Some Properties of Living Organisms

BI 201 Natural History of Guam

Class Presentation 22

- What is life?
  - A precise definition has eluded scientists and philosophers for centuries
  - American Heritage Dictionary definition:
    - the property or quality manifested in functions such as metabolism, growth, response to stimulation, and reproduction, by which living organisms are distinguished from dead organisms or from inanimate matter

- Many attempts to define life just describe the properties of living organisms
- MRS GREN
  - Movement
  - Respiration
  - Sensitivity
  - Growth
  - Reproduction
  - Excretion
  - Nutrition

- **Life** resists a simple, one-sentence definition, because it is associated with a hierarchy of structural organization without counterpart among inanimate objects
- Life can perhaps best be summed up as **metabolism**
  - Metabolism is an integrated network of enzyme-catalyzed biochemical reactions occurring in living organisms or cells as a whole

- Metabolism consists of two processes
  - **anabolism**
    - a chain of enzyme-catalyzed biochemical reactions involving
      - i) the formation of macromolecules from simpler molecules, and
      - ii) the storage of energy
  - **catabolism**
    - a chain of enzyme-catalyzed biochemical reactions in which complex molecules are broken down to release energy

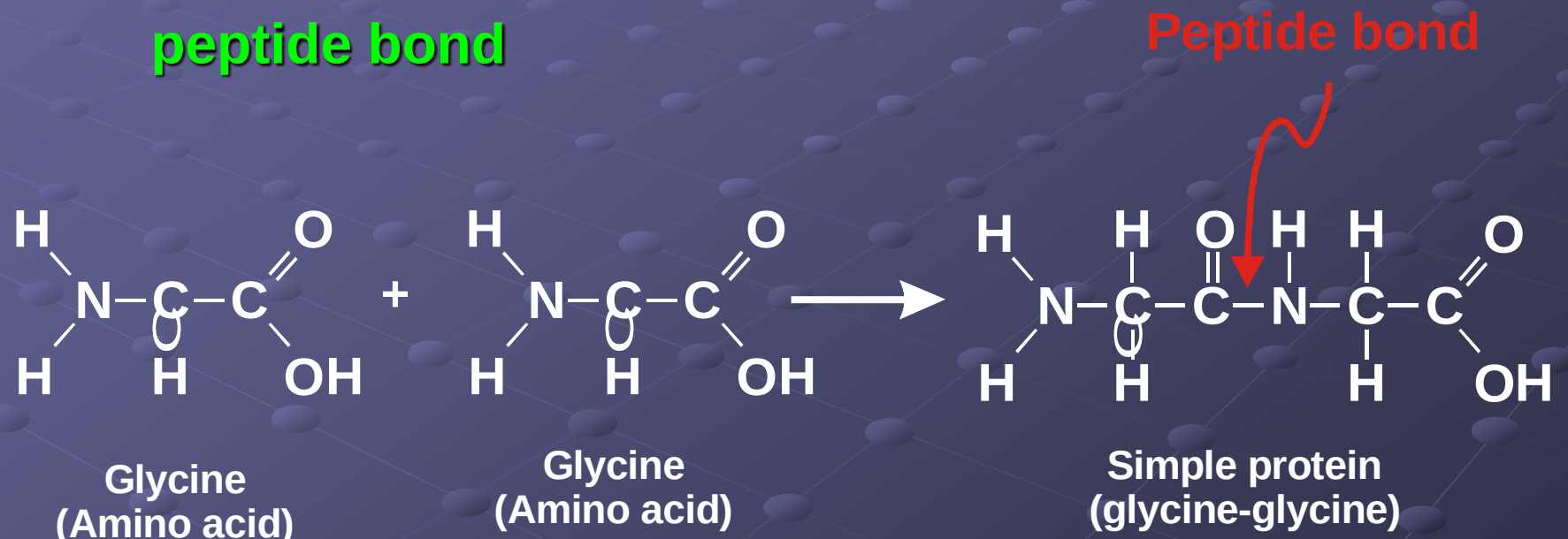
- The ingredients of life
  - **organic compounds**
    - organic compounds have one thing in common, they all contained the elements carbon and hydrogen
  - **inorganic compounds**
    - compounds comprised of any other element or elements

- classes of organic compounds
  - **proteins**
  - **carbohydrates**
  - **lipids**
  - **nucleic acids**

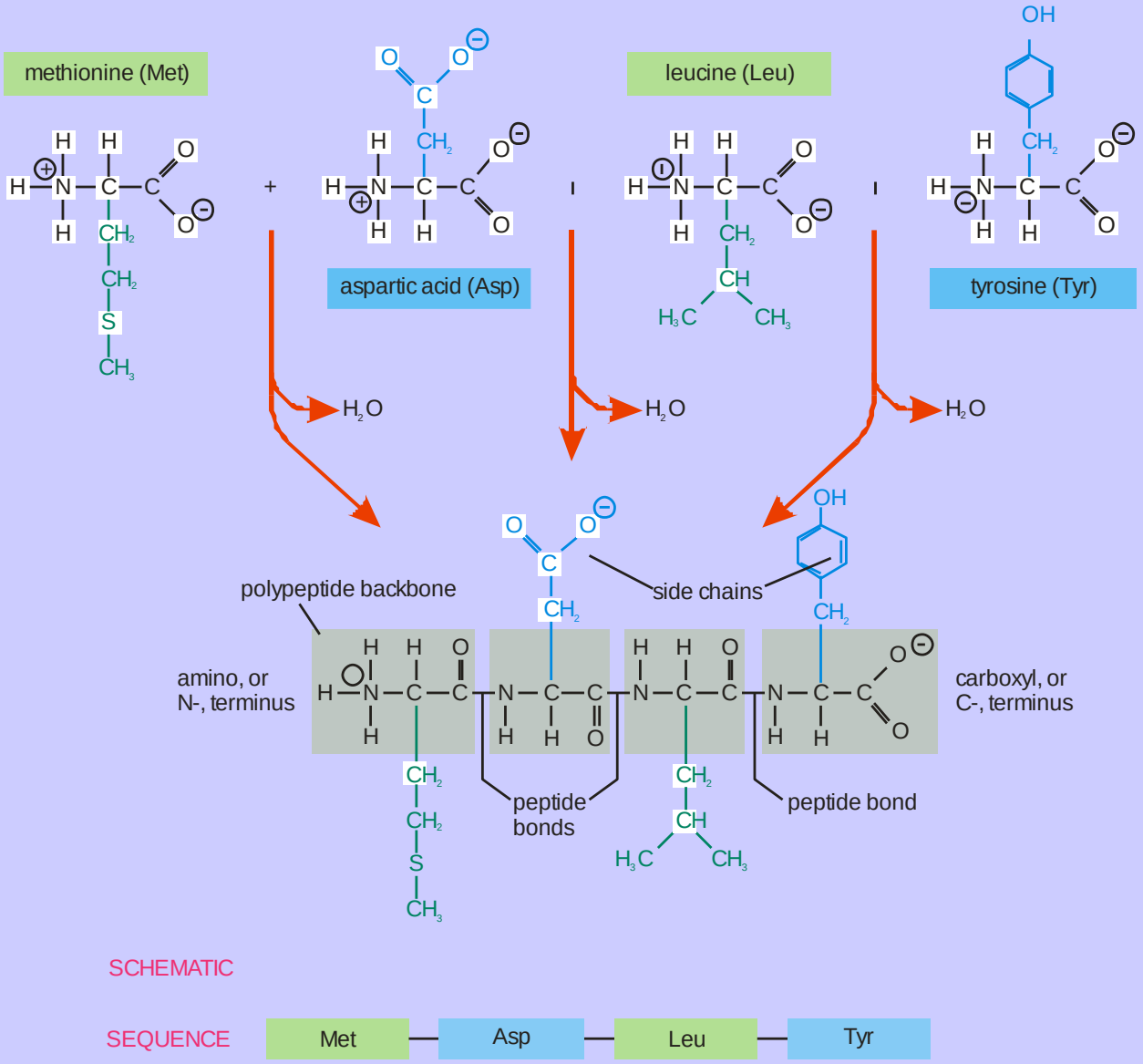
Proteins

- The principal elements of proteins are carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and sulfur (S)
- Proteins are one of chief constituents of living matter
- Proteins consist of long chains (polymers) of **amino acids** linked end-to-end
- There are 20 amino acids, which have a carboxylic acid (–COOH) on one end and an amine group ($–NH_3$)on the other end

- when linked, the acid end reacts with the amine end to form a **peptide bond**

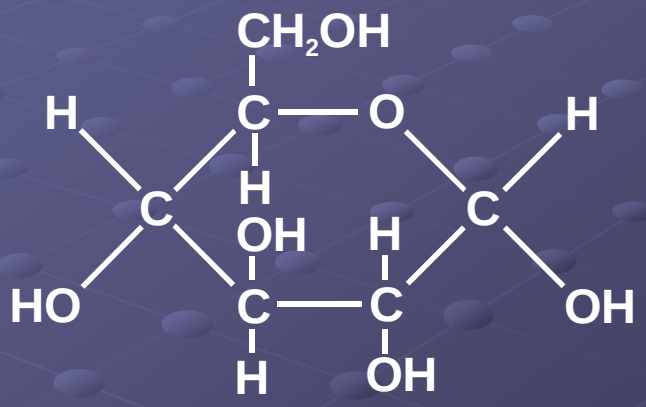


- Amino acids are linked together like building blocks in **polypeptide chains** to form macromolecules that we call proteins
- Each protein has a unique, genetically determined amino acid sequence

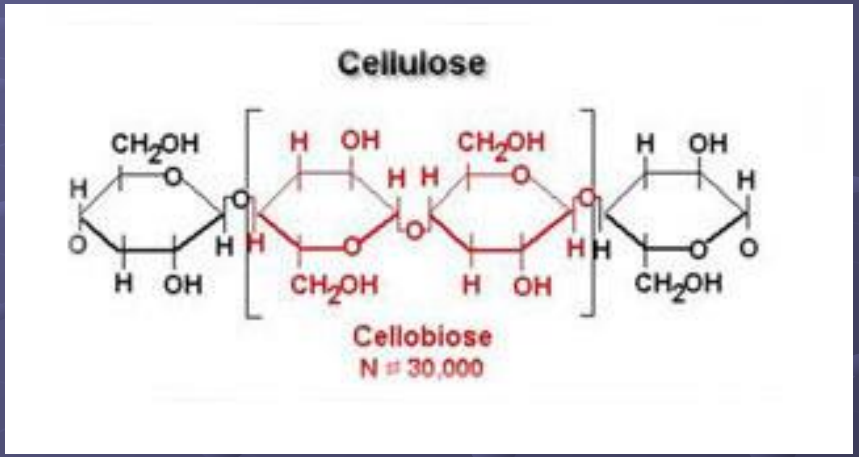

methionine (Met)
aspartic acid (Asp)
leucine (Leu)
tyrosine (Tyr)
H2O
H2O
H2O
polypeptide backbone
side chains
amino, or
N-, terminus
carboxyl, or
C-, terminus
peptide
bonds
peptide bond
SCHEMATIC
SEQUENCE
Met
Asp
Leu
Tyr

- Proteins synthesized by translation of the messenger RNA (mRNA) template at the ribosomes
- Proteins function
  - as enzymes
  - as structural constituents of cells and tissues
  - in control of gene expression

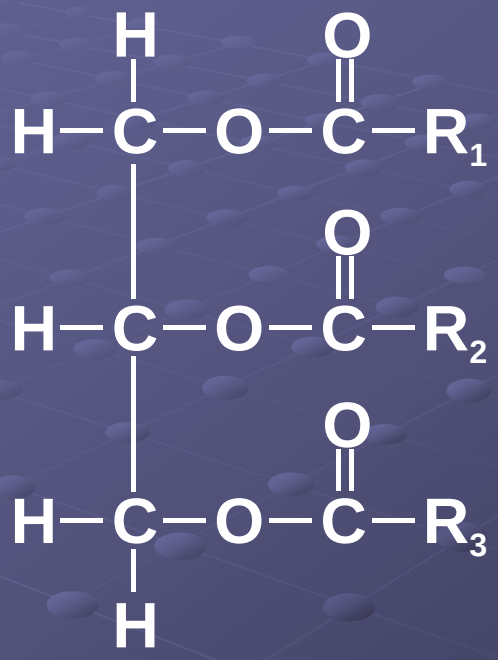
- **Carbohydrates**
  - The general formula of carbohydrates is $C_x(H_2O)_y$
  - Carbohydrates include simple sugars and polysaccharides
  - Simple sugars are usually in the form of monosaccharides that have a general formula of $(CH_2O)_n$ where $n \geq 3$; for example,
    - glyceraldehyde (a *triose* sugar, n = 3)
    - ribose (a *pentose* sugar, n = 5)
    - glucose (a *hexose* sugar, n =6)


CH2OH
H
C
O
H
H
C
C
OH
H
HO
C
C
OH
H
OH

- Monosaccharides and disaccharides are the basic building blocks for long-chain polysaccharides, e.g., starch and cellulose
- Carbohydrates function as
  - structural molecules
  - short-term energy reserves



- **Lipids**
  - Lipids include fats, waxes, oils, and steroids
  - principal elements are carbon (C), hydrogen (H), oxygen (O), and phosphorus (P)
  - The basic unit of a lipid is a glycerol molecule bonded to three fatty acids, which is known as a **triglyceride**



General structure for a lipid
(**R** = a long chain of carbon atoms)

- Lipids are insoluble in water, and they are heat stable
- Some functions of lipids include
  - energy storage and fuel molecules
  - essential components of biological membranes
  - in marine organisms, lipids function in buoyancy and thermal insulation

- **Nucleic acids**
  - Nucleic acids are very large molecules containing carbon (C), hydrogen (H), oxygen (O), nitrogen (N), and phosphorus (P) as the principal elements
  - Nucleic acids are chains of repeating subunits called **nucleotides**

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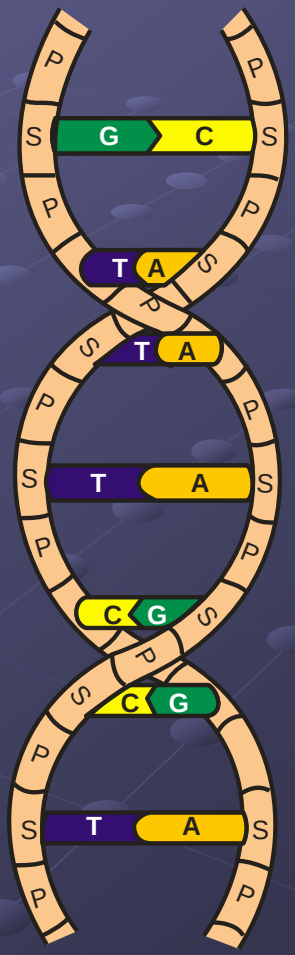
  - There are five types:
    - adenine, guanine, cytosine, thymine in DNA
    - adenine, guanine, cytosine, uracil in RNA



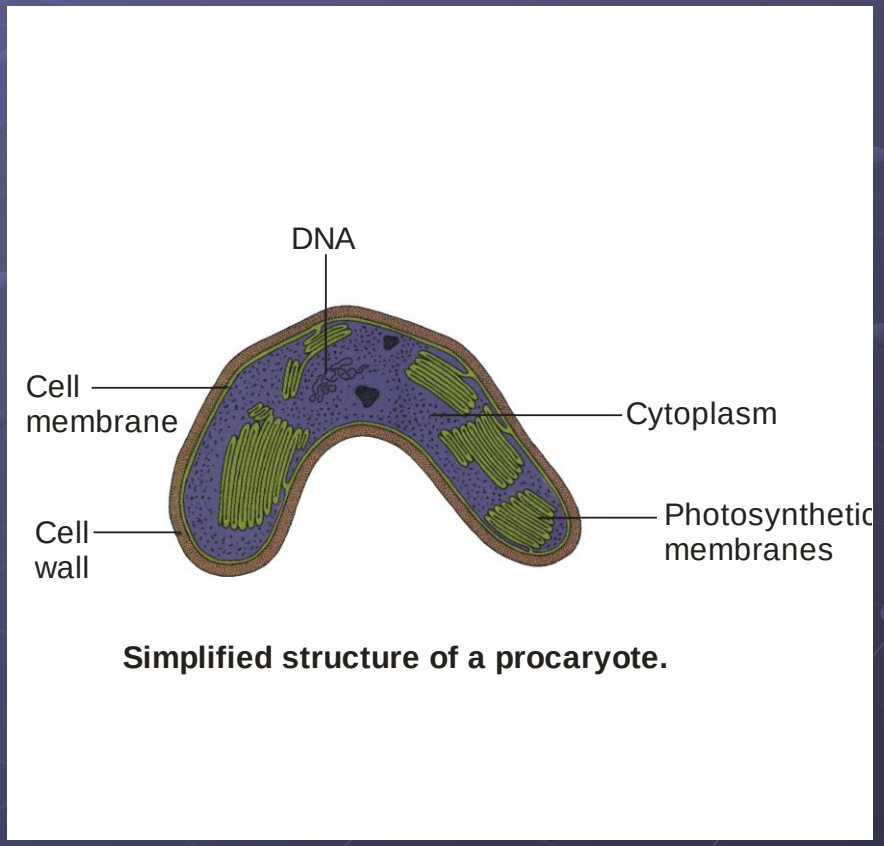
- Nucleic acids are composed of one (= RNA) or two (= DNA) polynucleotide chains
- Nucleic acids are essential components of living cells
- The functions of nucleotides include
  - serving as physical carriers of genetic information (DNA and mRNA) [as well as components of ribosomes (i.e., rRNA)
  - assisting in deciphering the genetic code (i.e., tRNA)]

- Building blocks of life
  - The basic structural building block of living organisms is the **cell**
  - Therefore, the cell is the fundamental unit of life
  - Cells are composed of organic and inorganic molecules
  - These molecules organized into discrete structures known as **organelles** that perform special functions in the cells

- Cells of some organisms contain a vast array of complex organelles, while others possess simpler structures

- **prokaryotes**
  - Prokaryotes are relatively simple organisms, characteristic of what scientists believe primitive life forms were like
  - Prokaryotes are characterized by a lack of membrane-bound organelles

- Prokaryotes possess a **diffuse nucleus**
  - i.e., their genetic material is not bounded by nuclear membrane
  - Often, their hereditary material, i.e., DNA, is a single, convoluted loop attached to inner side of cell membrane



Simplified structure of a procaryote.

- Most prokaryotes lack complex internal organelles
- However, there are cellular inclusions, such as
  - **metabolic enzymes**
    - release energy in the form of ATP for cell functions
    - most non-photosynthetic prokaryotes derive energy from the process known as **fermentation**, a form of anaerobic respiration
  - **photosynthetic pigments**
    - for example, chlorophyll, which absorbs light
    - chlorophyll is often dispersed in the cytoplasm on in-folded layers of the cell membrane

- numerous **granules and vacuoles**
  - serve as storage sites for a variety of substances, e.g., starch, lipids, sulfur, and iron
- the cytoplasm bounded by a **cell membrane**
  - the membrane is **selectively permeable** [i.e., allowing passage of particular substances through the membrane, while preventing passage of certain other substances]
  - the membrane is responsible for transporting materials between the external and internal environments of cell
- **cell wall**
  - the outer boundary of the cell, which is supportive in function

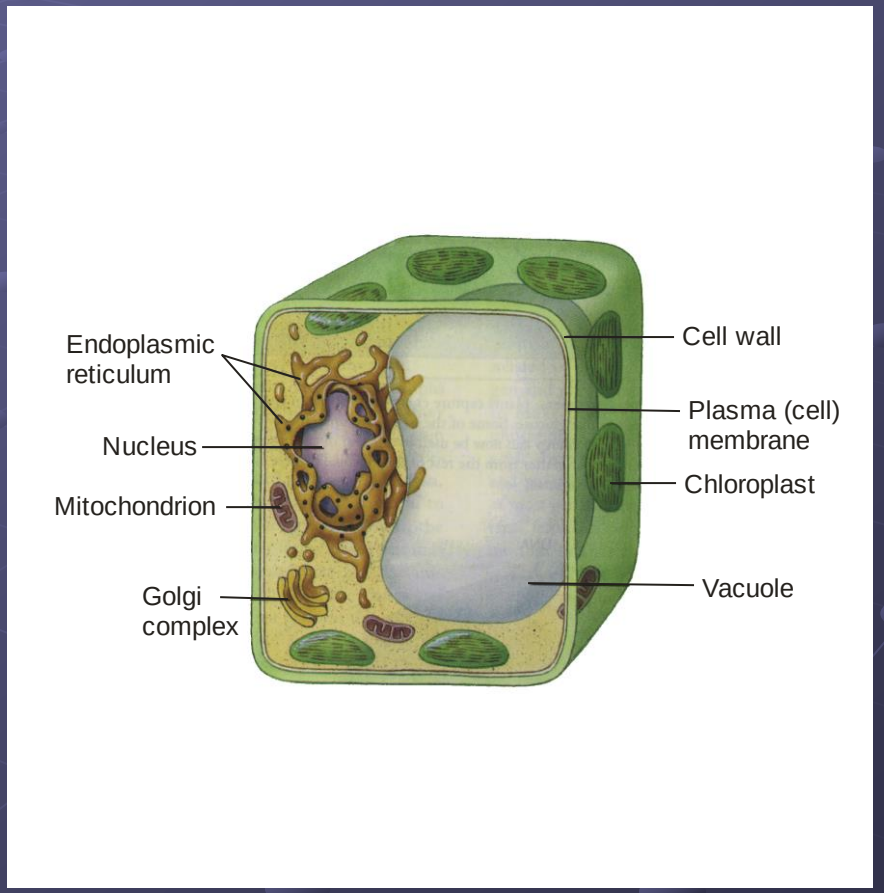
- **gelatinous sheath**
  - a mucous layer that often surrounds the cell wal
  - functions:
    - shields anaerobic prokaryotes from atmopheric oxygen
    - prevents dehydration
    - provides means of attachment to the substrate, e.g., to rock or sand grain
    - site of breakdown of food materials by digestive enzymes

- **eukaryotes**
  - Eukaryotes are characterized by a more complex organization of cellular contents
  - The most obvious development is a complex system of membranes throughout the cell
  - These membranes organize the internal structures into distinct compartments called **organelles**

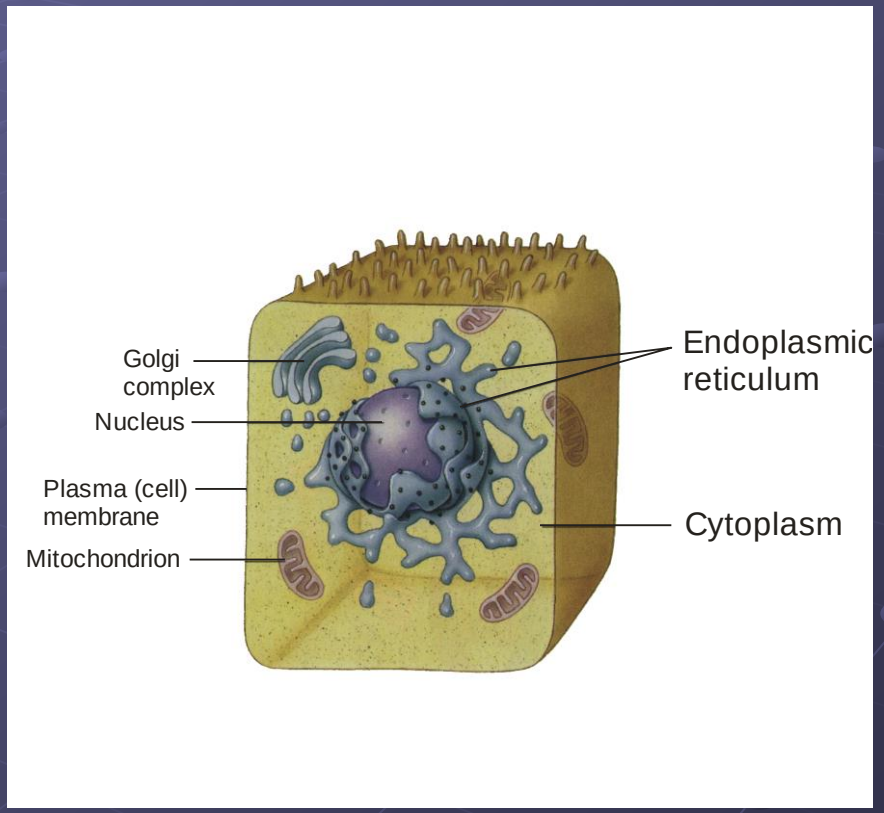
- **endoplasmic reticulum**
  - an extensive system of complex, interconnecting membranes extending throughout the cytoplasm
  - serves to transport materials to specific parts of the cell
  - a region of attachment for many organelles
- **Ribosomes**
  - sites of protein synthesis
  - most are attached to the endoplasmic reticulum, although some are also in the cytoplasm

- **Golgi complex**
  - a system of membranes involved in synthesizing, packaging, and transporting organic molecules used and secreted by the cell
- **mitochondria**
  - membrane-bound organelles containing most of the respiratory enzymes of the cell
  - their function is synthesis of molecules of ATP to provide energy for metabolic reactions
  - mitochondria contain their own DNA

- **chloroplasts**
  - organelles of photosynthetic cells
  - chloroplasts are complex membrane systems that function in capturing energy from sunlight to manufacture organic compounds
  - chloroplasts also contain their own DNA



- **Nucleus**
  - contains the remaining DNA of the cell in the form of **chromosomes**
  - genetic material is bounded by a **nuclear membrane**, which contains many pores to facilitate movement of molecules of RNA during transcription of the genetic code



- Levels of organization
  - The **cell** is the smallest self-contained unit capable of all the essential processes for life
    - indeed, many organisms consist of a single cell, and they are described as **unicellular**
    - e.g., all archaebacteria and eubacteria, plus many protists and fungi are unicellular

- Most eukaryotes are **multicellular**, i.e., consisting of more than one cell
  - Most multicellular organisms exhibit some degree of cellular specialization, resulting in a division of labor among the cells
    - e.g., nerve cells function to transmit electro-chemical messages
    - e.g., muscle cells contract to bring about movement

- Masses of similar specialized cells form **tissues** and work together to perform important functions
  - e.g., bone provides structure and support for other tissues
- Different tissues become organized into **organs**, which carry out more complex processes
  - e.g., the heart pumps blood throughout the body
- When organs function together as **organ systems**, a higher level of complexity occurs
  - e.g., digestive system digests food materials to provide fuel and materials for growth and maintenance of the organism

- Organ systems functioning together as a unit make up an individual **organism**
  - This is the reproductive unit, where selection occurs
- A group of organisms of the same species sharing a common genetic pool forms a **population**
  - This is the adaptive unit, where evolution occurs
- All the populations occupying the same habitat comprise a **biological community**
- Interacting biological communities, together with their physical environment, make up an **ecosystem**

- A climatically controlled group of ecosystems distributed over a wide area forms a **biome**

Levels of organization of biological systems

Level	Description	Examples	
Biome	Interacting ecosystems of characteristic composition distributed over a wide area	Tundra, tropical rainforest	Supra-organismal
Ecosystem	A community or communities in a large area, together with their physical environment	Coral reef ecosystem	
Community	All the populations in a particular environment	Intertidal limpet community	
Population	Group of organisms of the same species that occur together	Intertidal *Patelloda chamorrorum*	
Individual	A single organism	One limpet	Organismal
Organ system	A group of organs that work in cooperation	Digestive system, circulatory system	Sub-organismal
Organ	Tissues organized into discreet structures	Stomach, heart	
Tissue	Groups of cells that are bound together and specialized for the same function	Muscle tissue, epithelium	
Cell	Independent cells, the fundamental unit of living things	Muscle cell, nerve cell	
Organelle	A complex structure within cells; bound by an intracellular membrane	Nucleus, mitochondria, chloroplast	Subcellular
Molecule	Combination of atoms that are bonded together	Water, protein	
Atom	The fundamental unit of all matter	Hydrogen, oxygen	

Increasing complexity