1 # Macromolecules

Chapter 5

2 # macromolecules

- Large organic polymers
- 4 classes of macromolecules in living organisms
- Carbohydrates
- Lipids
- Proteins
- Nucleic acids
- Only 40-50 common monomers are used to construct macromolecules
- New properties emerge when these are arranged in different orders

3 # Condensation: Dehydration-synthesis rx

- Most polymerization reactions in living organisms are condensatjon reactions
- Polymerization reactions link 2 or more smaller molecules to form larger molecules with repeating structural units
- Monomers are covalently linked, producing a net removal on one water molecule for each linkage
- One monomer loses OH- and one loses H+
- Process requires energy
- Process requires biological catalysts or enzymes

4 # Hydrolysis

- Reactions process that breaks covalent bonds between monomers by the addition of water molecules
- H from the water bonds to one monomer and the OH from the water bonds to the adjacent monomer
- Digestive enzymes catalyze hydrolytic rx which break apart large food molecules

5 # Dehydration Synthesis rx

- http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20100/Bio%20100%20Lectures/Biochemistry/biochemi.htm

6 ## Condensation and Hydrolysis Rx

- http://www2.piedmont.cc.nc.us/faculty/AndersJ/BIO111%20-%20General%20Biology%20I/bio111_Chapter%203%20Notes.htm

7 # Carbohydrates

- Organic molecules made of sugars and their polymers
- Monomers are simple sugars:monosaccharides
- Polymers are formed by condensation rx: glycosidic linkage
- Classified by the # of simple sugars that make the polymer
- Used for energy or structure

8 # Sugar

- Major nutrients for cells; glucose is most common
- Can be produced by photosynthetic organisms from CO_2, H_2O, and sunlight
- Store energy in their chemical bonds which is harvested by cellular respiration

- C skeletons are raw material for other organic molecules
- Can be incorporated as monomers into disaccharides and polysaccharides
- CH_2O is empirical formula

9 Characteristics of Sugar

- OH group is attached to each C except one which is db bonded to O (carbonyl)
- C skeletons vary between 3 and 7 C
- Sugars are named for the number of C, eg. Pentose has 5 C
- Spatial arrangement around asymmetric carbons varies-enantiomers

10 Aldehydes and Ketones

11 Enantiomers

12 sucrose

- http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20100/Bio%20100%20Lectures/Biochemistry/biochemi.htm

13 Energy storage

- Cells hydrolyze starge polysaccharides into sugars as needed
- 2 most common are starch and glycogen
- Starch is a glucose polymer with alpha 1-4 glycosidic linkage
- Most animals have digestive enzymes to hydrolyze starch
- Sources include potatoes, grains
- Glycogen is glucose polymer that is a storage polysaccharide in animals; more highly branched than amylopectin
- Stored in muscle and live of humans and other vertebrates

14 Structural carbohydrates

- Cellulose and chitin
- Cellulose is linear unbranched polymer with beta 1-4 glycosidic linkage
- Major structural component of plant cell walls
- Reinforces plant cell walls w H bonds holding together parallel cellulose molecules in bundles of microfibrils
- Not digested by most organisms because lack enzyme to hydrolyze the linkage (exceptions are some bacteria and fungi)

15 Cellulose

- http://217.60.75.10/llt/Biokemi/di-og.htm

16 Chitin

- Structural polysaccharide that is a polymer of an amino sugar
- Forms exoskeletons of arthropods
- Bound as building material in cell walls of some fungi
- Monomer is amino sugar, which is similar to beta-glucose w N containing group replacing the OH on C2

17 ☐ **Chitin**

- http://www.rigest.com/products/chitin_chitosan.htm

18 ☐ **Explain what distinguishes lipids from other macromolecules.**

- Insoluble in water
- Will dissolve in nonpolar solvents (ether, chloroform, benzene)
- Important groups are fats, phospholipids, and steroids

19 ☐ **Building block molecules of lipids**

- Glycerol: 3C alcohol
- Fatty acid (COOH)
- Carboxyl group at one end and an attached hydrocarbon chain usually w an even # of C atoms (16-18)
- Nonpolar c-H bonds make the chain hydrophobic and not water soluble

20 ☐ **Identify ester linkage and describe how it is formed.**

- Enzyme catalyzed condensation reactions link glycerol to fatty acids by an ester linkage
- Ester linkage is a bond from between the OH group on the glycerol and the carboxyl group on the fatty acid
- Each of glycerol's 3 OH groups can bond to a fatty acids by ester linkage
- Triacylglycerol (triglyceride) is a fat composed of 3 fatty acids bonded to one glycerol by ester linkage

21 ☐ **triglyceride**

- http://www.mbarnes.dircon.co.uk/revision_chemistry/lipids.htm

22 ☐ **Distinguish between a saturated fat and an unsaturated fat.**

1
- Saturated fat
- No double bonds btwn C in fatty acid tail
- C skeleton of fatty acid is bonded to max # of H
- Solid at room temperature
- Most animal fats
- Bacon grease, lard, and butter

2
- Unsaturated fat
- One or more double bonds btwn C in fatty acid tail
- Tail kinks at each C=C, so molecules don't pack closely enough to solidify at room temperature
- Usually a liquid at room temperature
- Most plant fats
- Corn, peanut, and olive oil

23 ☐ **Unsaturated and Saturated Fats**

- http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20100/Bio%20100%20Lectures/Biochemistry/biochemi.htm

24 ☐ **Emergent properties that are a consequence of structural differences**

- Fats are insoluble in water
- Source of variation among fat molecules is the fatty acid composition
- Fatty acids in a fat may all be the same, or some may differ
- Fatty acids may bary in length
- Fatty acids may vary in # and location of C=C bonds
- Commercially prepared food have unsaturated fats that are artificially hydrogenated to prevent them from separating out as oil (peanut butter and margarine)

25 Function of fats

- Energy storage: one g fat stores 2x the energy as 1 g of polysaccharide
- Fat has a higher proportion of energy rich C-H bonds than polysaccharides
- More compact fuel reservoir than carbohydrates
- Animals store more energy w less weight than plants which use starch
- Cushions vital organs in mammals (like kidney)
- Insulates against heat loss

26 phospholipids

- Compounds w molecular building blocks of glycerol, 2 fatty acids, a phosphate groups and usually an additional small functional group attached to the phosphate
- Differ from fat in that the 3C of glycerol is joined to a negatively charged phosphate group
- Can have small variable molecules (usually charged or polar) attached to phosphate
- Are diverse depending upon differences in fatty acids and in phosphate attachments

27 Phospholipid Structure

28 Cell membrane structure

- http://sun.menloschool.org/~dspence/biology/chapter5/chapt5_3.html

29 Characteristics and function of phospholipids

- Show ambivalent behavior towards water-hydrocarbon tails are hydrophobic and polar heads are hydrophilic
- Cluster in water as their hydrophobic portions turn away from water
- A micelle is a type of cluster assembled so that the hydrophobic tails turn towards the water-free interior, and the hydrophilic phosphate heads arrange facing out in contact w water
- Function as a major constituent of cell membranes-amphipathic membranes

30 steriods

- Lipids which have 4 fused C rings w various functional groups attached
- Cholesterol is the precursor to many other steroids including vertebrate sex hormones and bile acids
- Cholesterol is a common component of animal cell membranes
- Cholesterol can contribute to atherosclerosis

31 Cholesterol

- http://origin.imbb.forth.gr:8888/mor_biol/membranes/photos/Cell-cholesterol.htm

32 Estradiol and Testosterone

- http://www.chem.uwec.edu/Webpapers2002/Pages/Papers/heezennj/pages/introduction.html

33 Proteins

- Macromolecule that consists of one or more polypeptide chains folded and coiled into specific conformations
- Polypeptide chains are polymers of amino acids that are arranged in a specific linear sequence
- Are abundant, making up 50% of cellular dry weight
- Vary extensively in structure; each type has a unique 3D conformation
- Are commonly made of only 20 amino acid monomers

34 Protein Functions

- Structural support (collagen)
- Storage (of amino acids)
- Transport (hemoglobin)
- Signaling (chemical messengers)
- Cellular response to chemical stimuli (receptor proteins)
- Defense against foreign substances and disease-causing organisms (antibodies)
- Catalysis of biochemical reactions (enzymes)

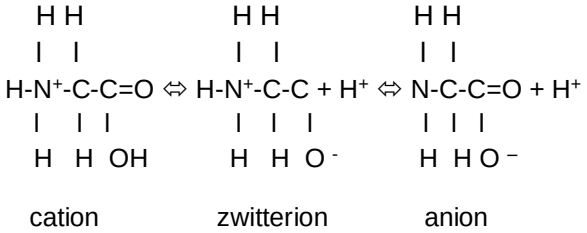
35 Amino acid

- Building block molecule of a protein; most consist of an asymmetric C, termed the α carbon, which is covalently bonded to:
- Hydrogen atom
- Carboxyl group
- Amino group
- Variable R group (side chain) specific to each amino acid
- Physical and chemical properties of the side chain determines the uniqueness of each amino acid

36 Structure of amino acid

- http://www.ebi.ac.uk/2can/biology/molecules_small.html

37 Amino Acids can exist as 3 ionic states



positive dipolar ion negative

38 20 common amino acids

- Grouped by properties of side chains
- Nonpolar side groups are hydrophobic
- Polar side groups hydrophilic
- Polar side groups divided into uncharged polar groups and charged polar groups (acidic or basic)

39 Peptide bond

- http://cmgm.stanford.edu/biochem/biochem201/Slides/Protein%20Structure/Forming%20Peptide%20Bond.JPG

40 Peptide bond

- Covalent bond formed by dehydration synthesis reaction that links the carboxyl group of one amino acid to the amino group of another
- Has polarity w an amino group on one end (N-terminus) and a carboxyl group on the other (C-terminus)
- Has a backbone of the repeating sequence –- N-C-C-N-C-C-
- Have unique linear sequences of amino acids

41 Conformations of Proteins

42 Protein Conformation

- Function depends on its conformation which will be unique due to the unique sequence of amino acids
- Conformation is the 3D shape of a protein
- Native conformation enables protein to recognize and bind specifically to another molecule (hormone/receptor; enzyme/substrate; antibody/antigen)
- Produced when polypeptide chain coils and folds
- Is stabilized by chemical bonds and weak interactions btwn neighboring regions of the folded protein

43 4 levels of structure

- Primary structure: peptide bonds
- Secondary structure: hydrogen bonds
- Tertiary structure:
- Quaternary structure

44 Primary structure

- peptide chain unique sequence determined by genes (Sanger determined sequence of insulin)

45 Secondary Structure

- Regular repeated coiling and folding of protein's polypeptide backbone
- Stabilized by hydrogen bonds btwn peptide linkages in the protein's backbone (carbonyl and amino groups)
- Alpha helix (Linus Pauling and Robert Corey) found in fibrous proteins (collagen and keratin) and some globular proteins
- and beta pleated sheets are the two major types
- Beta pleats have parallel regions held together by either intrachain or interchain hydrogen bonds
- Make up core of many globular proteins and some fibrous proteins (fibroin-silk)

46 ## Alpha helices

- http://cmgm.stanford.edu/biochem/biochem201/Slides/Protein%20Structure/Alpha%20Helices.JPG

47 ## Beta pleats

- http://cmgm.stanford.edu/biochem/biochem201/Slides/Protein%20Structure/Pleated%20Beta-sheets.JPG

48 ## Tertiary structure

- Irregular folding of protein due to bonding btwn side chains (R groups)
- Held by weak interactions and disulfide bridges
- Weak interactions include hydrogen bonding btwn polar side chains, ionic bonds btwn charged side chains and hydrophobic interactions btwn nonpolar side chains
- Disulfide bridges are covalent linkage which forms btwn 2 cysteine (amino acid) monomers brought together by folding of protein (strong, reinforcing bond)

49 ## Disulfide Bridges

- http://www.pasteur.fr/recherche/unites/Lmn/en/toxines.html
- http://www.mun.ca/biochem/courses/3107/images/Stryer/Stryer-F14-34.jpg

50 ## Tertiary Protein Conformation

- http://is.asu.edu/plb108/course/life/macrom/page9.html

51 ## Quaternary Structure

- Multiple polypeptides held together w hydrophobic interactions or van der Waals attraction
- http://is.asu.edu/plb108/course/life/macrom/page9.html

52 ## RNA polymerASE

- http://www.biochem.umd.edu/biochem/kahn/molmachines/newpolII/subunits.html

53 ## Protein denaturation

- Process by which a protein's native conformation and biological activity is altered
- May be denatured by addition of an organic solvent (inside hydrophobic chains would move to outside)
- Chemical agents that alter pH: disrupt hydrogen bonds, ionic bonds, and disulfide bridges
- Excessive heat-increased temperatures disrupts weak interactions
- Some denatured proteins are able to return to native conformation if the primary structure is intact

54 ## Protein Folding

- Proteins pass through several intermediate stages
- A protein's native conformation may be dynamic, altering between several shapes
- Folding of proteins made by ribosomes attached to the endoplasmic reticulum is

facilitated by the lumen of the endoplasmic reticulum
- Folding of proteins that are made in the cytosol by free ribosomes are aided by chaperone proteins

55 ## Nucleic acids

- Polymer of nucleotides linked together by dehydration synthesis reactions
- Nucleotide is a building block molecule made of 5 carbon sugar covalently bonded to a phosphate group and a nitrogenous base (either purine or pyramidine)
- 2 types are DNA and RNA

56 ## RNA

- Ribonucleic acid
- Functions in the actual synthesis of proteins coded for by DNA
- form sites of protein synthesis are on ribosomes in the cytoplasm
- Messenger RNA carries encoded genetic message from the nucleus to the cytoplasm
- Flow of genetic information goes from DNA to RNA to protein
- Some viruses have only RNA
- May have been the first genetic molecules

57 ## DNA

- Deoxyribonucleic acid
- Contains coded information that programs all cell activity
- Contains directions for its own replication
- Is copied and passed from one generation of cells to another
- In eukaryotic cells, is found primarily in the nucleus
- Makes up genes that contain instructions for protein synthesis-genes that do not directly make proteins, but direct the synthesis of mRNA

58 ## DNA

- http://faculty.clintoncc.suny.edu/faculty/Michael.Gregory/files/Bio%20100/Bio%20100%20Lectures/Biochemistry/biochemi.htm

59 ## Sugars

- http://3eme-cycle.ch/~vjongene/molbio/chapt_2.htm

60 ## DNA Structure

- 1953 James Watson and Francis Crick proposed the db helix structure based on X ray crystallography by Rosalind Franklin; Franklin reviewed their construction and it fit her calculations
- Sugar-phosphate backbones are on the outside of the helix
- Nitrogenous bases are paired in the interior of the helix and are held together by H bonds
- Base pairing rules are A:T and C:G
- 2 strands of DNA are complimentary and antiparallel

61 ## Purines and pyrimidines

- http://3eme-cycle.ch/~vjongene/molbio/chapt_2.htm

62 ## Inheritance

- Precise copying makes inheritance possible
- Most DNA molecules are long w thousands or millions of base pairs
- Closely related species have similar sequence in DNA and amino acids, than more distantly related species
- Evolutionary relationships btwn species may be deduced from this evidence