1

2 **3.1 Atoms**

- Organisms are chemical machines
- Any substance in the universe that has mass and occupies space is comprised of matter
  - –all matter is made up of atoms

3 **3.1 Atoms**

- All atoms have the same structure
  - –at the core is a dense nucleus comprised of two subatomic particles
    - protons (positively charged)
    - neutrons (no associated charge)
  - –orbiting the nucleus is a cloud of another subatomic particles
    - electrons (negatively charged)

4 **3.1 Atoms**

- Atoms are characterized by # of protons it has or by its overall mass
  - –atomic number
    - # of protons in the nucleus
    - atoms w/ same atomic # exhibit the same chemical properties and are considered to belong to same element
  - –mass number (atomic mass)
    - # of protons + # of neutrons in nucleus
    - electrons have negligible mass
    - Defines the isotope

5 **3.1 Atoms**

- Electrons determine the chemical behavior of atoms
  - –these subatomic components are the parts of the atom that come close enough to each other in nature to interact

6 **3.1 Atoms**

- Electrons are associated with energy
  - –electrons have energy of position, called *potential energy*
  - –the field of energy around an atom is arranged as levels called electron shells
    - within this volume of space, orbitals are where electrons

are most likely to be found

7 **3.1 Atoms**

- Electron shells have specific numbers of orbitals that may be filled with electrons

  –atoms that have *incomplete* electron orbitals tend to be *more* reactive
  –atoms will lose, gain, or share electrons in order to fill completely their outermost electron shell
  –these actions are the basis of chemical bonding

8 **3.1 Atoms**

- as electrons move to a lower energy level, closer to the nucleus, energy is released

- moving electrons to energy levels farther out from the nucleus requires energy

9 **3.2 Ions and Isotopes**

- Ions – atoms that have gained or lost one or more electrons

- Isotopes – atoms that have the same # of protons but different # of neutrons
  –most elements in nature exist as mixtures of different isotopes

10 **Figure 3.5 Isotopes of the element carbon**

11 **More on Isotopes**

- Some isotopes are unstable
  – break up into particles w/ lower atomic numbers
  –this process is known as radioactive decay

- Radioactive isotopes have multiple uses
  –nuclear medicine
  –dating fossils

12 **Isotopes**

- Short-lived isotopes decay rapidly and do not harm the body

- Can be used as tracers to study how the body functions

13 **Another Use for Isotopes**

- Dating fossils
  - –rate of decay of a radioactive element is constant
  - –by measuring the fraction of radioactive elements that have decayed, scientists can date fossils
  - –the *older* the fossil, the *greater* the fraction of its radioactive atoms that have decayed

14 **Figure 3.7 Radioactive isotope dating**

- C12 most common carbon isotope
- C14 is a short lived isotope
- C12:C14 ratio constant
- When animal dies, C14 decays. C12 stays same.
- Ratio of C14: C12 ↓s by ½ every 5,730 yrs
- This is the half life of carbon 14.

15 **3.3 Molecules**

- Molecule: grp of atoms held together by energy
  - – called a chemical bond

  <u>3 principal types of chemical bonds</u>

  1.ionic
  2.covalent
  3.hydrogen

16 **IONIC BONDS can form molecules**

- Ionic bonds involve the attraction of opposite electrical charges

- Molecules comprised of these bonds are often most stable as crystals

17 **Covalent bonds can form molecules**

- form between 2 atoms when they share electrons

  –the # of electrons shared varies depending on how many the atom needs to fill its outermost electron shell

–covalent bonds are stronger than ionic bonds

18 **Last but not least: Hydrogen Bonds**

- are weak bonds that form due to covalent bonds where one nucleus attracts the shared electrons more than another nucleus

  –this attraction for electrons by a nucleus is called the atom's electronegativity

  –e- from H more strongly attracted to the O nucleus than its own H nucleus. This causes a strong – charge by the O nucleus and a more + charge near the H nucleus.

  –POLAR molecule

19 **Figure 3.9 (a) Water molecules contain two covalent bonds**

20 **3.3 Molecules**

- Hydrogen bonds form in association with polar molecules
  –each atom with a partial charge acts like a magnet to bond weakly to another polar atom with an opposite charge
  –H bonds have cumulative strength

21 **3.4 Hydrogen Bonds Give Water Unique Properties**

- Water is essential for life

  –the chemistry of life is water chemistry

- Water is a polar molecule

  –water can form hydrogen bonds
  –hydrogen bonding confers on water many different special properties

22 **5 Unique Properties of Water**

- Heat Storage
  –water temperature changes slowly and holds temperature well

- Ice Formation
  - –few hydrogen bonds break at low temperatures
    - water becomes less dense as it freezes because hydrogen bonds stabilize and hold water molecules farther apart

- High Heat of Vaporization
  - –at high temperatures, hydrogen bonds can be broken
    - water requires tremendous energy to vaporize because of all the hydrogen bonds that must be broken

23 **3.4 Hydrogen Bonds Give Water Unique Properties**

- Water molecules are sticky
  - –cohesion – when one water molecule is attracted to another water molecule
  - –adhesion – when polar molecules other than water stick to a water molecule

24 **The last unique property of water is that it is <u>highly polar</u>**

in solution, water molecules tend to form the maximum number of hydrogen bonds

- hydrophilic molecules are attracted to water and dissolve easily in it
  - –these molecules are also polar and can form hydrogen bonds

- hydrophobic molecules are repelled by water and do not dissolve
  - –these molecules are non-polar and do not form hydrogen bonds

25 **3.5 Water Ionizes**

- The covalent bond within a water molecule breaks spontaneously

- This produces two ions in a process called ionization

–because of the great strength of covalent bonds, this does not occur too often

26 **3.5 Water Ionizes**

- The amount of ionized hydrogen from water in a solution can be measured as pH

- The pH scale is logarithmic, which means that a pH scale difference of 1 unit actually represents a 10-fold change in hydrogen ion concentration

27 **Figure 3.14 The pH scale**

28 **3.5 Water Ionizes**

- Pure water has a pH of 7
  –there are equal amounts of [H+] relative to [OH-]

- Acid – any substance that dissociates in water and increases the [H^+]
  –acidic solutions have pH values below 7

- Base – any substance that combines with [H^+] when dissolved in water
  –basic solutions have pH values above 7

29 **3.5 Water Ionizes**

- The pH in most living cells and their environments is fairly close to 7
  –proteins involved in metabolism are sensitive to any pH changes

- metabolic activities & dietary intake and processing creates acids and bases

- Organisms use buffers to minimize pH disturbances

30 **3.5 Water Ionizes**

- Buffer – a chemical substance that takes up or releases hydrogen ions

  –buffers don’t remove the acid or the base affecting pH but minimize their effect on it

–most buffers are pairs of substances, one an acid and one a base

31 **Ch. 4 Molecules of Life**

- 4 types of Macromolecules (polymers)
  - –Proteins
  - –Nucleic Acids
  - –Carbohydrates
  - –Lipids

Monomers: single unit that repeats to make up a polymer.

32

- Organic Molecule: any molecule that has a carbon based core with special groups attached.
- These special groups give the molecule it's identity.

33 **How to make and break a macromolecule**

- Dehydration Synthesis: BUILDS
  - –Remove a H_2O (H from one and OH from another)
- Hydrolysis: DESTROYS a polymer
  - –Add a H_2O molecule

  –Requires Enzymes to do this

34 **Figure 4.2 (a) Dehydration synthesis**

35 **Figure 4.2(b) Hydrolysis**

36 **4.2 Proteins**

- amino acids
  - –the covalent bond linking two amino acids together is called a peptide bond
  - –the assembled polymer is called a polypeptide

37 **Table 4.2 The many functions of proteins**

38 **4.2 Proteins**

- AA are small molecules with a simple basic structure, a carbon atom to which three groups are added
  - an amino group ($-NH_2$)
  - a carboxyl group ($-COOH$)

- a functional group (R)

- The functional group gives amino acids their chemical identity
  - there are 20 different types of amino acids

39 **4.2 Proteins**

- Protein structure is complex
  - the order of the AA that form the polypeptide is important
    - the sequence of the amino acids affects how the protein folds together
  - the way that a polypeptide folds to form the protein determines the protein's function
    - some proteins are comprised of more than one polypeptide

40 **4.2 Proteins**

- There are four general levels to protein structure

  1. Primary: the sequence of AA in the polypeptide chain
  2. Secondary: folded
  3. Tertiary: 3d
  4. Quaternary: Multiple polypeptide chains

41 **Figure 4.5 Levels of protein structure (circle the primary structure)**

42 **4.2 Protein**

- The shape of a protein affects its function
  - changes to the environment of the protein may cause it to unfold or denature
    - increased temperature or lower pH affects hydrogen bonding, which is involved in the folding process
  - a denatured protein is inactive

43 **4.2 Proteins**

- Enzymes are globular proteins that have a special 3-D shape that fits precisely with another chemical
  - –cause the chemical that they fit with to undergo a reaction
  - –process of enhancing a chemical reaction: catalysis

44 **4.2 Proteins**

- Proteins fold specifically
  - –the folding process is helped by special proteins called chaperone proteins
    - these proteins somehow correct a misfolded protein
    - defective chaperone proteins may play a role in certain genetic disorders that involve defective proteins
      - –Cystic fibrosis
      - –Alzheimer's

45 **4.3 Nucleic Acids: 2 types**

- Nucleic acids are very long polymers that store information
  - – Monomers: nucleotides
    - each nucleotide has 3 parts
      1. a five-carbon sugar
      2. a phosphate group
      3. an organic nitrogen-containing base
  - – 5 different types of nucleotides
    - information is encoded in the nucleic acid by different sequences of these nucleotides

46 **2 types of nucleic acids**

- –Deoxyribonucleic acid (DNA)
- –Ribonucleic acid (RNA)

- RNA is similar to DNA except that
  - –it uses uracil instead of thymine
  - –it is comprised of just one strand
  - –it has a ribose sugar

47 **4.3 Nucleic Acids**

- The structure of DNA is a double helix because
  - –there are only two base pairs possible
    - Adenosine (A) pairs with thymine (T)

- Cytosine (C) pairs with Guanine (G)

–the bond holding together a base pair is hydrogen bond

–a sugar-phosphate backbone comprised of phosphodiester bonds gives support

48 **Figure 4.12 The DNA double helix**

49 **4.3 Nucleic Acids**

- The structure of DNA helps it to function

–the hydrogen bonds of the base pairs can be easily broken to unzip the DNA so that information can be copied

- each strand of DNA is a mirror image so the DNA contains two copies of the information

–having two copies means that the information can be accurately copied and passed to the next generation

50 **4.4 Carbohydrates**

- Carbohydrates are monomers that make up the structural framework of cells and play a critical role in energy storage

–a carbohydrate is any molecule that contains the elements C, H, and O in a 1:2:1 ratio

–the sizes of carbohydrates varies

- simple carbohydrates – made up of one or two monomers
- complex carbohydrates – made up of polymers

51 **Simple carbohydrates are small**

–monosaccharides consist of only one monomer subunit

- Ie: glucose ($C_6H_{12}O_6$)

–disaccharides consist of two monosaccharides

- Ie: sucrose, which is formed by joining together two monosaccharides, glucose and fructose

52 **Complex carbohydrates**

- are long polymer chains

–because they contain many C-H bonds, these carbohydrates are good for storing energy

- these bond types are the ones most often broken by organisms to obtain energy

–long chains are called polysaccharides

53 **4.4 Carbohydrates**

- Plants and animals store energy in polysaccharide chains formed from glucose
  - –plants form starch
  - –animals form glycogen

- Some polysaccharides are structural and resistant to digestion by enzymes
  - –plants form cellulose cell walls
  - –some animals form chitin for exoskeletons

54 **Carbohydrates and their function**

2 • Lactose is a disach.

- Storage polysaccharide in plants is starch
- Storage in animals as glycogen.

- Cellulose is a polysaccharide in cell walls.
- Chitin is a polysacch. In external skeletons of insects.

55 **4.5 Lipids**

- Lipids – fats and other molecules that are not soluble in water
  - –lipids are non-polar molecules
  - –lipids have many different types
    - fats
    - oils
    - steroids
    - rubber
    - waxes
    - pigments

56 **4.5 Lipids**

- Fats are converted from glucose for long-term energy storage
  - – fats have two subunits
    1. fatty acids
    2. glycerol

– fatty acids are chains of C and H atoms, known as hydrocarbons
  - the chain ends in a carboxyl (-COOH) group

57 **Fat Molecules: a 3 C glycerol + 3 FA tails**

- Most animal fats are saturated (each C has the max # of H) butter
- Sat. Fats: solid @ rm temp
- Most plant fats are unsaturated (Oil) contain double bonds Liquid @ rm temp

58 **Figure 4.17(b,c) Saturated and unsaturated fats**

- Saturated/ animal/ hard
- Unsaturated/ plant/ soft

59 **4.5 Lipids**

- Biological membranes involve lipids
  - –phospholipids make up the two layers of the membrane
  - –cholesterol is embedded within the membrane

60 **Other Types of Lipids**

- Phospholipids: glycerol, two fatty acids, and a phosphate group

61 **fatty acid tails are flexible, makes lipid bilayer fluid**

62