Slide 1

So far.......

1. Biology is the study of life
   - All life is based on the cell
   - The Earth, organisms, cells are all aqueous

2. Water’s uniqueness stems from its internal polarity
   - Solvent; Cohesion, Temperature regulation, Insulation
   - Spontaneous dissociation allows for pH changes and buffering

3. The chemistry of life is tetravalent carbon-based
   - Four covalent bonds allows simple to very complex molecules
   - Several key reactive groups found in biological carbon molcs.

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Slide 2

Structure and Function of Large Biological Molecules

• All living things are primarily made up of four classes of Macromolecules
  - ______________________
  - ______________________
  - ______________________
  - ______________________

• Molecular structure and function are inseparable

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Slide 3

Most Macromolecules are polymers, built from monomers

• A polymer is a long molecule consisting of many similar building blocks
• These small building-block molecules are called monomers
• Three of the four classes of life’s organic molecules are polymers:
  - Carbohydrates
  - Proteins
  - Nucleic acids

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Slide 4

The Synthesis and Breakdown of Polymers

- A condensation reaction or more specifically a dehydration reaction occurs when two monomers bond together through the loss of a water molecule.

Slide 5

The Synthesis and Breakdown of Polymers

- Polymers are disassembled to monomers by hydrolysis, a reaction that is essentially the reverse of the dehydration reaction.

Slide 6

The Diversity of Polymers

- Each cell has thousands of different kinds of macromolecules.
- Macromolecules vary among cells of an organism, vary more within a species, and vary even more between species.
- An immense variety of polymers can be built from a small set of monomers.
Carbohydrates serve as fuel and building material

- Monosaccharides
- Disaccharides
- Oligosaccharides
- Polysaccharides

Sugars

- Monosaccharides have molecular formulas that are usually multiples of CH₂O
- Glucose (C₆H₁₂O₆) is the most common monosaccharide
- Monosaccharides are classified by
  - The location of the carbonyl group (as aldose or ketose)
  - The number of carbons in the carbon skeleton

Fig. 5-3

Hexoses (C₆H₁₂O₆)
- Pentoses (C₅H₁₀O₅)
- Trioses (C₃H₆O₃)

Pentose and hexose sugars usually are ring structures in cells.
Slide 10

Linear and ring forms in Glucose

Slide 11

Dehydration reaction in the synthesis of disaccharides

Slide 12

**Polysaccharides**

- Energy storage vs. structural role
- Structure and function determined by:
  - types of sugar monomers
  - positions of glycosidic linkages
Polysaccharides

- Example: 3 glucose polysaccharides
  - **Glycogen**: Animal Energy Storage
  - **Starch**: Plant Storage, Animal Source
  - **Cellulose**: Plant Structure, Not a Source
Slide 16

Cell walls

Cellulose molecules in a plant cell wall

0.5 µm

10 µm

Hydrogen Bonds Between Strands

Slide 17

Enzymes that digest starch by hydrolyzing α linkages can't hydrolyze β linkages in cellulose.

Cellulose in human food passes through the digestive tract as insoluble fiber.

Some microbes use enzymes to digest cellulose.

Many herbivores, from cows to termites, have symbiotic relationships with these microbes.

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Chitin, another structural polysaccharide, is found in the exoskeleton of arthropods and the cell walls of many fungi.

(a) The structure of the chitin monomer.

(b) Chitin forms the exoskeleton of arthropods.

(c) Chitin is used to make a strong and flexible surgical thread.
Biological Lipids

- **Lipids** do not form polymers
- Hydrophobicity arises from nonpolar covalent hydrocarbons in the presence of a polar solvent
- Some lipids separate from water because water molecules form hydrogen bonds with each other and exclude them
- The most biologically important lipids are fats, phospholipids, and steroids

---

The major function of fats is?

What are adipose cells?

---

Fats

- **Fats** are constructed from two types of smaller molecules: glycerol and fatty acids
- Glycerol is a three-carbon alcohol with a hydroxyl group attached to each carbon
- A **fatty acid** consists of a carboxyl group attached to a long carbon skeleton
Slide 22

Dehydration reaction in the synthesis of a fat

Slide 23

What is a trans fat?

Slide 24

Phospholipids: two hydrophobic fatty acids and a hydrophilic head group, which contains a phosphate, are attached to glycerol.
Slide 25

Hydrophilic head
Hydrophobic tail

WATER

Slide 26

Steroids are lipids characterized by a carbon skeleton consisting of four fused rings

Cholesterol

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Protein: “Of first importance...”

- Proteins account for more than 50% of the dry mass of most cells

- What are some of the functions of proteins?
Slide 28

<table>
<thead>
<tr>
<th>Topic</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>...</td>
<td>...</td>
</tr>
</tbody>
</table>

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**What are enzymes?**

Slide 30

![Diagram of enzyme activity](image-url)
Protein Monomers and Polymers

- Protein monomers are ___________________
- Monomers are linked by __________________
- The polymers are _______________________
- The order of monomers is the polymer’s ___________________

Protein Monomers and Polymers

- How many amino acids do we use? _________
- What key functional groups do they have? _______________________
- They differ due to _______________________
- A protein consists of how many polypeptides? _______________________
- What are the polypeptides called when there is more than one? _________

Protein Monomers and Polymers

- Amino group
- Carboxyl group
- α carbon
Slide 34

![Peptide bond](image)

Fig. 5-18

Amino end (N-terminus)

Peptide bond

Side chains

Backbone

Carboxyl end (C-terminus)

(a) (b)

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

Slide 35

![Fig. 5-17](image)

Nonpolar

Glycine (Gly or G)

Alanine (Ala or A)

Valine (Val or V)

Leucine (Leu or L)

Isoleucine (Ile or I)

Methionine (Met or M)

Phenylalanine (Phe or F)

Trypotphan (Trp or W)

Proline (Pro or P)

Polar

Serine (Ser or S)

Threonine (Thr or T)

Cysteine (Cys or C)

Tyrosine (Tyr or Y)

Asparagine (Asn or N)

Glutamine (Gln or Q)

Electrically charged

Acidic

Aspartic acid (Asp or D)

Glutamic acid (Glu or E)

BASIC

Lysine (Lys or K)

Arginine (Arg or R)

Histidine (His or H)

What would you expect from these in an aqueous environ?

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

___________________________________

Slide 36

A functional protein consists of one or more polypeptides twisted, folded, and coiled into a unique shape. The sequence of amino acids determines a protein’s three-dimensional structure.

A ribbon model of lysozyme

A space-filling model of lysozyme

A protein’s structure determines its function.
Four Levels of Protein Structure

- The primary structure of a protein is
- Secondary structure consists of
- Tertiary structure is
- Quaternary structure is
The coils and folds of secondary structure result from hydrogen bonds between repeating constituents of the polypeptide backbone.

Tertiary structure is determined by interactions between R groups, rather than interactions between backbone constituents.

Quaternary structure results when two or more polypeptide chains form one macromolecule.

- It is hard to predict a protein's structure from its primary structure.
- Most proteins go through several states on the way to stable structure.
- Chaperonins are proteins that assist the proper folding of other proteins.
**Slide 43**

**Fig. 5-24**

Hollow cylinder

Cap

Chaperonin (fully assembled)

Steps of Chaperonin Action:

1. An unfolded polypeptide enters the cylinder from one end.
2. The cap attaches, causing the cylinder to change shape in such a way that it creates a hydrophilic environment for the folding of the polypeptide.
3. The cap comes off, and the properly folded protein is released.

**Slide 44**

**What Determines Protein Structure?**

- In addition to primary structure, physical and chemical conditions can affect structure.
- Alterations in pH, salt concentration, temperature, or other environmental factors can cause a protein to unravel.
- This loss of a protein’s native structure is called **denaturation**.
- A denatured protein is biologically inactive.

**Slide 45**

**Fig. 5-23**

Normal protein

Denaturation

Renaturation

Denatured protein
Slide 46

**Sickle-Cell Disease: A Change in Primary Structure**

- A slight change in primary structure can affect a protein's structure and ability to function
- Sickle-cell disease, an inherited blood disorder, results from a single amino acid substitution in the protein hemoglobin

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**Fig. 5-22**

<table>
<thead>
<tr>
<th>Primary structure</th>
<th>Secondary and tertiary structures</th>
<th>Quaternary structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normal hemoglobin (top view)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primary structure</td>
<td>Secondary and tertiary structures</td>
<td>Quaternary structure</td>
</tr>
<tr>
<td>Normal red blood cells are full of individual hemoglobin molecules, each carrying oxygen.</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Red blood cell shape</td>
<td>Normal red blood cells are full of individual hemoglobin molecules, each carrying oxygen.</td>
<td></td>
</tr>
<tr>
<td>10 µm</td>
<td>Normal hemoglobin</td>
<td></td>
</tr>
<tr>
<td></td>
<td>β</td>
<td></td>
</tr>
<tr>
<td></td>
<td>β</td>
<td></td>
</tr>
<tr>
<td>Exposed hydrophobic region</td>
<td>Sickle-cell hemoglobin</td>
<td></td>
</tr>
<tr>
<td>Molecules interact with one another and crystallize into a fiber; capacity to carry oxygen is greatly reduced.</td>
<td>Fibers of abnormal hemoglobin deform red blood cell into sickle shape.</td>
<td></td>
</tr>
<tr>
<td>β</td>
<td>α</td>
<td></td>
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<td>β</td>
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<td>β</td>
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<tr>
<td>10 µm</td>
<td>Sickle-cell hemoglobin</td>
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<tr>
<td></td>
<td>GluProThrLeuHisVal Val</td>
<td></td>
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<tr>
<td></td>
<td>12345 6 7</td>
<td></td>
</tr>
</tbody>
</table>

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The primary amino acid sequence of a polypeptide is the source of its structure and function but what is the source of that sequence?
**Nucleic Acids**

- What are the two types of nucleic acids?
- What is replication?
- What is transcription?
- What are ribosomes?
Slide 52

Fig. 5-26

- mRNA Synthesis of mRNA in the nucleus
- Movement of mRNA into the cytoplasm via nuclear pore
- Ribosome
- Amino acids
- Polypeptide
- Synthesis of protein

Slide 53

The Structure of Nucleic Acids

- What are the nucleic acids monomers called?
- What are the nucleic acid polymers called?

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- Each nucleotide consists of a nitrogenous base, a pentose sugar, and a phosphate group
- Polynucleotide, or nucleic acid
- The nucleotide without the phosphate is called a nucleoside
Covalent bonds formed between the –OH group on the 3’ carbon of one nucleotide and the phosphate on the 5’ carbon on the next

The sequence of bases along a DNA or RNA polymer is unique for each gene

One DNA molecule includes many genes!

Sugar-phosphate backbones

3’ end

3’ end

3’ end

3’ end

5’ end

5’ end

5’ end

5’ end

Base pair (joined by hydrogen bonding)

Old strands

New strands

Nucleotide about to be added to a new strand

Two polynucleotides spiraling around an imaginary axis form a Double Helix

What is meant by Antiparallel?

What DNA bases can pair up?

_________ and __________

_________ and __________
Slide 58

What DNA and RNA bases can pair up?

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
</tr>
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</table>

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DNA and Proteins as Tape Measures of Evolution

- The linear sequences of nucleotides in DNA molecules are passed from parents to offspring.
- Two closely related species are more similar in DNA than are more distantly related species.
- Molecular biology can be used to assess evolutionary kinship.

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What have we learned so far?

The Molecules of Life

1. List the four major classes of macromolecules.
2. Distinguish between monomers and polymers.
3. Draw diagrams to illustrate condensation and hydrolysis reactions.
What have we learned so far?

Carbohydrates Serve as Fuel and Building Material

- 1. Distinguish between monosaccharides, disaccharides, and polysaccharides.
- 2. Describe the formation of a glycosidic linkage.
- 3. Compare and contrast the structures, functions, and locations of starch, glycogen, cellulose and chitin.

What have we learned so far?

Lipids are a Diverse Group of Hydrophobic Molecules

- 1. Describe the building-block molecules, structure, and biological importance of fats, phospholipids, and steroids. Discuss the primary functions of each type of lipid.
- 2. Identify an ester linkage and describe how it is formed.
- 3. Distinguish between saturated and unsaturated fats.
- 4. Describe the process that results in the production of trans fat molecules.
- 5. Discuss the role of saturated fats and trans fats in the potential development of atherosclerosis.

What have we learned so far?

Proteins have Many Structures, Resulting in a Wide Range of Functions

- 1. Distinguish between a protein and a polypeptide.
- 2. Explain how a peptide bond forms between two amino acids.
- 3. Name the two ends of a protein and explain the reason for their names.
- 4. List and describe the four major components of an amino acid. Explain how amino acids may be grouped according to the physical and chemical properties of the R group.
Slide 64

What have we learned so far?

5. Explain what determines protein structure and why it is important.
6. Explain how the primary structure of a protein is determined.
7. Name two types of secondary protein structure. Explain the role of hydrogen bonds in maintaining secondary structure. Explain how weak interactions and disulfide bridges contribute to tertiary protein structure.
8. List three conditions under which proteins may be denatured.
9. Explain how chaperonins may assist in proper folding of proteins.
10. Explain how a single nucleotide change in the beta-globin gene can lead to sickle cell anemia disease.

Slide 65

What have we learned so far?

Nucleic Acids Store and Transmit Hereditary Information

1. List the major components of a nucleotide, and describe how these monomers are linked to form a nucleic acid. Name the type of bond that holds two nucleotides together.
2. Distinguish between:
   a. pyrimidine and purine
   b. nucleotide and nucleoside
   c. ribose and deoxyribose
   d. 5’ end and 3’ end of a nucleotide
3. Briefly describe the three-dimensional structure of DNA.

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What have we learned so far?

4. Compare and contrast DNA and RNA.
5. Explain how DNA or protein comparisons may allow us to assess evolutionary relationships between species.
6. Briefly discuss the flow of genetic information (from DNA to RNA to protein).