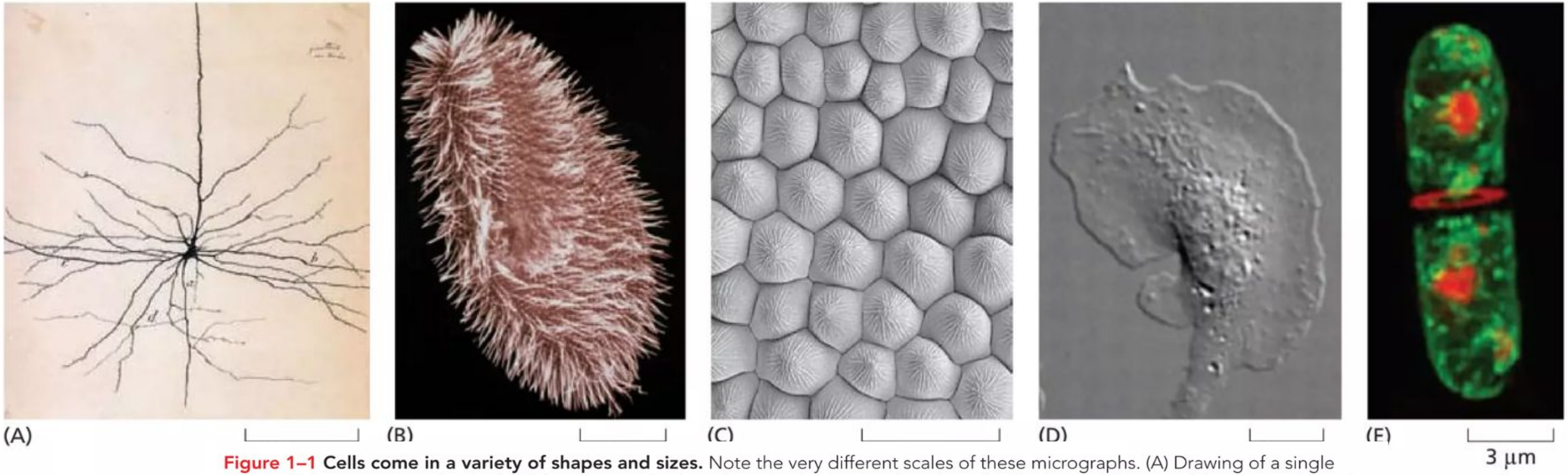


Figure 1–1 Cells come in a variety of shapes and sizes. Note the very different scales of these micrographs. (A) Drawing of a single nerve cell from a mammalian brain. This cell has a single, unbranched extension (axon), projecting toward the top of the image, through which it sends electrical signals to other nerve cells, and it possesses a huge branching tree of projections (dendrites) through which it receives signals from as many as 100,000 other nerve cells. (B) *Paramecium*. This protozoan—a single giant cell—swims by means of the beating cilia that cover its surface. (C) The surface of a snapdragon flower petal displays an orderly array of tightly packed cells. (D) A macrophage spreads itself out as it patrols animal tissues in search of invading microorganisms. (E) A fission yeast is caught in the act of dividing in two. The medial septum (stained *red* with a fluorescent dye) is forming a wall between the two nuclei (also stained *red*) that have been separated into the two daughter cells; in this image, the cells' membranes are stained with a *green* fluorescent dye. (A, Herederos de Santiago Ramón y Cajal, 1899; B, courtesy of Anne Aubusson Fleury, Michel Laurent, and André Adoutte; C, courtesy of Kim Findlay; D, from P.J. Hanley et al., *Proc. Natl Acad. Sci. USA* 107:12145–12150, 2010. With permission from National Academy of Sciences; E, courtesy of Janos Demeter and Shelley Sazer.)

Cellular Unity: all cells on earth share a universal features

- **A delimiting membrane** separates the inside of the cell from the external environment.
- **Common biochemistry**: all cells use the same basic building blocks
  (DNA, RNA, amino acids, lipids, carbohydrates).
- **Common macromolecules, supramolecular structures, and physiology**
  (e.g., lipid bilayers, ribosomes, and the use of ATP as an energy currency).
- **Metabolism** builds complex molecules from food and generates energy-rich molecules from light *(photosynthesis)* or through *respiration*.
- **Capacity for reproduction and maintenance of cellular function** through the flow of genetic information:

\+ *Genes → transcription → translation → structure and regulation*

\+ *DNA → mRNA → proteins → subunits and enzymes*

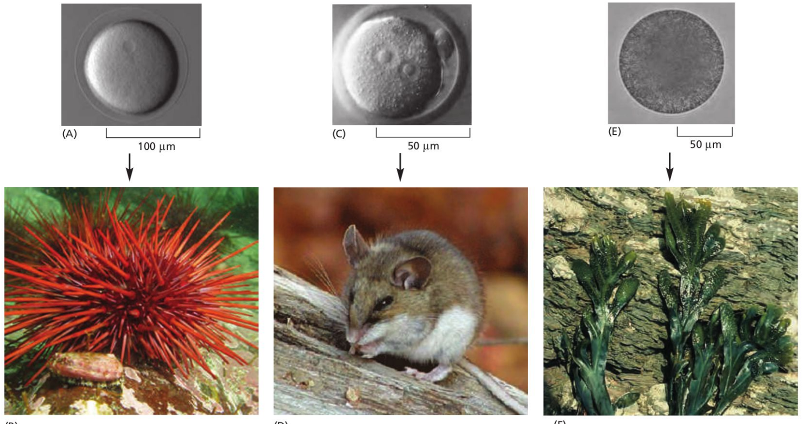
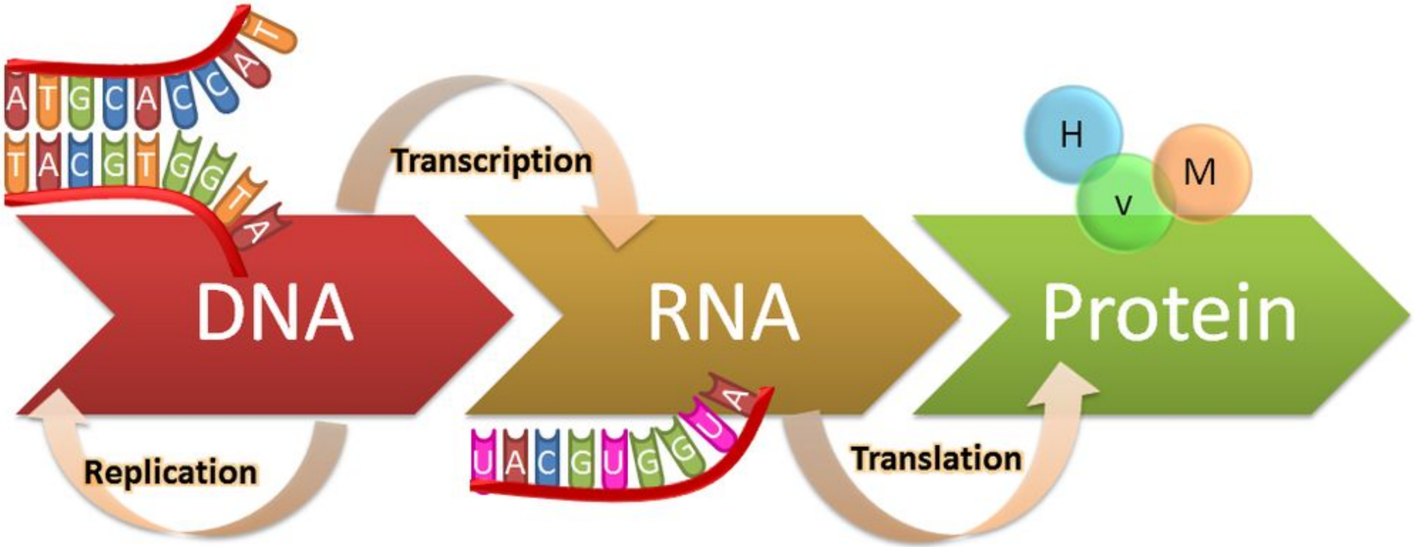


Figure 1–1 The hereditary information in the fertilized egg cell determines the nature of the whole multicellular organism. Although their starting cells look superficially similar, as indicated: a sea urchin egg gives rise to a sea urchin (A and B). A mouse egg gives rise to a mouse (C and D). An egg of the seaweed *Fucus* gives rise to a *Fucus* seaweed (E and F). (A, courtesy of David McClay; B, courtesy of M. Gibbs, Oxford Scientific Films; C, courtesy of Patricia Calarco, from G. Martin, *Science* 209:768–776, 1980. With permission from AAAS; D, courtesy of O. Newman, Oxford Scientific Films; E and F, courtesy of Colin Brownlee.)

Central Dogma: a universal information flow



DNA: replication & heredity

- All Cells Store Their Hereditary Information in the Same Linear Chemical Code: DNA
- All Cells Replicate Their Hereditary Information by Templated Polymerization.

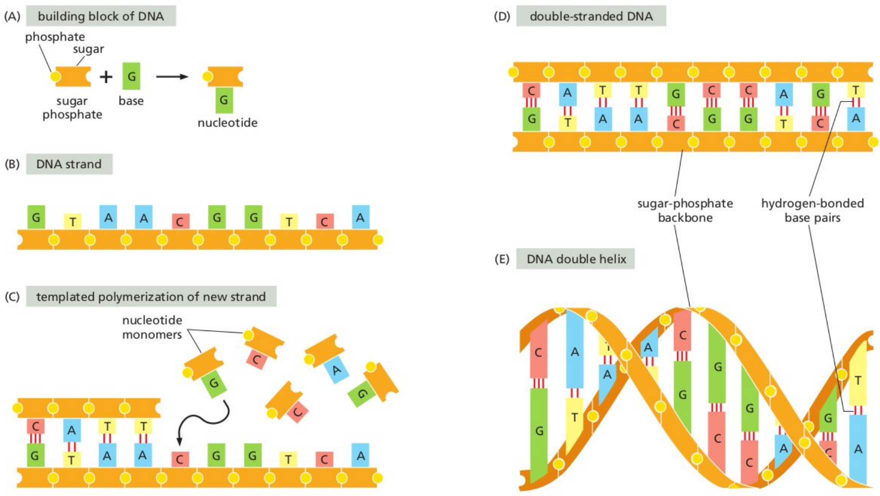


Figure 1–2 DNA and its building blocks.

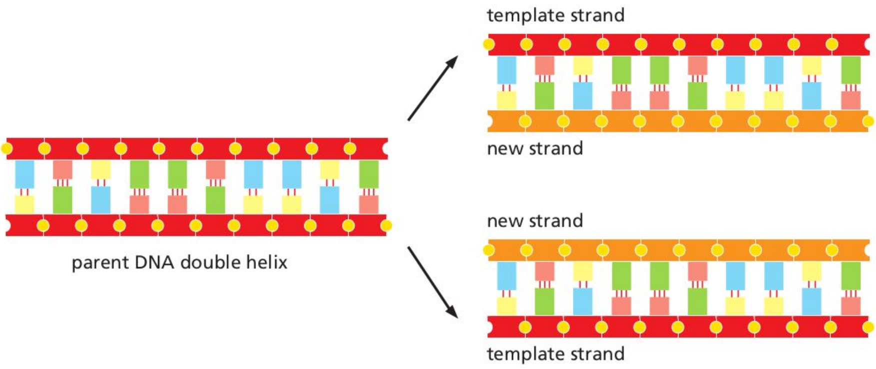


Figure 1–3 The copying of genetic information by DNA replication. In this process, the two strands of a DNA double helix are pulled apart, and each serves as a template for synthesis of a new complementary strand.

Transcription: From DNA to RNA

- All Cells Transcribe Portions of Their Hereditary Information into the Same Intermediary Form: RNA

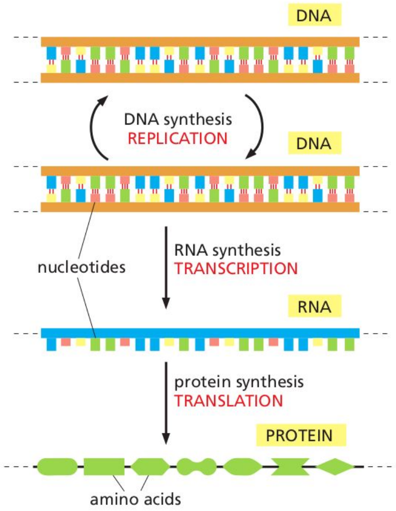


Figure 1–4. From DNA to protein.

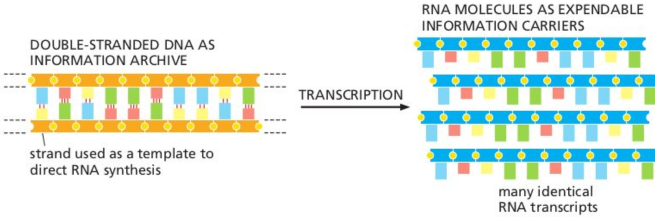


Figure 1–5 How genetic information is broadcast for use inside the cell.

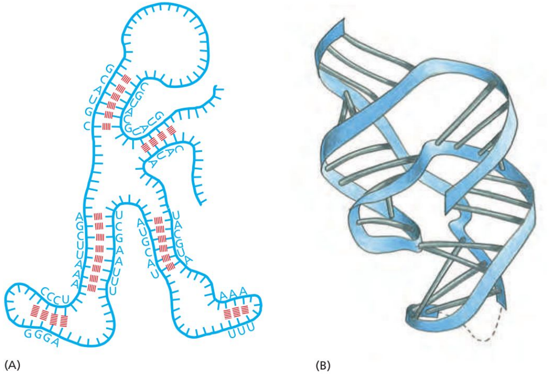
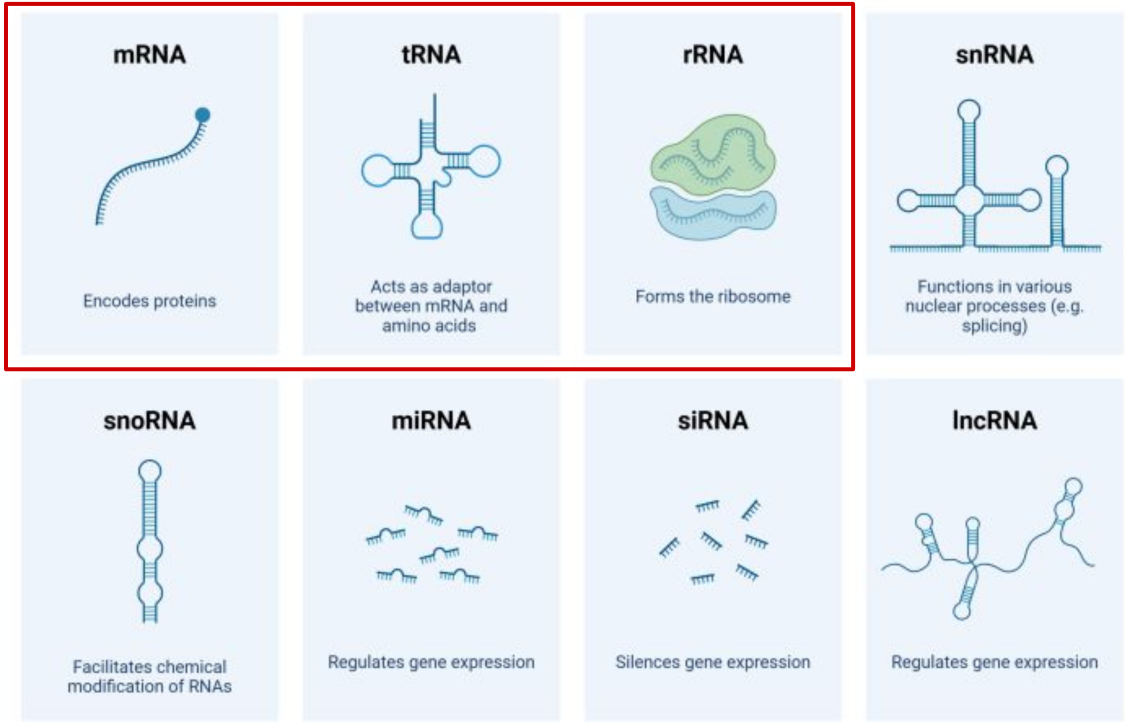


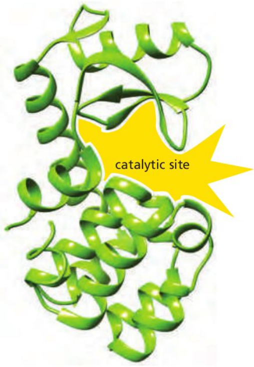
Figure 1–6 The conformation of an RNA molecule.

Types of RNA

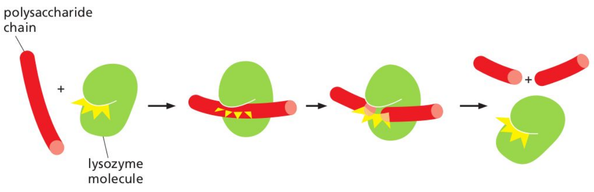

mRNA
Encodes proteins
tRNA
Acts as adaptor between mRNA and amino acids
rRNA
Forms the ribosome
snRNA
Functions in various nuclear processes (e.g. splicing)
snoRNA
Facilitates chemical modification of RNAs
miRNA
Regulates gene expression
siRNA
Silences gene expression
lncRNA
Regulates gene expression

Protein: translation & catalysis

- All Cells Use Proteins as Catalysts
- All Cells Translate RNA into Protein in the Same Way
- Each Protein Is Encoded by a Specific Gene

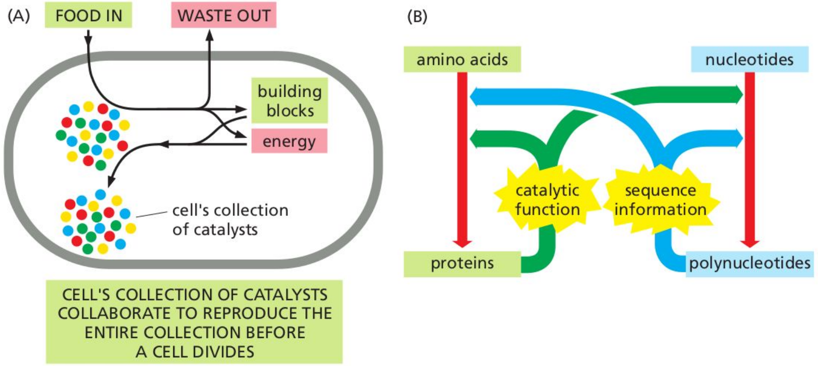


(A) lysozyme



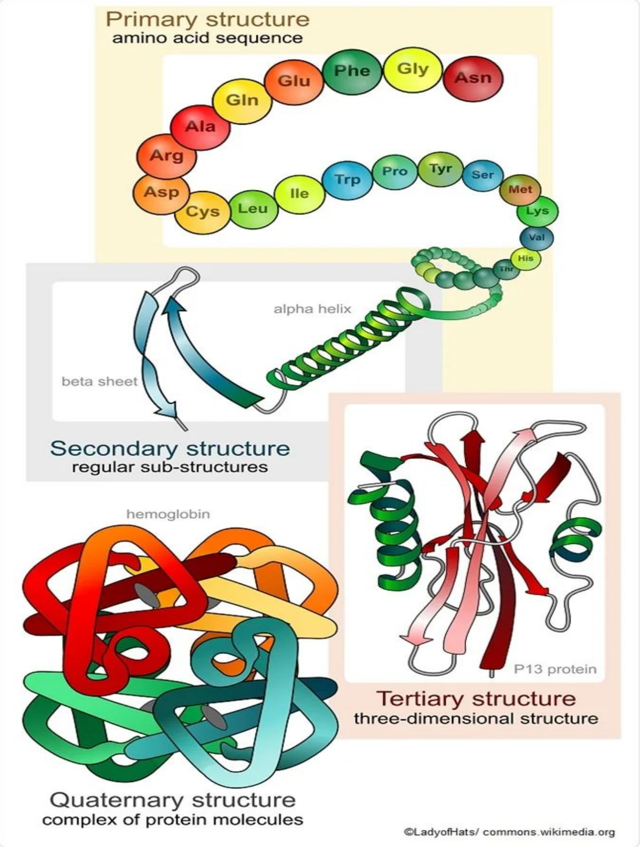
(B)

Figure 1–7 **How a protein molecule acts as a catalyst for a chemical reaction.** (A) In a protein molecule, the polymer chain folds up into a specific shape defined by its amino acid sequence. A groove in the surface of this particular folded molecule, the enzyme lysozyme, forms a catalytic site. (B) A polysaccharide molecule *(red)*—a polymer chain of sugar monomers—binds to the catalytic site lysozyme and is broken apart, as a result of a covalent bond-breaking reaction catalyzed by the amino acids lining the groove (see Movie 3.9). (PDB code: 1LYD.)

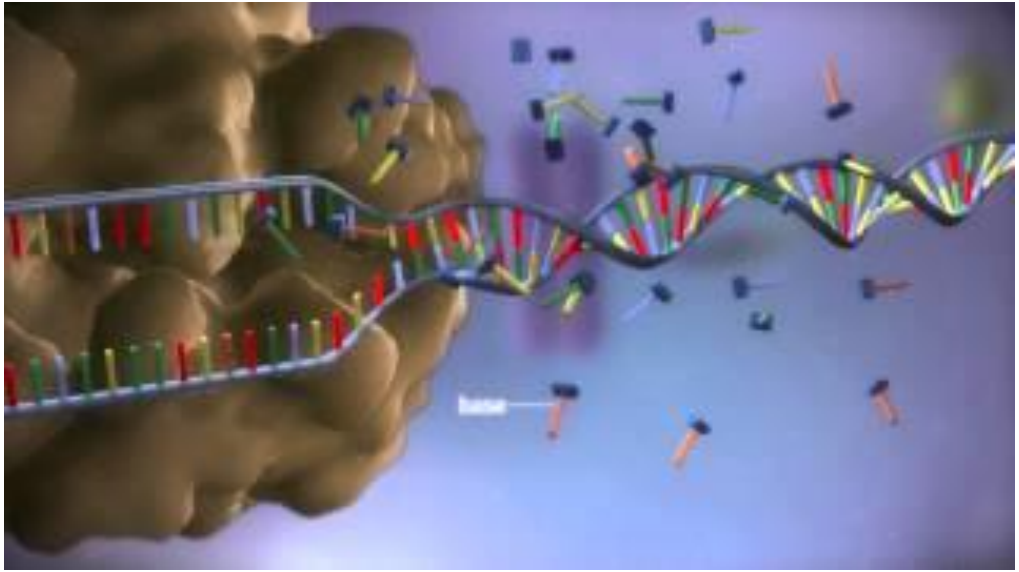


Protein structure

- Primary structure:
  - amino acid linear sequence of the polypeptide chain
- Secondary structure:
  - highly regular local sub-structures (alpha helix, beta strand or beta sheets)
- Tertiary structure:
  - three-dimensional structure of a protein molecule (given by hydrophilic and hydrophobic properties of molecules)
- Quaternary structure:
  - three-dimensional structure of a multi-subunit protein and how the subunits fit together



From DNA to protein



Gene & Protein Nomenclature: International Standards

Feature	**General Rule**	**Human** (*Homo sapiens*)	**Mouse** (*Mus musculus*)
Capitalization		**ALL UPPERCASE**	**Title Case** (First letter only)
Gene / RNA	*Italicized*	***HOXA4***	***Hoxa4***
Protein	Roman (Non-italic)	**HOXA4**	**Hoxa4**

Key Takeaways:
• **Italics** always denote **DNA** or **RNA** sequences.
• **Roman type** (standard) always denotes **Protein** products.
• **Human** symbols are fully capitalized; **Mouse** symbols are only capitalized at the start.

Question

Q1. Match the following terms with their definitions: (Plasma membrane, Gene, Genome, Enzyme).

1. A protein that catalyzes a specific chemical reaction.
2. The total genetic information of a cell or organism as embodied in its complete DNA sequence.
3. Region of DNA that controls a discrete hereditary characteristic of an organism, usually corresponding to a single protein or RNA.
4. The selective barrier surrounding a living cell.

Q2. What is it about DNA that makes it a better material than RNA for the storage of genetic information?

Q3. Fill in the blanks to complete the "Central Dogma" of molecular biology: Genetic information flows from (1) to (2) via a process called Transcription, and from (2) to (3) via a process called Translation.

Q4. One strand of a section of DNA isolated from E. coli reads: 5'-GTAGCCTACCCATAGG-3' A. Suppose that an mRNA were transcribed using the complement of this DNA strand as the template. What would the sequence of the mRNA in this region be?

Answers

A1. Match the following terms with their definitions: (Plasma membrane, Gene, Genome, Enzyme).

1. A protein that catalyzes a specific chemical reaction. Enzyme
2. The total genetic information of a cell or organism as embodied in its complete DNA sequence. Genome
3. Region of DNA that controls a discrete hereditary characteristic of an organism, usually corresponding to a single protein or RNA. Gene
4. The selective barrier surrounding a living cell. Plasma membrane

A2. What is it about DNA that makes it a better material than RNA for the storage of genetic information?

1. Stability
2. Repair

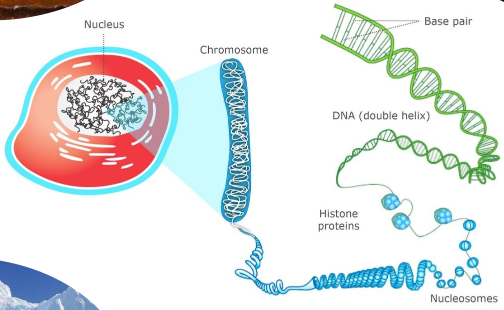
A3. Fill in the blanks to complete the "Central Dogma" of molecular biology: Genetic information flows from (1) to (2) via a process called Transcription, and from (2) to (3) via a process called Translation.

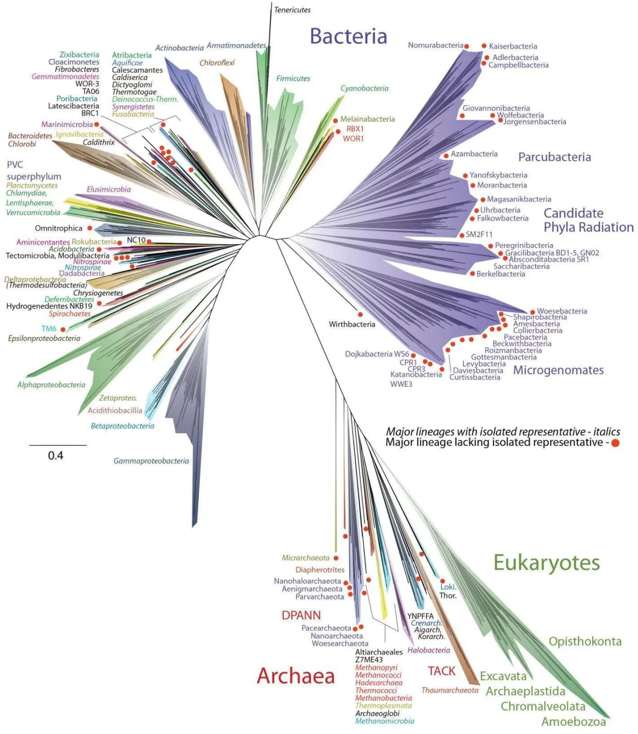
(1) DNA → (2) RNA → (3) Protein

A4. One strand of a section of DNA isolated from E. coli reads: 5'-GTAGCCTACCCATAGG-3' A. Suppose that an mRNA were transcribed using the complement of this DNA strand as the template. What would the sequence of the mRNA in this region be?

The mRNA sequence would be 5'-GUAGCCUACCCAUAGG-3'. (The RNA sequence is identical to the coding strand shown, except T is replaced by U)

The diversity of Genomes and the tree of life



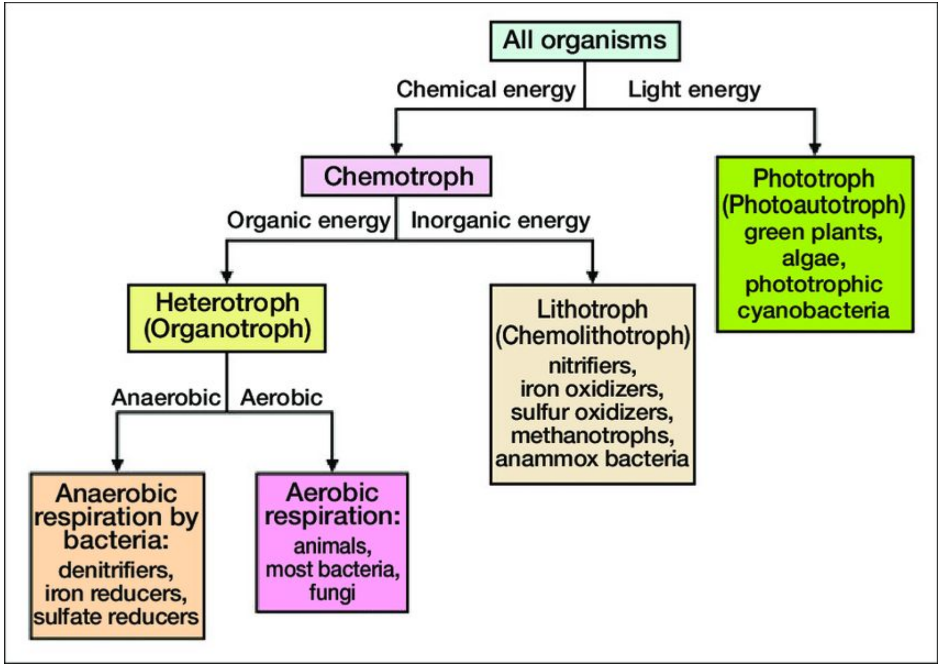


A 2016 (metagenomic) representation of the tree of life (unrooted) using ribosomal protein sequences

Cells Can Be Powered by a Variety of Free-Energy Sources

How Cells Obtain Energy

- Organisms obtain energy in different ways.
- **Organotrophs** feed on organic molecules (animals, fungi, many bacteria).
- **Phototrophs** use sunlight (plants, algae, photosynthetic bacteria) → source of Earth's oxygen.
- **Lithotrophs** use inorganic chemicals and often live in extreme environments.
- Some lithotrophs are aerobic; others are anaerobic, similar to early Earth.
-



Life Without Sunlight: Chemosynthetic Ecosystems

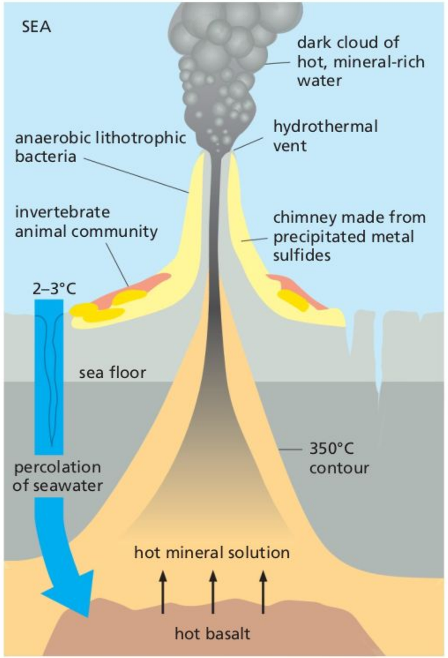


Figure 1–11 The geology of a hot hydrothermal vent in the ocean floor.

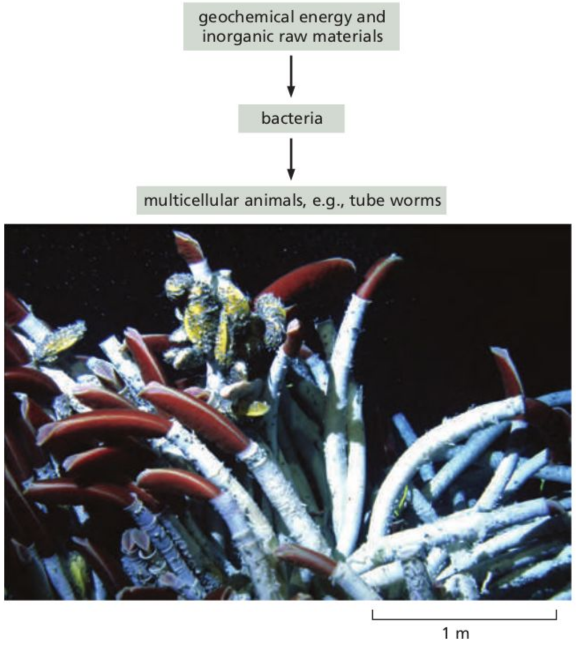
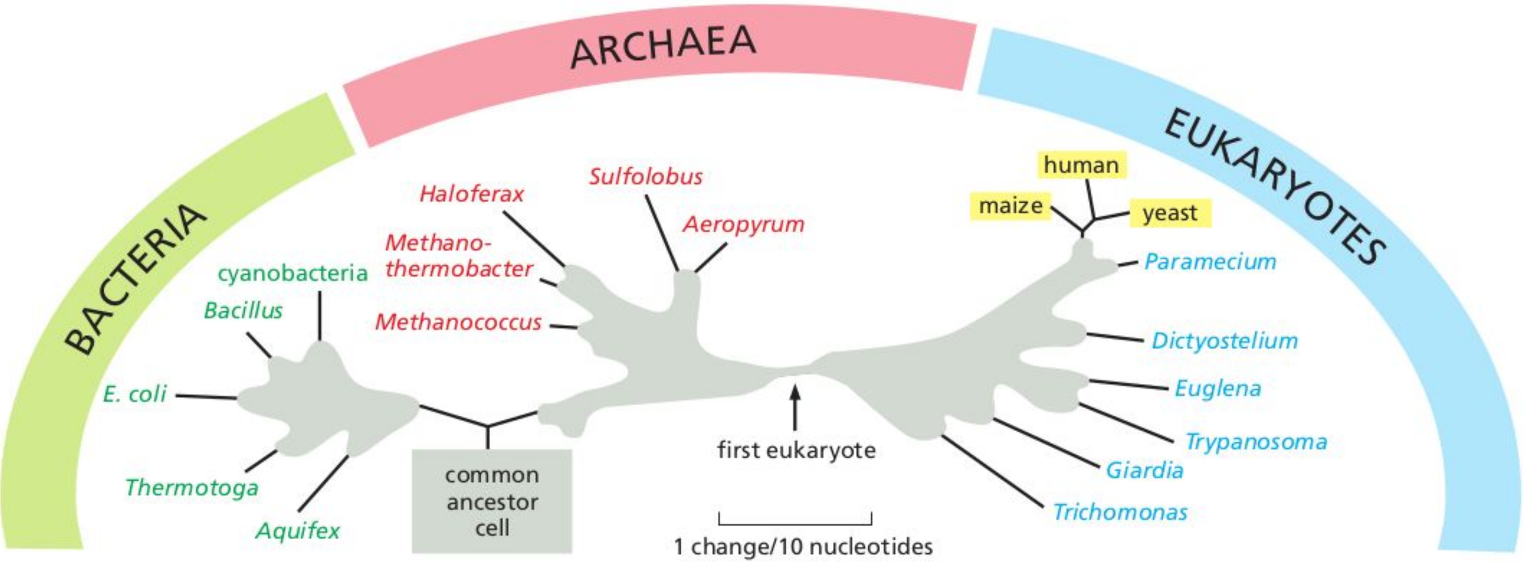


Figure 1–12 Organisms living at a depth of 2500 meters near a vent in the ocean floor.

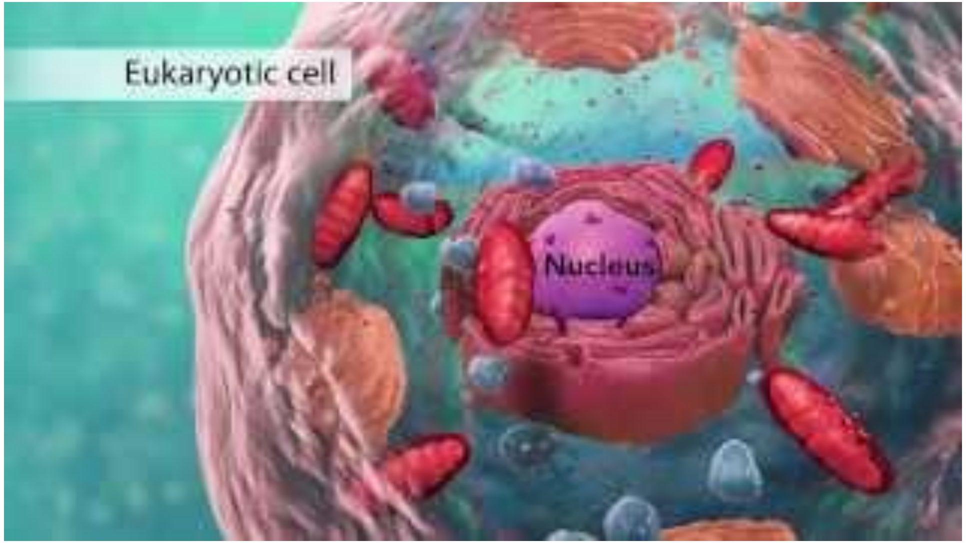
The Tree of Life Consists of Three Domains

- **Eukaryotes** (nuclear envelope)
- **Prokaryotes** (no nuclear envelope): including *Bacteria* and *Archaea*



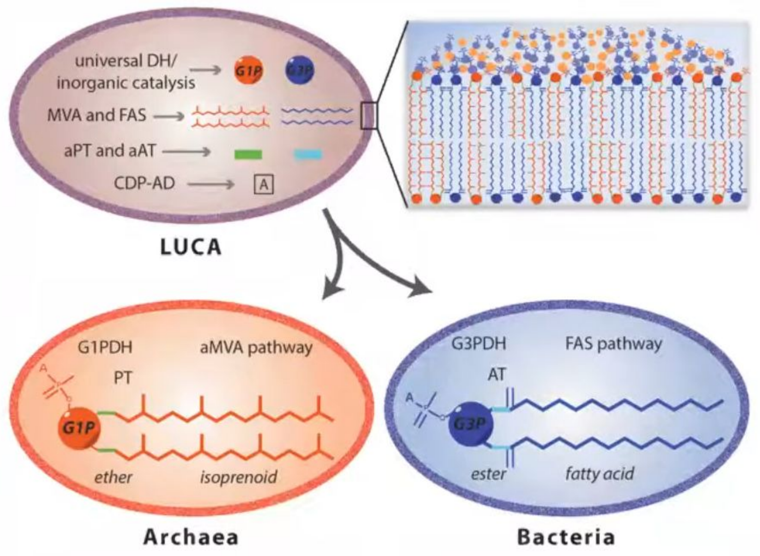
All cells contain common structures

- **Cell membrane**
  - + Lipid bilayer that surrounds the cell – defines the boundary of the cell
- **Cytoplasm**
  - + Aqueous solution inside the cell membrane
- **Cells are either eukaryotic or prokaryotic**
  - + Eukaryotic – DNA contained in nucleus
  - + Prokaryotic – no nucleus



Prokaryotes are divided into 2 domains

- **Bacteria**
  + Live in “normal” environments
  + Soil, water, humans
- **Archaea**
  + Live in “hostile” environments
  + Acid, salt, extreme cold, extreme heat



The Greatest Biochemical Diversity Exists Among Prokaryotic Cells

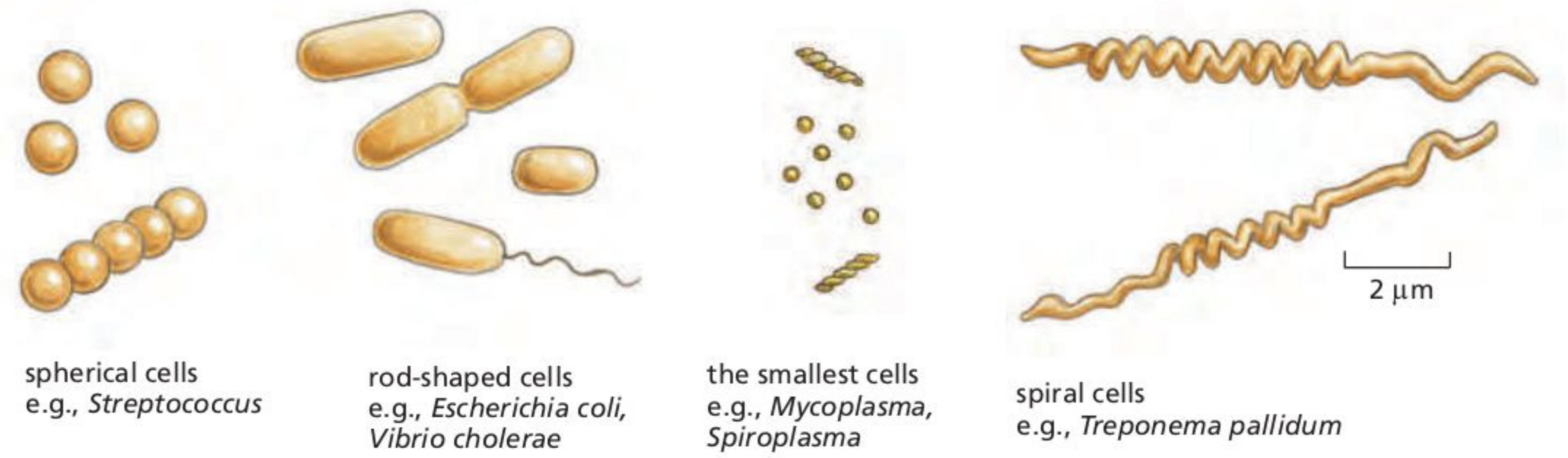
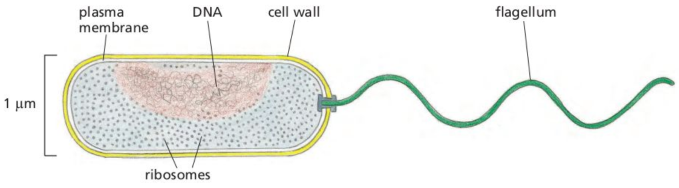


Figure 1–13 Shapes and sizes of some bacteria.

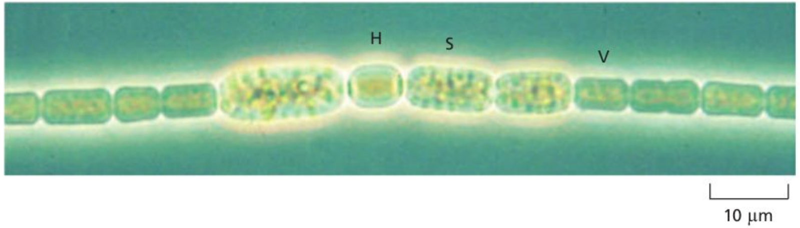
The Greatest Biochemical Diversity Exists Among Prokaryotic Cells

- Prokaryotic cells are small and structurally simple but show the greatest biochemical diversity among living organisms.
- They possess all essential cellular components.
- Some bacteria exhibit cellular specialization
- Prokaryotes occupy diverse environments and metabolic strategies Organotrophic, Phototrophic: Lithotrophic
- Most prokaryotes remain unexplored (~99%)

(B)

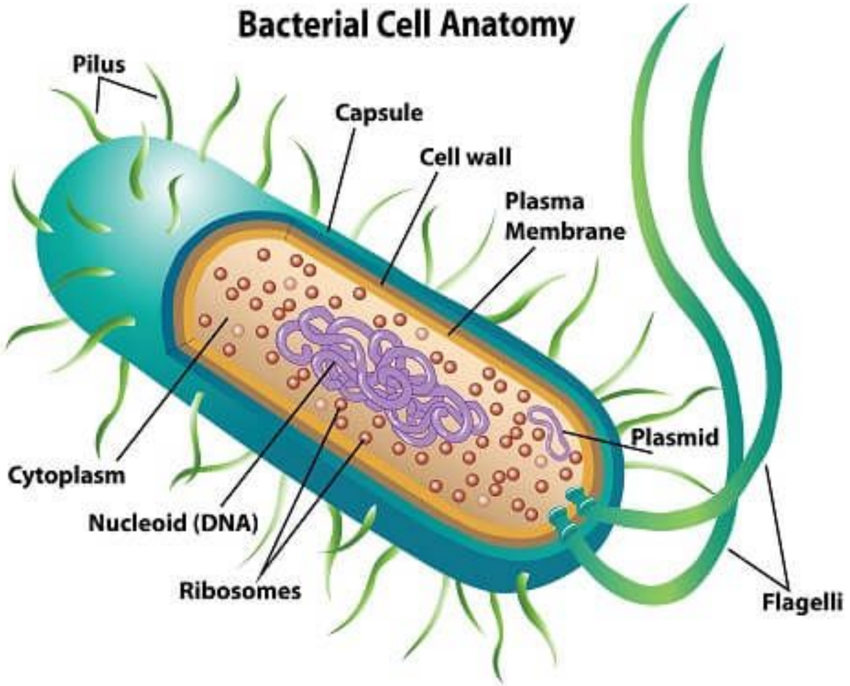


(A)



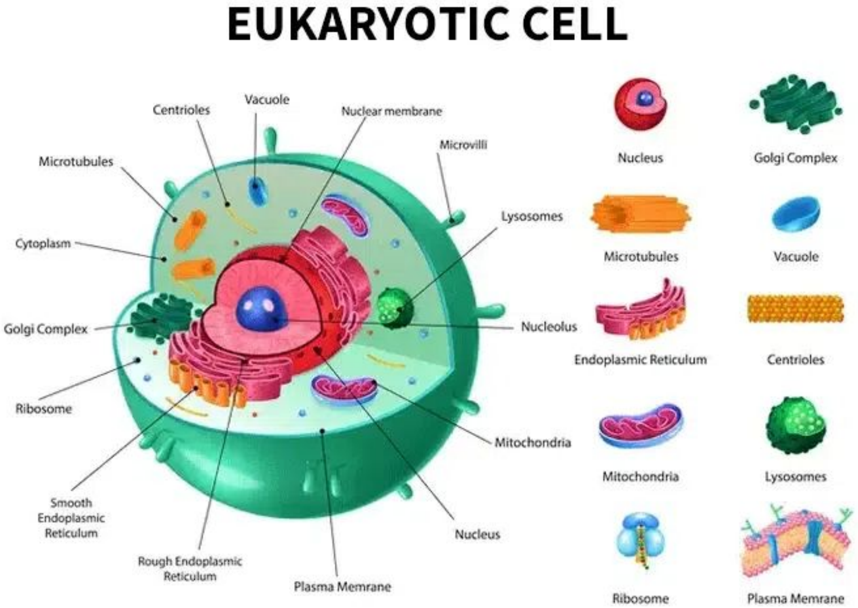
Prokaryotic cells are simple in structure

- **Capsule:** Layer of polysaccharide (sugars) that protects the bacterial cell. Often associated with pathogenic bacteria as it serves as a barrier against phagocytosis by white blood cells.
- **Cell wall:** Composed of peptidoglycan (polysaccharide + protein). Maintains the overall shape and structure of the cell.
- **Plasma membrane:** The external membrane. Regulates selective transport into and out of the cell.
- **Flagella:** Stiff helical structure rotated by a rotary engine
- embedded in the membrane.
- **Pili:** Hollow, hair-like structures that allow bacterial conjugation.
- **Nucleoid:** DNA in the bacterial cell is generally confined to this region - not bounded by a membrane.
- **Ribosomes:** The sites of protein synthesis - smaller than the ribosomes in eukaryotic cells.



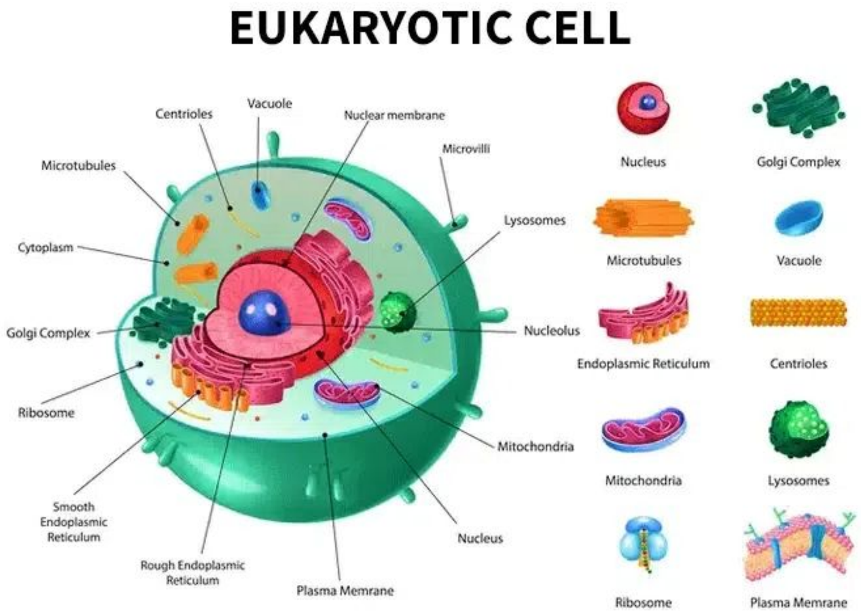
Eukaryotic cells

- **Plasma membrane:** The external membrane. Regulates selective transport into and out of the cell. Has proteins that serve as receptors and cell-cell connectors.
- **Nucleus:** Houses most of the cell's genetic material as DNA packaged into chromatin. The site of DNA replication and gene transcription. Bound by a double membrane with access possible through nuclear pores.
- **Mitochondria:** Composed of a double membrane (like the nucleus). Cellular "power factory" - major site of ATP synthesis. Possesses its own DNA and ribosomes (believed to be evolved from bacteria)
- **Ribosomes:** Molecular machines that read mRNAs and direct protein synthesis. Soluble in cytosol and bound to Rough Endoplasmic Reticulum (RER) Endoplasmic reticulum (ER): Site of lipid biosynthesis: Site of membrane protein synthesis (by RER-bound ribosomes) and of proteins destined for secretion Golgi apparatus: Stacks of membrane-bound discs. Proteins coming from the ER are modified with sugars (glycosylation)



Eukaryotic cells (cont)

- **Lysosomes:** Contain proteases and digestive enzymes. Fuse with endocytic vesicles to digest contents
- **Peroxisomes:** Contain oxidative enzymes for lipid and amino acid metabolism. Hydrogen peroxide (very toxic) generated and degraded here.
- **Cytosol:** A solution of large and small molecules - very dynamic.
- **Cytoskeleton:** 3 types of filamentous polymers that act as a scaffolding to give cells shape and mechanical strength. Tracks for transport of organelles and machinery for cell division.
- **Centrosome:** Organizes cytoskeleton. Pairs of centrioles + pericentriolar material (PCM).



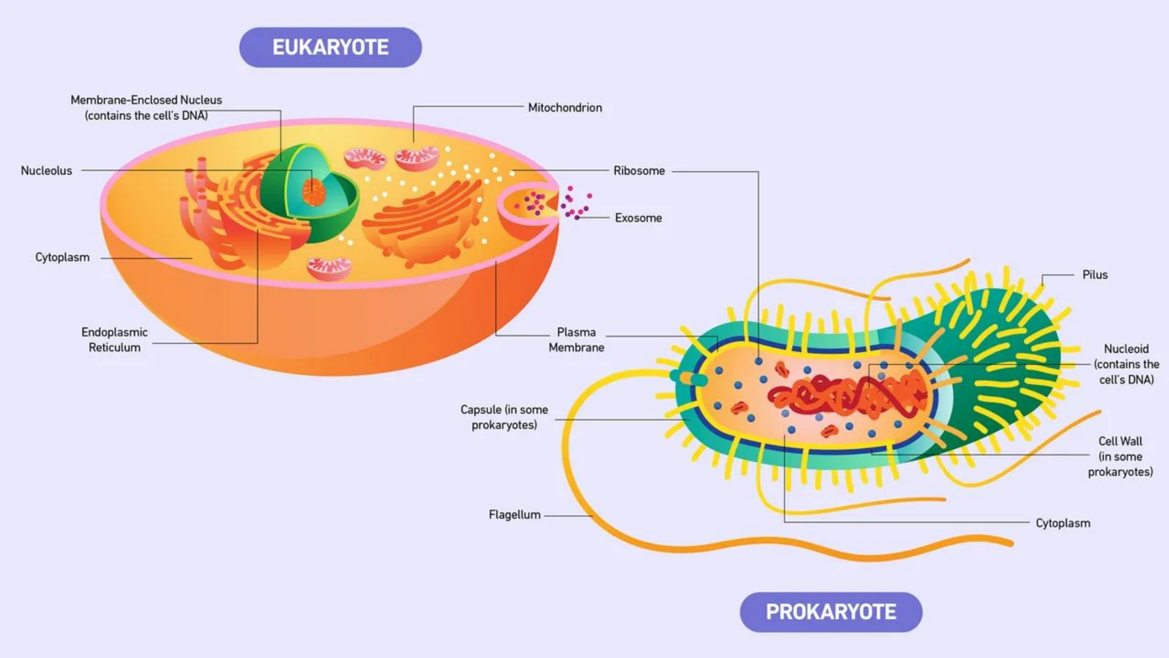
Eukaryotic vs Prokaryotic cells' structures

Prokaryotic cells

- Simple in structure
- No membrane-bound organelles
- No nucleus (DNA not enclosed by a nuclear membrane)
- Exist in a variety of shapes and sizes
- Can live in a wide range of environments

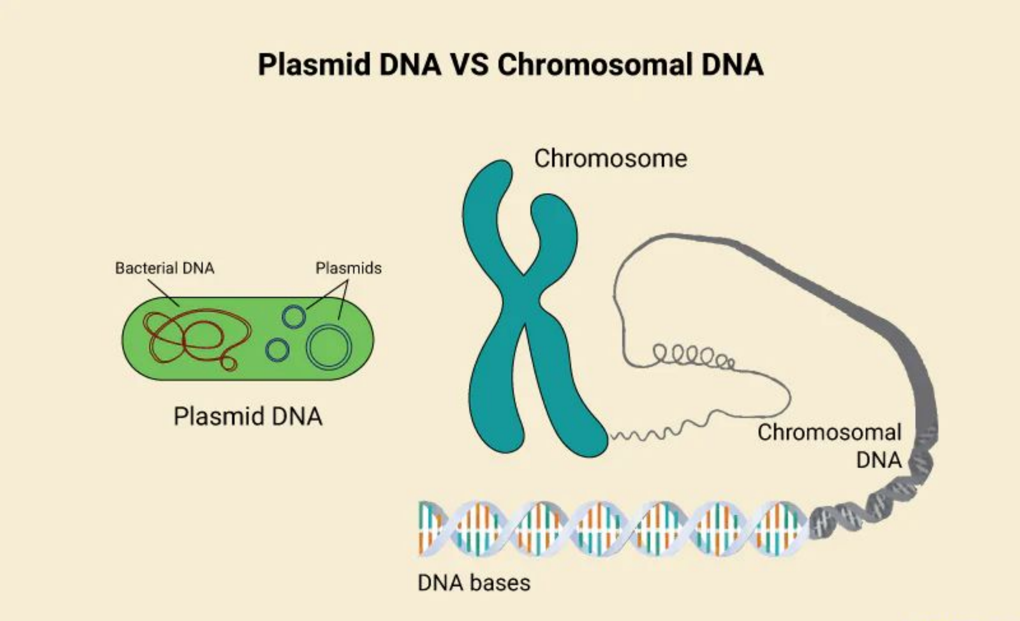
Eukaryotic cells

- More elaborate than prokaryotic cells
- Contain a true nucleus that houses DNA
- Possess membrane-bound organelles, including:
  - Endoplasmic reticulum
  - Golgi apparatus
  - Lysosome, endosome, peroxisome Mitochondria
  - Chloroplasts (in plants)



Genome of prokaryote

- DNA located in the **nucleoid region** (no nucleus)
- Usually **one circular chromosome**
- Genes packed closely → **little non-coding DNA**
- Often contain **plasmids** (extra DNA molecules)
- Genome size: ~**1,000–6,000 genes**
- Efficient organization → **fast growth & replication**



Genome Evolution in Prokaryotes

How genes change and spread

- Genes can move between bacteria and archaea (horizontal gene transfer).
- Viruses often carry DNA from one cell to another.
- Bacteria can also absorb free DNA from the environment.
- This allows rapid acquisition of new traits (e.g., antibiotic resistance).

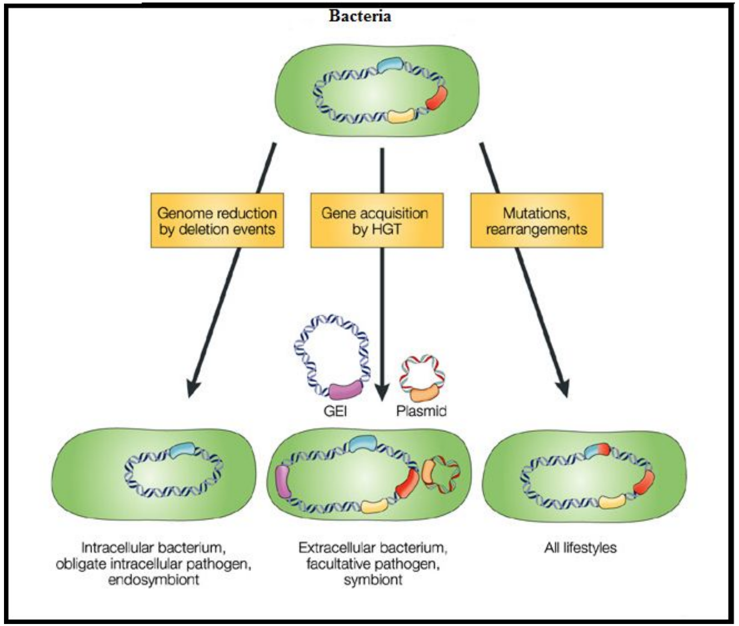
Sex as gene exchange (within species)

- Sexual reproduction mixes genes between individuals.
- Creates genetic diversity for natural selection.

Using genome sequences

- Comparing gene sequences helps predict gene function.
- Shared genes across domains reveal ancient ancestry.

➡ Prokaryotic genomes evolve through mutation, gene transfer, and selection.



Some Genes Evolve Rapidly; Others Are Highly Conserved

- **Mutations** arise during DNA replication
- Beneficial, neutral, and harmful mutations occur.
- Natural selection drives evolution.
- Genes evolve at different rates + *Non-essential regions change rapidly.*
  + *Essential genes evolve slowly → **highly conserved**.*
- Conserved genes reveal deep evolutionary relationships.
- rRNA comparisons helped define the three domains:
  Bacteria – Archaea – Eukaryotes.
- rRNA is highly conserved because ribosomes are essential for life.
- Most Bacteria and Archaea Have 1000–6000 Genes

```
GTTCCGGGGGGAGTATGGTTGCAAAGCTGAAACTTAAAGGAATTGACGGAAGGGCACCACCAGGAGTGGAGCCTGCGGCTTAATTTGACTCAACACGGGAAACCTCACCC  human
GCCGCCTGGGGAGTACGGTCGCAAGACTGAAACTTAAAGGAATTGGCGGGGGAGCACTACAACGGGTGGAGCCTGCGGTTTAATTGGATTCAACGCCGGGCATCTTACCA  Methanococcus
ACCGCCTGGGGAGTACGGCCGCAAGGTTAAAACTCAAATGAATTGACGGGGGCCCGC.ACAAGCGGTGGAGCATGTGGTTTAATTCGATGCAACGCGAAGAACCTTACCT  E. coli
GTTCCGGGGGGAGTATGGTTGCAAAGCTGAAACTTAAAGGAATTGACGGAAGGGCACCACCAGGAGTGGAGCCTGCGGCTTAATTTGACTCAACACGGGAAACCTCACCC  human
```

Figure 1–18 Genetic information conserved since the days of the last common ancestor of all living things.

New Genes Are Generated from Pre-existing Genes

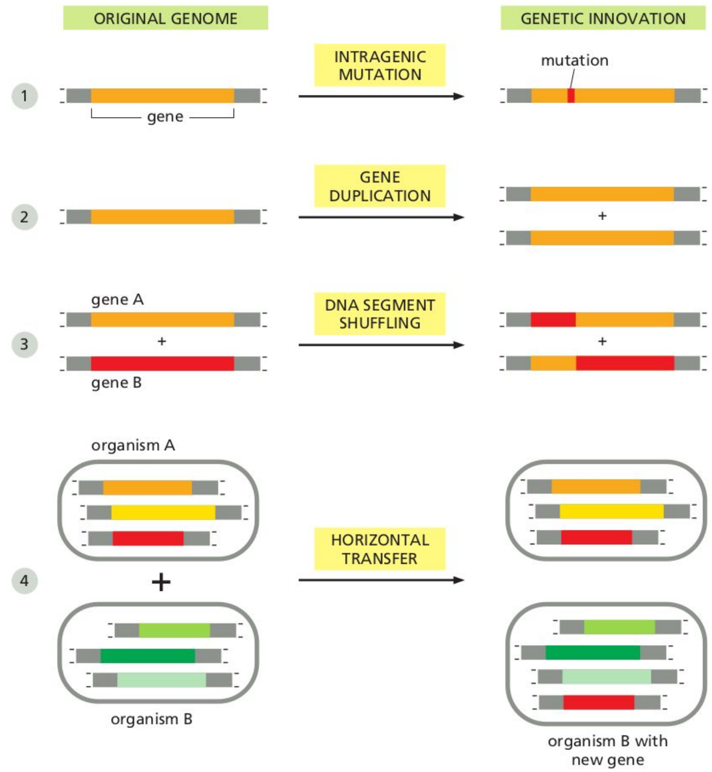


Figure 1–19 Four modes of genetic innovation and their effects on the DNA sequence of an organism.

- Evolution does **not create genes from scratch;**
- New genes arise by modifying, copying, recombining, or transferring existing DNA;
- **Four Mechanisms of Genetic Innovation**

  1) Intrargenic mutation

  Small changes in a gene's DNA sequence

  → Can alter protein function

  2) Gene duplication

  A gene is copied

  → One keeps the original role; the other may evolve a new function

  3) DNA segment shuffling

  Parts of different genes recombine

  → Produces hybrid genes

  4) Horizontal gene transfer (HGT)

  DNA moves between cells (not parent → offspring)

  → Common in bacteria; enables rapid adaptation (e.g., antibiotic resistance)

Gene Duplications Give Rise to Families of Related Genes Within a Single Cell

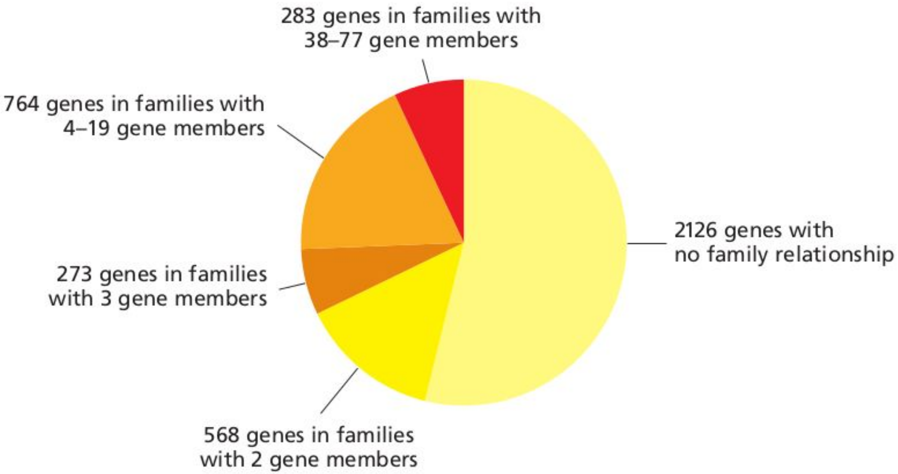


Figure 1–20 Families of evolutionarily related genes in the genome of Bacillus subtilis.

Gene duplication within a genome creates **gene families**.

- One copy keeps the original function; the other can diverge and evolve new roles.
- This process greatly increases functional diversity.
- In *Bacillus subtilis*, ~47% of genes belong to gene families.

Evolution relationship

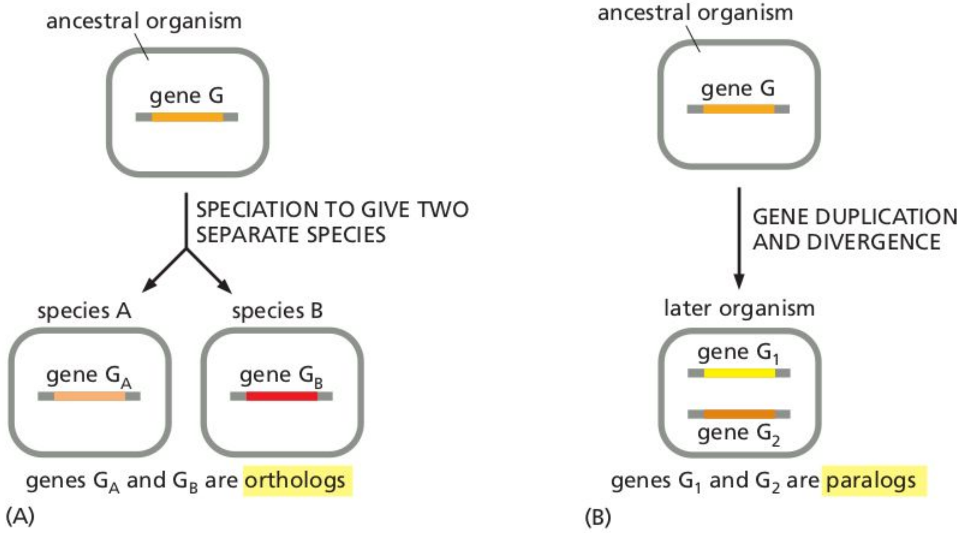


Figure 1–21 Paralogous genes and orthologous genes: two types of gene homology based on different evolutionary pathways. (A) Orthologs. (B) Paralogs.

Paralogs

- Genes produced by **duplication** in **one genome.**
- Often diverge in function.

Orthologs

- Genes in different species after **speciation.**
- Usually retain similar functions.

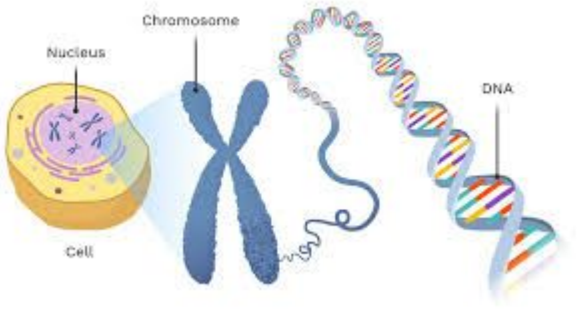
Homologs

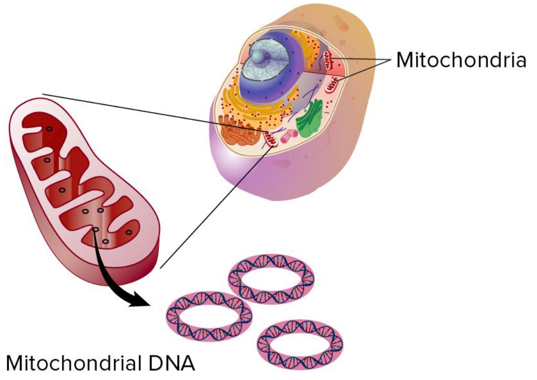
- Genes sharing a **common ancestor.**
- Includes both **paralogs and orthologs.**

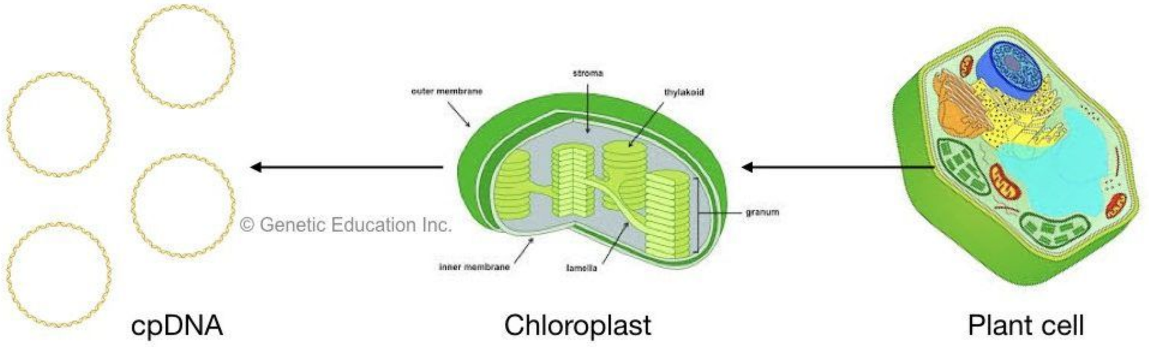
Multiple genomes in Eukaryotes

DNA in Eukaryotic Cells:

- **Nuclear DNA**
  - Main genome of the cell
  - Contains most genes
- **Mitochondrial DNA**
  - Small, circular genome
  - Derived from bacteria
  - Encodes proteins for respiration
- **Chloroplast DNA** *(plants & algae)*
  - From photosynthetic bacteria
  - Functions in photosynthesis



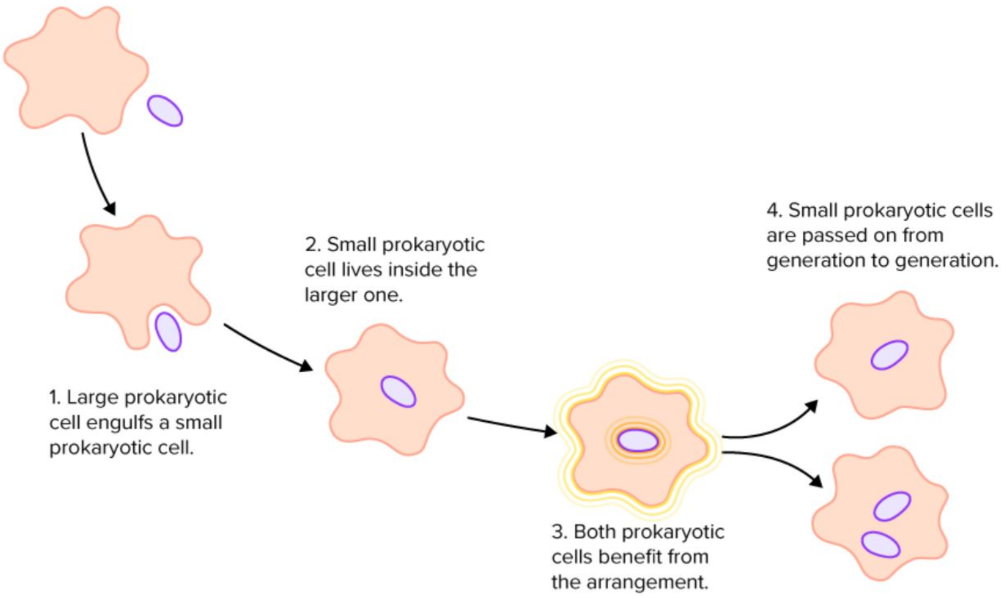




Genome Evolution in Eukaryotes

- Mutations
- Genetic recombination during meiosis
- Gene duplication / whole-genome duplication
- Natural selection
- Ancient endosymbiosis → mitochondria & chloroplasts

➡ Eukaryotes evolve mainly through recombination and duplication, while prokaryotes are strongly shaped by horizontal gene transfer.



From Independent Cell to Organelle. The endosymbiotic theory explains how eukaryotic cells evolved.

Eukaryotes vs Prokaryotes genome size

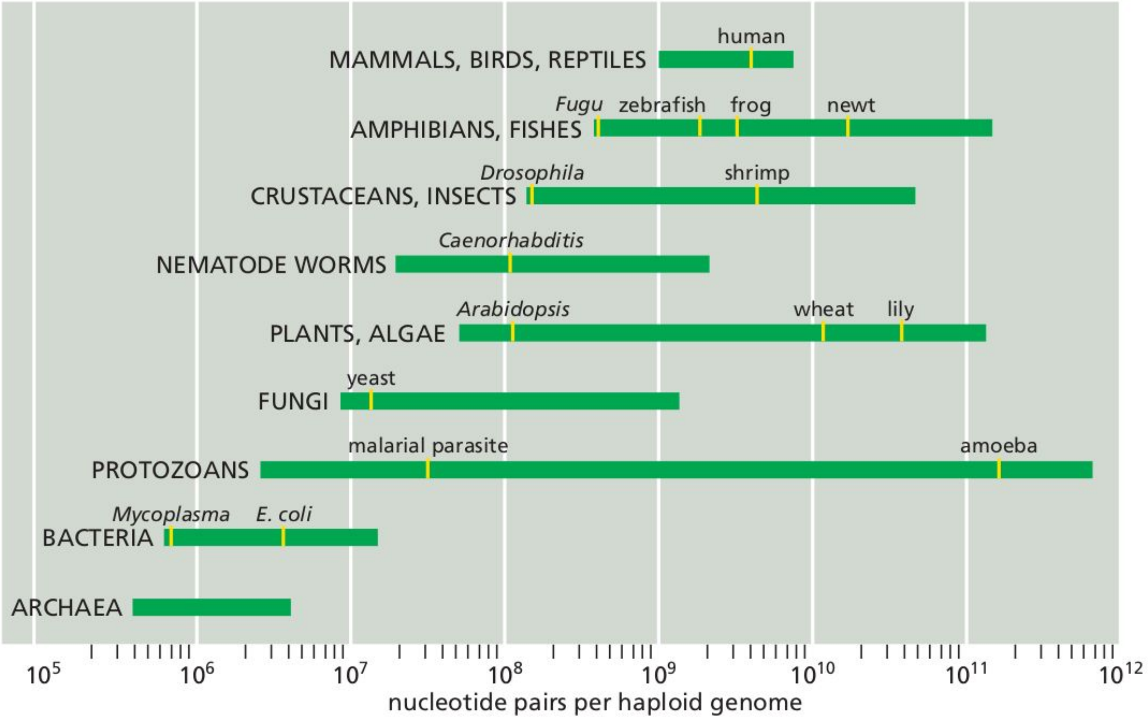


Figure 1–32 Genome sizes compared. Genome size is measured in nucleotide pairs of DNA per haploid genome, that is, per single copy of the genome. (The cells of sexually reproducing organisms such as ourselves are generally diploid: they contain two copies of the genome, one inherited from the mother, the other from the father.) Closely related organisms can vary widely in the quantity of DNA in their genomes, even though they contain similar numbers of functionally distinct genes. (Data from W.H. Li, Molecular Evolution, pp. 380–383. Sunderland, MA: Sinauer, 1997.)

Question

1. A small packet of genetic material that has evolved as a parasite on the reproductive and biosynthetic machinery of host cells.

2. One of the two divisions of prokaryotes, typically found in hostile environments such as hot springs or concentrated brine.

3. Living organism composed of one or more cells with a distinct nucleus and cytoplasm.

4. Major category of living cells distinguished by the absence of a nucleus.

Answers

1. A small packet of genetic material that has evolved as a parasite on the reproductive and biosynthetic machinery of host cells. Virus

2. One of the two divisions of prokaryotes, typically found in hostile environments such as hot springs or concentrated brine. Archaea

3. Living organism composed of one or more cells with a distinct nucleus and cytoplasm. Eukaryote

4. Major category of living cells distinguished by the absence of a nucleus. Prokaryote

True or False

1. Eukaryotic cells contain either mitochondria or chloroplasts, but not both.

2. Horizontal gene transfer is more prevalent in single-celled organisms than in multicellular organisms.

True or False

1. Eukaryotic cells contain either mitochondria or chloroplasts, but not both. False

2. Horizontal gene transfer is more prevalent in single-celled organisms than in multicellular organisms. True

THOUGHT PROBLEMS

Question 1: Animal cells lack cell walls and chloroplasts, whereas plant cells have both. Fungal cells lie somewhere in between: they have cell walls but lack chloroplasts. Are fungi likely to be animal cells that gained a cell wall, or plant cells that lost their chloroplasts?

Question 2: Why can the bacterium *E. coli* divide every 20 minutes, while animal cells typically take 24 hours?

THOUGHT PROBLEMS

Question 1: Animal cells lack cell walls and chloroplasts, whereas plant cells have both. Fungal cells lie somewhere in between: they have cell walls but lack chloroplasts. Are fungi likely to be animal cells that gained a cell wall, or plant cells that lost their chloroplasts?

Comparisons of gene sequences (specifically rRNA genes) show that fungi are more closely related to animals than to plants.

Question 2: Why can the bacterium *E. coli* divide every 20 minutes, while animal cells typically take 24 hours?

E. coli can divide rapidly because:

- Small size → high surface-to-volume (S/V) ratio → fast metabolic exchange
- Small, simple genome → rapid DNA replication

Cells under Microscope

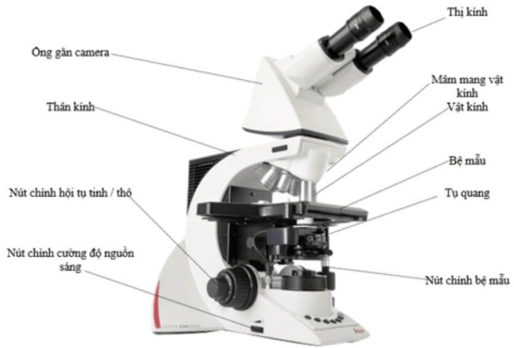
Two Major Types of Microscopy in Cell Biology

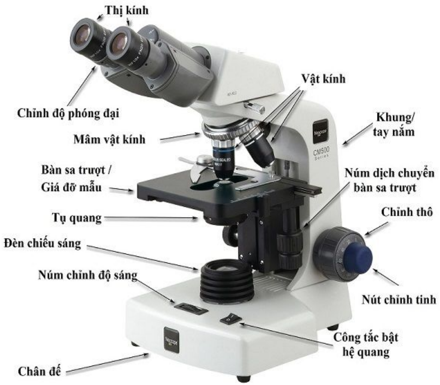
1) Light Microscopy

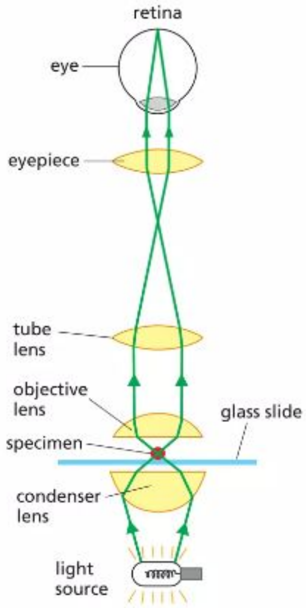
- Uses visible light
- Techniques: Brightfield, Phase contrast/DIC, Fluorescence, Confocal, Super-resolution
- Used to observe:
  - Living cells
  - Fluorescent-labeled proteins
  - Micrometer-scale structures

2) Electron Microscopy

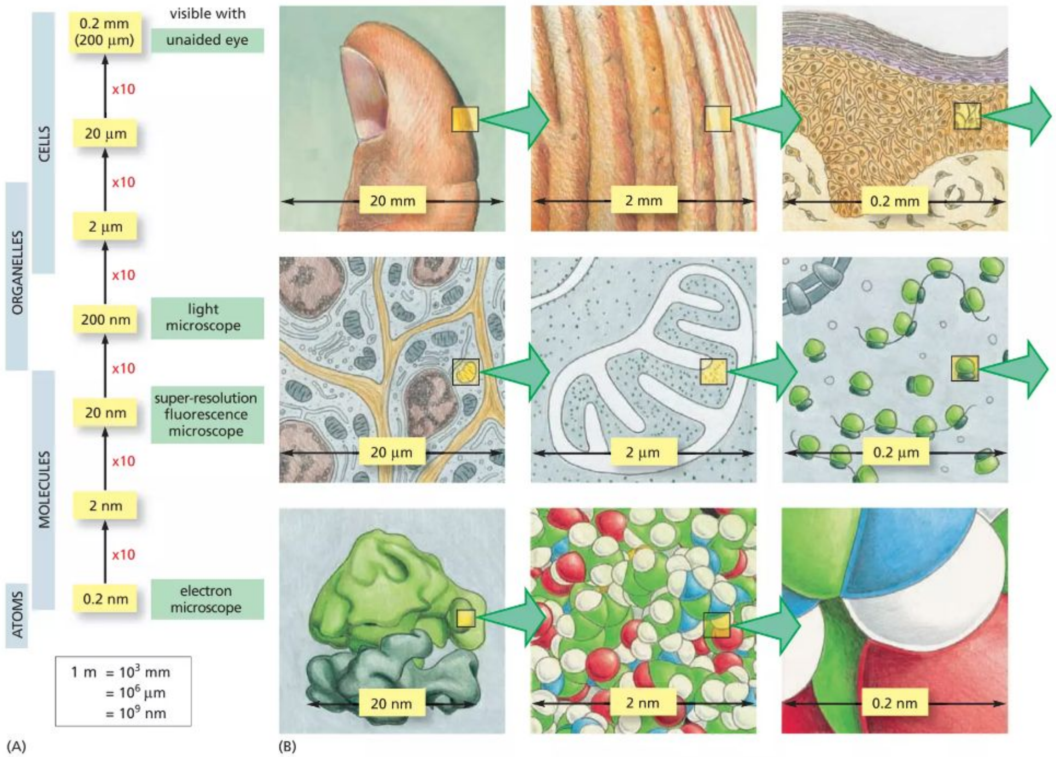
- Uses electron beams → much higher resolution
- Types: TEM (internal structure), SEM (3D surface)
- Used to observe:
  - Ultrastructure
  - Organelles, membranes, ribosomes







How big are cells and their components



Light Microscopes Reveal Some of a Cell's Components

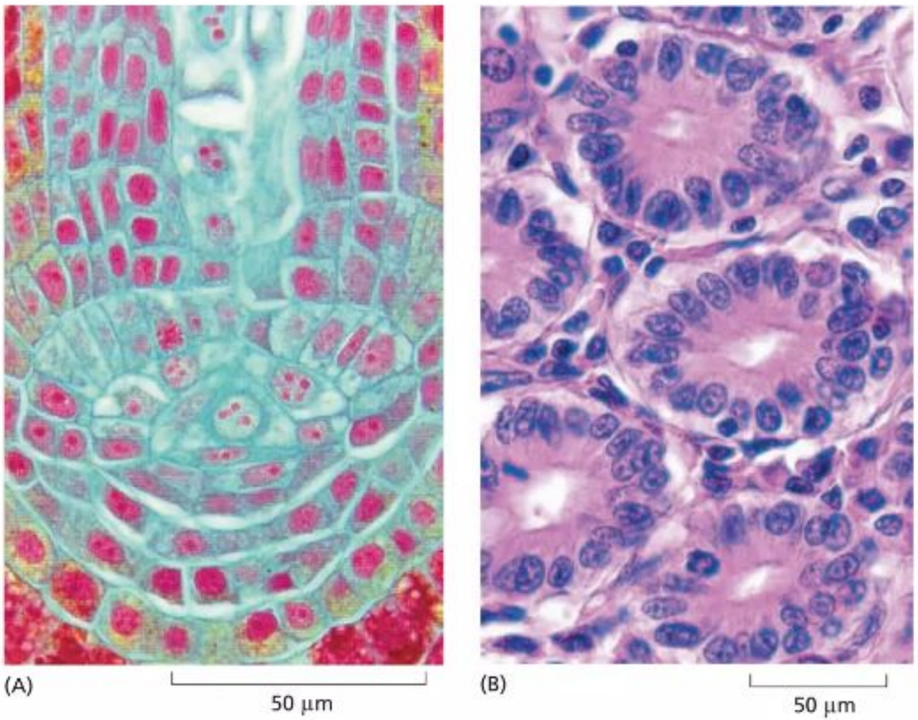
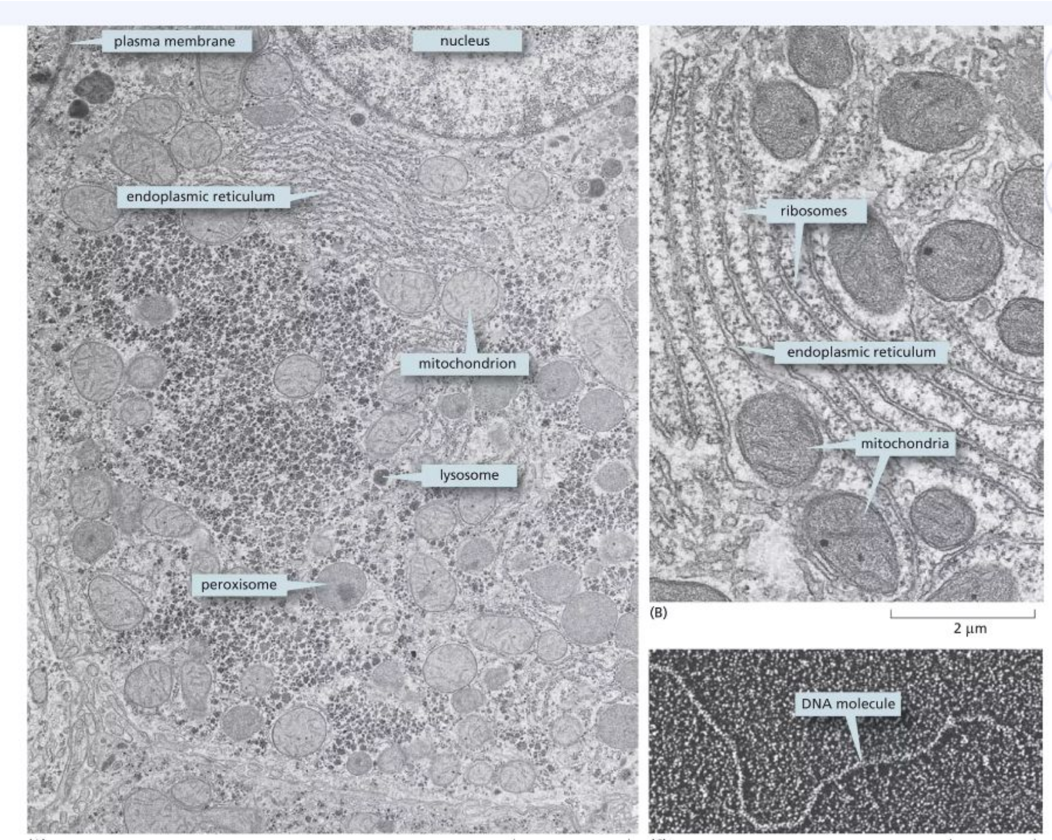
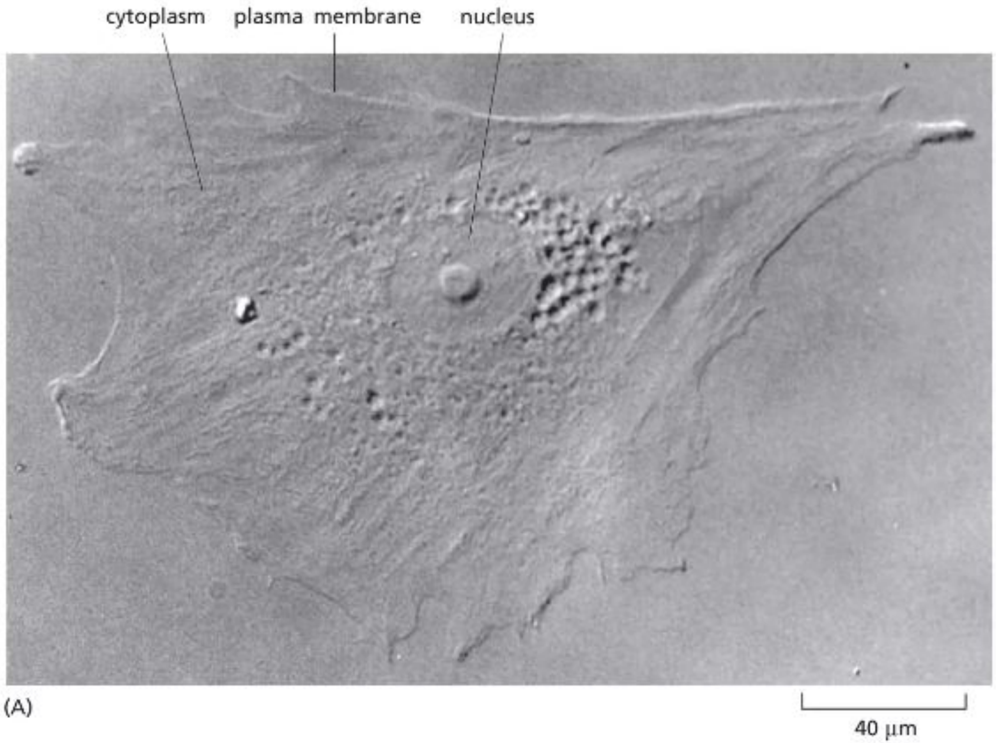


Figure 1–6 Cells form tissues in plants and animals. (A) Cells in the root tip of a fern. The DNA-containing nuclei are stained *red*, and each cell is surrounded by a thin cell wall (*light blue*). The *red* nuclei of densely packed cells are seen at the bottom corners of the preparation. (B) Cells in the crypts of the small intestine. Each crypt appears in this cross section as a ring of closely packed cells (with nuclei stained *blue*). The ring is surrounded by extracellular matrix, which contains the scattered cells that produced most of the matrix components. (A, courtesy of James Mauseth; B, Jose Luis Calvo/Shutterstock.)

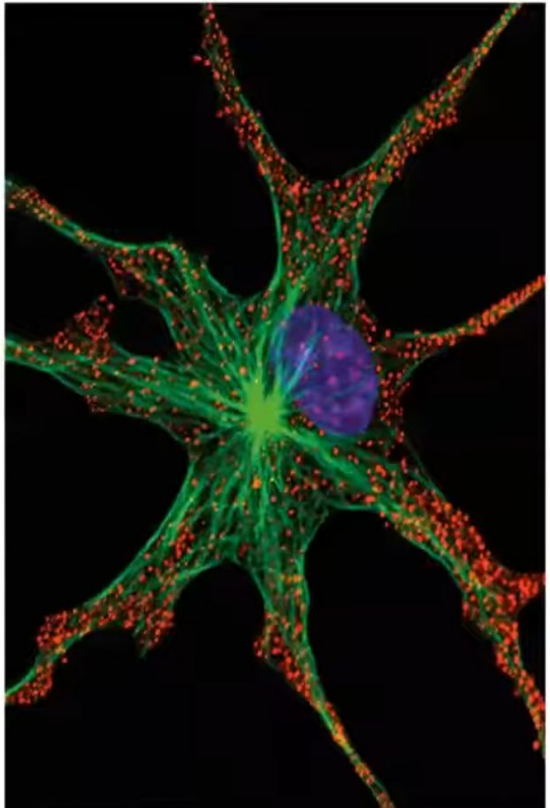
The fine structure of a cell can be seen in a transmission electron microscope

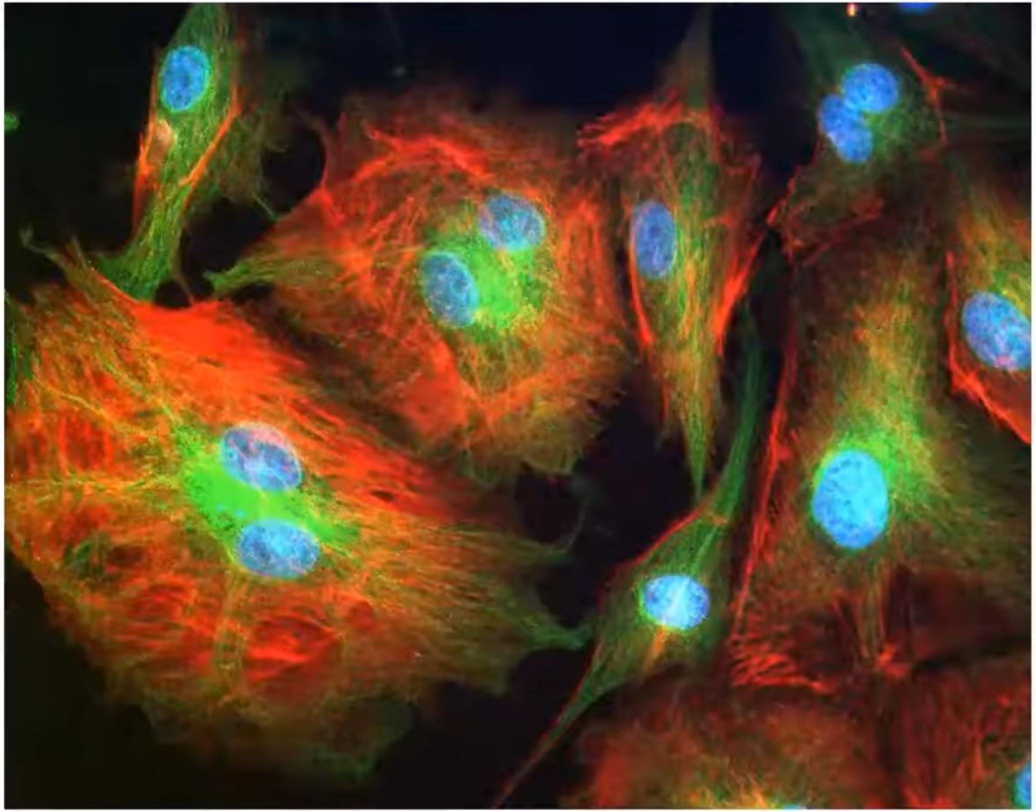


Phase-contrast microscope allow internal structures to be discened

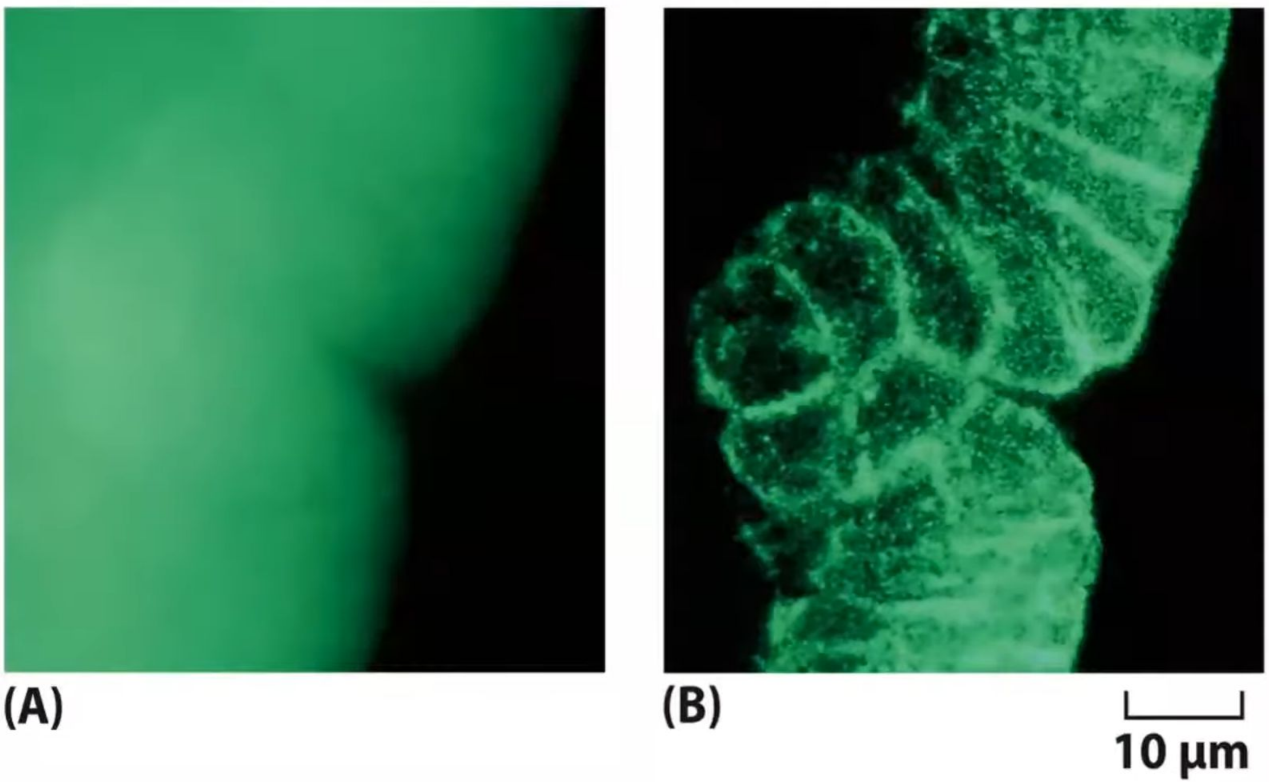


Fluorescence microscopy uses fluorescent dyes

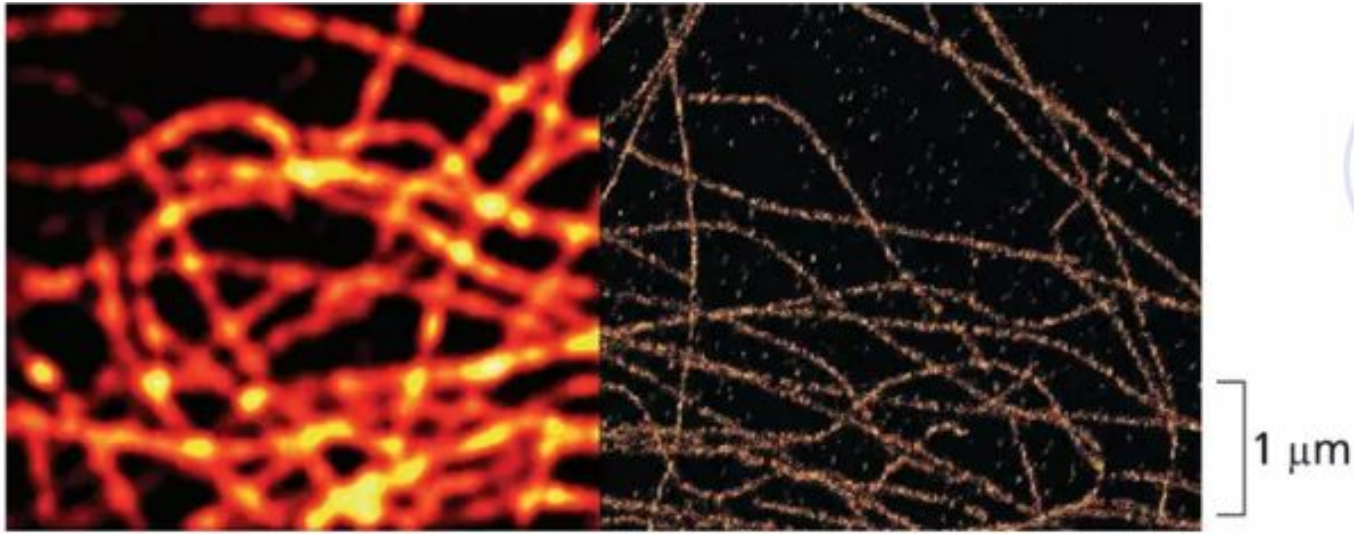




Confocal microscopy allows for 3D-image resolution



Super-Resolution Fluorescence Microscopy is able to show structures more clearly



Microtubules viewed with conventional fluorescence microscope (*left*) and with super-resolution optics (*right*). In the super-resolution image, the microtubule can be clearly seen at the actual size, which is only 25 nm in diameter.

Question

Câu hỏi: Hãy ghép kỹ thuật hiển vi (Cột A) với ứng dụng hoặc ưu điểm chính của nó (Cột B).

Cột A (Kỹ thuật)	Cột B (Ứng dụng/Ưu điểm)
1. Kính hiển vi tương phản pha *(Phase-Contrast Microscopy)*	**A. Quan sát siêu cấu trúc bên trong** (ví dụ: ribosome, màng) ở độ phân giải nanomet.
2. Kính hiển vi điện tử truyền qua *(Transmission Electron Microscopy - TEM)*	**B. Vượt qua giới hạn nhiễu xạ** để phân giải các chi tiết phân tử nhỏ tới 20 nm.
3. Kính hiển vi huỳnh quang *(Fluorescence Microscopy)*	**C. Quan sát hình dạng chung và chuyển động** của các tế bào sống không nhuộm màu.
4. Kính hiển vi đồng tiêu *(Confocal Microscopy)*	**D. Xác định vị trí cụ thể của một protein** (ví dụ: Protein A) bằng cách sử dụng kháng thể hoặc thẻ đánh dấu phát sáng.
5. Kính hiển vi siêu phân giải *(Super-Resolution Microscopy)*	**E. Tạo hình ảnh 3D sắc nét** và các lát cắt quang học bằng cách loại bỏ ánh sáng bị nhòe (ngoài tiêu điểm).

Question

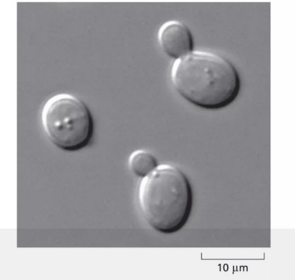
Câu hỏi: Hãy ghép kỹ thuật hiển vi (Cột A) với ứng dụng hoặc ưu điểm chính của nó (Cột B).

Cột A (Kỹ thuật)	Cột B (Ứng dụng/Ưu điểm)
1. Kính hiển vi tương phản pha *(Phase-Contrast Microscopy)*	**A. Quan sát siêu cấu trúc bên trong** (ví dụ: ribosome, màng) ở độ phân giải nanomet.
2. Kính hiển vi điện tử truyền qua *(Transmission Electron Microscopy - TEM)*	**B. Vượt qua giới hạn nhiễu xạ** để phân giải các chi tiết phân tử nhỏ tới 20 nm.
3. Kính hiển vi huỳnh quang *(Fluorescence Microscopy)*	**C. Quan sát hình dạng chung và chuyển động** của các tế bào sống không nhuộm màu.
4. Kính hiển vi đồng tiêu *(Confocal Microscopy)*	**D. Xác định vị trí cụ thể của một protein** (ví dụ: Protein A) bằng cách sử dụng kháng thể hoặc thẻ đánh dấu phát sáng.
5. Kính hiển vi siêu phân giải *(Super-Resolution Microscopy)*	**E. Tạo hình ảnh 3D sắc nét** và các lát cắt quang học bằng cách loại bỏ ánh sáng bị nhòe (ngoài tiêu điểm).

1-C, 2-A, 3-D, 4-E, 5-B

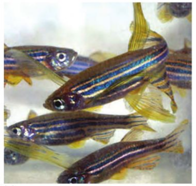
Model organisms

- Molecular biologists have traditionally focused on **E. coli** as a model organism
- Brewer's yeast serves as a simple model **eukaryotic organism**
- **Arabidopsis** has been selected as the primary **model plant**
- Common **model animals** include flies, worms, fish, and mice
- Biologists also directly study **humans and human cells**
- Comparing genome sequences reveals the **shared evolutionary heritage of life**
- Genomes contain **much more information than just genes**

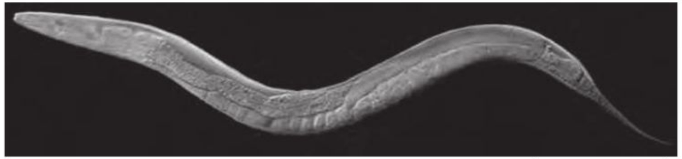


1 cm

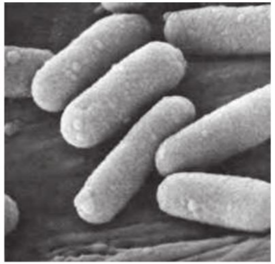
20 µm



(A) 1 cm



0.2 mm



(A) *Escherichia coli* K-12
4,639,221 nucleotide pairs

Thanks for your attention!