7. Which of the following is a mixture?
- **a.** sodium chloride
- **b.** rice and beans
- **c.** magnesium sulfate
- **d.** water

8. The mass of an atom is almost entirely contributed by its
- **a.** nucleus.
- **b.** protons.
- **c.** electrons and protons.
- **d.** neutrons.

9. If an atom consists of 9 protons and 10 neutrons, its
- **a.** atomic number is 10.
- **b.** mass number is 10.
- **c.** number of electrons is 9.
- **d.** electrical charge is 9.

10. Which of the following is true of an atom?
- **a.** It consists of protons, neutrons, and electrons.
- **b.** It has a nucleus consisting of protons, neutrons, and electrons.
- **c.** The protons are equal in number to the electrons, so the nucleus is electrically neutral.
- **d.** All of the above are true.

Answers

1. c. Atoms are electrically neutral; the number of electrons is equal to the number of protons.
2. b. Mass number is the number of protons plus the number of neutrons: 60 + 75 = 135.
3. d. The atomic number is the number of protons—in this case, 17.
4. b. By definition, isotopes have different numbers of neutrons. Therefore, they differ in atomic weight.
5. c. The number of neutrons is equal to the atomic mass minus the atomic number (the number of protons): 118 – 58 = 60.
6. b. This is part of Dalton's atomic theory.
7. b. Rice and beans are not chemically combined and can be separated into their constituent parts by physical means.
8. a. The protons and neutrons of an atom are found in the nucleus.
9. c. Atoms are electrically neutral. If there are 9 protons, each with a +1 charge, 9 electrons with a –1 charge are needed to balance.
10. a. An atom consists of protons, neutrons, and electrons; the nucleus contains protons and neutrons. The protons are equal in number to the electrons, but the nucleus itself is not electrically neutral.

B. Periodic Table (page 202)

1. Periodic Law

Periodic law is when the properties of the elements are a periodic function of their atomic number.

Periodic table is an arrangement of the elements according to similarity in their chemical properties and in order of increasing atomic number.

2. Properties of the Periodic Table

a. Periods

Periods are one of the seven horizontal rows of a periodic table of elements having the same number of electron shells (or levels).

b. Groups

Groups are the vertical column of elements with the same number of electron(s) in their outermost shell. The group number indicates the number of valence (or outermost) electrons. Elements in the same group share similar chemical properties.

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 **H** 1.00794																1 **H** 1.00794	2 **He** 4.002602
3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.00674	8 **O** 15.9994	9 **F** 18.9984032	10 **Ne** 20.1797
11 **Na** 22.989770	12 **Mg** 24.3050											13 **A1** 26.981538	14 **Si** 28.0855	15 **P** 30.973761	16 **S** 32.066	17 **Cl** 35.4527	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.955910	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938049	26 **Fe** 55.845	27 **Co** 58.933200	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.29
55 **Cs** 132.90545	56 **Ba** 137.327	57 **La*** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.96655	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98038	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac**** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (269)	111 **Uuu** (272)	112 **Uub** (277)		114 **Uug** (289) (287)		116 **Uuh** (289)		118 **Uuo** (293)

* **Lanthanide series**	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92534	66 **Dy** 162.50	67 **Ho** 164.93032	68 **Er** 167.26	69 **Tm** 168.93421	70 **Yb** 173.04	71 **Lu** 174.967
** **Actinide series**	90 **Th** 232.0381	91 **Pa** 231.03588	92 **U** 238.0289	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

c. Metals

A **metal** is an element that is a good conductor of heat and electricity in addition to being shiny (reflecting light), malleable (easily bent), and ductile (made into wire). Metals are electropositive, having a greater tendency to lose their valence electrons. They are grouped in the left of the periodic table (groups I–III).

d. Nonmetals

A **nonmetal** is an element with poor conducting properties. They are electronegative and accept electrons in their valence shell. They are found in the upper right-hand corner of the periodic table.

e. Metalloids

A **metalloid** is an element with properties that are intermediate between those of metals and nonmetals, such as semiconductivity. They are also found between metals and nonmetals in the periodic table.

3. Electronic Structure of Atoms

a. Bohr Atom

Niels Bohr's planetary model of the hydrogen atom, in which a nucleus was surrounded by orbits of electrons, resembles the solar system. Electrons could be excited by **quanta** of energy and move to an outer orbit (excited level). They could also emit radiation when falling to their original orbit (ground state).

b. Energy Level

Energy level is the volume of space where certain electrons of specific energy are restricted to move around the nucleus. Energy levels consist of one or more orbitals.

c. Orbitals

An **orbital** is the space where one or two paired electrons can be located. These are mathematical functions (or figures) with restricted zones, called **nodes**, and specific shapes—for example, *s* orbitals are spherical; *p* orbitals are dumbbell-shaped).

d. Outer Shell (or valence shell)

The **outer shell** is the last energy level in which loosely held electrons are contained. These are the electrons that engage into bonding and are therefore characteristic of the element.

e. Hund Rule

Hund's Rule states that the most stable arrangement of electrons in the same energy level is the one in which electrons have parallel spins (same orientation).

f. Pauli' s Exclusion Principle

Pauli's Exclusion Principle states that an orbital can hold a maximum of two electrons if they are of opposite spins.

g. Electron Configuration

Electron Configuration describes the exact arrangement of electrons (given in a superscript number) in successive shells (indicated by numbers 1, 2, 3, and so on) and orbitals (*s*, *p*, *d*, *f*) of an atom, starting with the innermost orbital.

For example, $1s^2\,2s^2\,2p^6$.

You Should Review

- periodic table: structure; specific names of the different groups (group I: alkali metal, group II: alkaline earth, group VII: halogens, etc); the location of metals, nonmetals, and metalloids
- Bohr atom
- ground state
- quantization of energy
- quantum number
- Heisenberg uncertainty principle
- the maximum number of electrons that can be held in each energy level

Questions

11. If the electron configuration of an element is written $1s^2\,2s^2\,2p_x^{\,2}\,2p_y^{\,2}\,2p_z^{\,2}\,3s^1$, the element's atomic
a. number is 11.
b. number is 12.
c. weight is 11.
d. weight is 12.

12. Choose the proper group of symbols for the following elements: potassium, silver, mercury, lead, sodium, iron.
a. Po, Ar, Hr, Pm, So, Fm
b. Pb, Sl, Me, Le, Su, Io
c. Pt, Sr, My, Pd, Sd, In
d. K, Ag, Hg, Pb, Na, Fe

13. What is the maximum number of electrons that each *p* orbital can hold?
a. 8
b. 2
c. 6
d. 4

14. What is the maximum number of electrons that the second energy level can hold?
a. 8
b. 6
c. 2
d. 16

15. What is the name of the individual who proposed that the atom was similar to a solar system, with a dense nucleus and concentric circles around it?
a. Hund
b. Dalton
c. Pauli
d. Bohr

16. The horizontal rows of the periodic table are called
a. families.
b. groups.
c. representative elements.
d. periods.

17. Which of the following is an alkali metal (group IA)?
a. calcium
b. sodium
c. aluminum
d. alkanium

18. Who stated that an orbital can hold as many as two electrons if they have opposite spins, one clockwise and one counterclockwise?
a. Hund
b. Dalton
c. Pauli
d. Bohr

19. Which elements conduct electricity?
a. metals
b. nonmetals
c. metalloids
d. ions

20. If the electron configuration of an element is written: $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^3$, the element's atomic
a. number is 15.
b. number is 5.
c. weight is 15.
d. weight is 5.

Answers

11. a. Since there are 11 electrons in the element's electron configuration, the element has 11 protons and, therefore, an atomic number of 11.
12. d. See the periodic table.
13. b. Each *p* orbital holds two electrons. There are three *p* orbitals, holding a total of six electrons.
14. a. The second energy level has one s orbital and three *p* orbitals, holding a total of eight electrons.
15. d. Bohr proposed the model defined in the question.
16. d. By definition, the periods are the horizontal rows on the periodic table.
17. b. Sodium is an alkali metal.
18. c. The question defines Pauli's exclusion principle.
19. a. Metals, by definition, conduct electricity.
20. a. Since the element has 15 electrons, it also has 15 protons and an atomic number of 15.

C. Chemical Bonds

1. Octet Rule

Octet rule is when atoms bond by surrounding themselves with eight (octet) outer electrons (two electrons for H). They tend to acquire the stability of their closest noble gases in the periodic table, either by losing (metals), gaining (nonmetals), or sharing electrons in their valence shell.

2. Ions

a. Anions

When an atom gains one or more electrons, it becomes a negatively charged entity called an **anion**. Most anions are nonmetallic. Their names are derived from the elemental name with an ending in the suffix, *-ide*. For example, a chlor*ide* ion (Cl^-) occurs when a chlorine atom Cl has gained one electron to achieve the octet structure of Argon, or Ar. An ox*ide* ion (O^{2-}) occurs when an oxygen atom (O) has acquired two electrons in its valence shell and has the same, stable electron configuration as Neon, or Ne.

b. Cations

A **cation** results when an atom loses one or more electrons, becoming positively charged. Most cations are metallic and have the same name as the metallic element. For example, lithium ion Li^+ has one electron fewer than lithium atom Li, having acquired the noble gas electron structure of Helium, or He.

3. Ionic Compounds

Ionic compounds are compounds formed by combining cations and anions. The attractive electrostatic forces between a cation and an anion is called an **ionic bond**.

4. Molecular Compounds

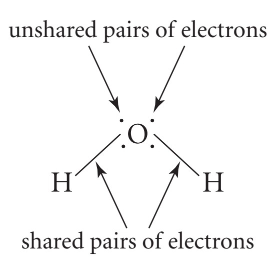
a. Covalent Bonds

A **covalent bond** is a type of bond formed when two atoms share one or more pairs of electrons to achieve an octet of electrons.

b. Lewis Structures

Lewis structures are formulas for compounds in which each atom exhibits an octet of valence electrons. These are represented as dots (or a line for every shared pair of electrons, leaving unshared pairs of electrons as dots).

H_2O:



c. Valence Shell Electron Pair Repulsion (VSEPR) Theory

The **VSEPR model** is based on electrostatic repulsion between electron pair orbitals. By pushing each other as far as possible, electron pairs dictate which geometry or shape a molecule will adopt. Molecules should be written as Lewis structures (see the electron-dot notation above).

d. Electronegativity and Dipoles

Electronegativity is the ability of an atom in a bond to attract the electron density more than the other atom(s) in the bond. Electronegativity increases from left to right and from bottom to top in the periodic table. Thus, fluorine (F) is the most electronegative element of the periodic table, with the maximum value of 4.0 in the Pauling scale of electronegativity. The Pauling scale is a range of electronegativity values based on fluorine having the highest value at 4.0. These values have no units. Metals are electropositive (with a minimum value of 0.8 for most alkali metals).

A **dipole** results in a covalent bond between two atoms of different electronegativity. Partial positive ($+\delta$) and negative charge ($-\delta$) develop at both ends of the bond, creating a dipole (i.e., two poles) oriented from the positive end to the negative end.
For example: $H^{+\delta}$–$Cl^{-\delta}$

5. Hydrogen Bonds

Hydrogen bonds are weak bonds that form between dipoles of consecutive polar molecules (intermolecular) or polar groups of macromolecules (intramolecular), such as proteins and DNA, in which they play an important structural role.

You Should Review

- polyatomic ions
- molecular structures
- structures of water molecules and of biological compounds

Questions

21. The bond between oxygen and hydrogen atoms in a water molecule is
a. a hydrogen bond.
b. a polar covalent bond.
c. a nonpolar covalent bond.
d. an ionic bond.

22. Which of the following is a nonpolar covalent bond?
- **a.** the bond between two carbons
- **b.** the bond between sodium and chloride
- **c.** the bond between two water molecules
- **d.** the bond between nitrogen and hydrogen

23. The type of bond formed between two molecules of water is a
- **a.** polar covalent bond.
- **b.** hydrogen bond.
- **c.** nonpolar covalent bond.
- **d.** peptide bond.

24. Which of the following lists contains the formulas for these ions, in the order given: ammonium, silver, bicarbonate/hydrogen carbonate, nitrate, calcium, fluoride?
- **a.** Am^-, Si^{++}, HCO_3^-, NA^+, CM^-, F^+
- **b.** AM^+, Ag^+, CO_3^{2-}, NO_3^-, Cal^+, Fl^-
- **c.** NH_4^-, Ag^+, HCO_3^-, NO_3^-, Cal^+, Fl^-
- **d.** NH_4^+, Ag^+, HCO_3^-, NO_3^-, Ca^{2+}, F^-

25. If X (atomic number 4) and Y (atomic number 17) react, the formula of the compound formed will be
- **a.** XY_2.
- **b.** YX_2.
- **c.** X_2Y_2.
- **d.** XY_4.

26. To acquire an outer octet, an atom of element 19 has to
- **a.** lose one electron (and acquire a charge of +1).
- **b.** lose two electrons (and acquire a charge of +2).
- **c.** gain one electron (and acquire a charge of –1).
- **d.** gain two electrons (and acquire a charge of –2).

27. The most common ions of the elements of group VIIA have electrical charges of
- **a.** +7.
- **b.** –7.
- **c.** +1.
- **d.** –1.

28. Which of the following is true according to the octet rule?
- **a.** Ions of all Group IIA elements have electron configurations that conform to those of the noble gases and have charges of +1.
- **b.** The reactions of the active atoms of the representative elements of the periodic table generally lead to noble gas configurations.
- **c.** An ion of a metallic element that has lost electrons to achieve noble gas configuration is less active than an atom of the same element.
- **d.** The most reactive elements are generally those whose atoms are nearest, but not equal, to noble gas configurations.

29. Electron transfer is best described as a process
- **a.** by which ionic compounds are formed from atoms of their elements.
- **b.** in which a covalent bond is made.
- **c.** that occurs between two nonmetals.
- **d.** that occurs between two metals.

30. How many electrons do the following have in their outer levels: S^{2-}, Na^+, Cl^-, Ar, Mg^{2+}, and Al^{3+}?
- **a.** three
- **b.** five
- **c.** seven
- **d.** eight

Answers

21. b. A covalent bond exists between H and O in the H_2O molecule. Since the bond is formed between two different elements, it is polar.

22. a. The bond formed is covalent. Since it is between two identical elements, it is non-polar.

23. b. Hydrogen bonds from the H of one water molecule to the O of another hold water molecules together.

24. d. The other choices give incorrect symbols for the elements or for the charge.

25. a. The electron configuration of X is $1s^22s^2$, and the electron configuration of Y is $1s^22s^22p^63s^23p^5$. X needs to give away two electrons to achieve the stable noble gas configuration of He, which is $1s^2$. Y needs to accept one electron to achieve the outer octet. Therefore, two Y are needed to accept two electrons.

26. a. The electron configuration of element 19 is $1s^22s^22p^63s^23p^64s^1$. To achieve the outer octet, it must give away one electron.

27. d. Group VIIA elements need to accept one electron to achieve the outer octet.

28. d. The alkali metals (group I) and the halogens (VIIA) have atoms that are near but not equal to noble gas configurations.

29. a. Ionic compounds are formed between a metal and a nonmetal by electron transfer.

30. d. There are eight electrons in the outer octet of these ions.

D. Chemical Equations and Stoichiometry

1. Molecular Weight

Molecular weight is the sum of the atomic weights of all the atoms in a molecular formula. It is the same as the molar mass (in grams) without the unit.

2. Moles

A **mole** of a particular substance is equal to the number of as many atoms as there are atoms in exactly 12 g of the carbon-12 atom. Experiments established that number to be $6.02214199 \times 10^{23}$ particles (Avogadro's number).

3. Chemical Equations

a. Balancing Equations

The method of **balancing equations** is called "trial and error."

- Write the correct formulas for all reactants and products.
- Compare the number of atoms on the reactant and product(s) sides.
- Rebalance and recheck if necessary.
- Always balance the heavier atoms before trying to balance lighter ones, such as H.
- Use fractions if necessary to reduce coefficients or use the smallest possible whole number.
- Verify (again!) that the number of atoms of each element is balanced.

b. Use of Moles in Chemical Equations

Stoichiometry establishes the quantities of reactants used and products obtained based on a balanced chemical equation.

$$\#\text{ moles} = \frac{\text{mass (in g)}}{\text{molar mass}} \left(\text{in } \frac{\text{g}}{\text{mol}}\right)$$

4. Percentage Yield

Percentage yield is a ratio of the actual yield of a product over the expected one, called a **theoretical yield**.

$$\%\text{ yield} = \left(\frac{\text{actual yield}}{\text{theoretical yield}}\right) \times 100\%$$

5. Basic Types of Chemical Reactions

- Combination reactions:
  $A + B \rightarrow C$
  $H_2 + \frac{1}{2}O_2 \rightarrow H_2O$
- Decomposition reactions:
  $C \rightarrow A + B$
  $CaCO_3 \rightarrow CaO + CO_2$
- Single displacement reactions:
  $A + BC \rightarrow B + AC$
  $Zn + 2HCl \rightarrow H_2 + ZnCl_2$
- Double displacement reactions:
  $AB + CD \rightarrow AC + BD$
  $HCl + NaOH \rightarrow H_2O + NaCl$

You Should Review

- balancing equations and using polyatomic ions in balancing equations

Questions

31. The molecular weight (in amu) of aluminum carbonate, $Al_2(CO_3)_3$, is
a. 55.
b. 114.
c. 234.
d. 201.

32. The formula of carbon dioxide is CO_2. Its molecular weight is 44 amu. A sample of 11 grams of CO_2 contains
a. 1.0 mole of carbon dioxide.
b. 1.5 grams of carbon.
c. 3.0 grams of carbon.
d. 6.0 grams of oxygen.

33. How many grams are contained in 0.200 mol of calcium phosphate, $Ca_3(PO_4)_2$?
a. 6.20
b. 62.0
c. 124
d. 31.0

34. The symbol 5 O_2 signifies
a. 5 atoms of oxygen.
b. 80 grams of oxygen.
c. 160 grams of oxygen.
d. 5 grams of oxygen.

35. In the reaction $CaCl_2 + Na_2CO_3 \rightarrow CaCO_3 + 2NaCl$, if 0.5 mole of NaCl is to be formed,
a. 1 mole of Na_2CO_3 is needed.
b. 0.5 mole of $CaCO_3$ is also formed.
c. 0.5 mole of Na_2CO_3 is needed.
d. 0.25 mole of $CaCl_2$ is needed.

36. In the reaction $2Cu_2S + 3O_2 \rightarrow 2Cu_2O + 2SO_2$, if 24 moles of Cu_2O are to be prepared, then how many moles of O_2 are needed?
a. 24
b. 36
c. 16
d. 27

37. Which of the following equations is balanced?
a. $2H_2O_2 \rightarrow 2H_2O + O_2$
b. $Ag + Cl_2 \rightarrow 2AgCl$
c. $KClO_3 \rightarrow KCl + O_2$
d. $Na + H_2O \rightarrow NaOH + H_2$

38. Butane (C_4H_{10}) burns with oxygen in the air according to the following equation:
$2C_4H_{10} + 13O_2 \rightarrow 8CO_2 + 10H_2O$.
In one experiment, the supply of oxygen was limited to 98.0 g. How much butane can be burned by this much oxygen?
a. 15.1 g C_4H_{10}
b. 27.3 g C_4H_{10}
c. 54.6 g C_4H_{10}
d. 30.2 g C_4H_{10}

39. What type of chemical equation is $2NH_3 \rightarrow N_2 + 3H_2$?
- **a.** combination reaction
- **b.** decomposition reaction
- **c.** single displacement reaction
- **d.** double displacement reaction

40. Which of the following equations is balanced?
- **a.** $Mg + N_2 \rightarrow Mg_3N_2$
- **b.** $Fe + O_2 \rightarrow Fe_2O_3$
- **c.** $C_{12}H_{22}O_{11} \rightarrow 12C + 11H_2O$
- **d.** $Ca + H_2O \rightarrow Ca(OH)_2 + H_2$

Answers

31. c. There are 2 atoms of Al; 3 atoms of C; and 9 atoms of O. So look at the atomic weights in the periodic table:
$2 \times Al = 2 \times 27 = 54$ amu
$3 \times C = 3 \times 12 = 36$ amu
$9 \times O = 9 \times 16 = 144$ amu
Then add them up to get the formula weight, which is 234 amu.

32. c. $11\text{ g } CO_2 \times \frac{\text{mol C}}{44\text{ g } CO_2} \times \frac{12\text{ g}}{\text{mol C}} = 3.0\text{ g}$

33. b. 1 mole of $Ca_23(PO_4)_2 = 310$ g;
$0.200\text{ mol} \times \frac{310\text{ g}}{\text{mol}} = 62\text{ g}$

34. c. $5O_2 = 5\text{ mol} \times \frac{32\text{ g}}{\text{mol}} = 160\text{ g}$

35. d. One mole of $CaCl_2$ would be needed to get 2 mol NaCl. Since 0.5 mol of NaCl, or 25% of 2 moles, is to be formed, 0.25 mol $CaCl_2$ (25% of 1 mole) is needed.

36. b. $24\text{ mol } Cu_2O \times \frac{3\text{ mol } O_2}{2\text{ mol } Cu_2O} = 36\text{ mol } O_2$

37. a. There are 4 H in the reactants and 4 H in the products, and 4 O in the reactants and 4 O in the products.

38. b. Normally 2 moles of C_4H_{10} react with 13 moles of O_2. The supply of oxygen is limited to 98 g, or 3.06 moles; $98.0\text{ g } O_2 \times \frac{\text{mol } O_2}{32.0\text{ g } O_2} \times \frac{2\text{ mol } C_4H_{10}}{13\text{ mol } O_2} \times \frac{58.0\text{ g}}{\text{mol } C_4H_{10}} = 27.3\text{ g}$

39. b. A decomposition reaction takes the form $C \rightarrow A + B$.

40. c. There are 12 C on both sides, 22 H on both sides, and 11 O on both sides.

E. Energy and the States of Matter

1. Properties of Gases

All gases behave according to the following characteristics:

- When contained in a container, they expand to assume the volume and shape of their container.
- Many gases mix evenly and completely when confined in the same container.
- Gas molecules collide with each other; they do not attract or repel each other.
- Gas molecules have higher kinetic energy at higher temperatures.

2. Pressure

Pressure is the force that is exerted over an unit area. The atmospheric pressure exerted by the Earth's atmosphere is a function on the planet and the weather conditions. It decreases with higher altitude. Some useful units of pressure are the atmosphere (atm): 1 atm = 760 mm Hg = 760 torr = 101,325 Pa (pascals).

3. Gas Laws

a. Boyle's Law (at constant temperature)

The volume of a sample of gas decreases as its pressure increases ($P \propto \frac{1}{V}$): $P_1V_1 = P_2V_2$

b. Charles's Law (at constant pressure)

The volume of a sample of gas maintained at constant pressure increases with its temperature ($V \propto T$): $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

c. Gay-Lussac's Law (at constant volume)

The pressure of any sample of gas increases (maintained at constant volume) with the temperature ($P \propto T$): $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

d. Avogadro's Law (at constant T and P)

The volume of gas increases with the number of moles of gas present at constant temperature and pressure ($V \propto n$): $\frac{V_1}{n_1} = \frac{V_2}{n_2}$

Standard temperature and pressure (STP) condition is achieved at 273 K and 1 atm (760 torr) when one mole (or 6.02 3 10^{23} particles) of any gas occupy a volume of 22.4 liters (molar volume at STP).

e. Dalton's Law of Partial Pressure

In a mixture of gases, individual gases behave independently so that the total pressure is the sum of partial pressures; $P_T = P_1 + P_2 + P_3 + \ldots$

f. Graham's Law of Gas Diffusion

Graham's law of gas diffusion is that:

$$\frac{(\text{Diffusion rate of A})^2}{(\text{Diffusion rate of B})^2} = \frac{\text{MW of B}}{\text{MW of A}}$$

g. Ideal Gas Law

An ideal gas is a gas whose pressure, volume, and temperature obey the relation, $PV = nRT$ (a combination of Boyle's, Charles's, and Avogadro's laws), R being the gas constant. The same relation can also be expressed by: $\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$

4. Liquids

A **liquid** is a fluid state of matter characterized by a definite volume but no definite shape. Liquids are also slightly compressible.

5. Solids

A **solid** is the state of matter characterized by a definite volume and shape. Solids are not compressible.

You Should Review

- properties of gases, liquids, and solids
- kinetic theory of gases
- kinetic theory and chemical reactions

Questions

41. A pressure of 740 mm Hg is the same as
a. 1 atm.
b. 0.974 atm.
c. 1.03 atm.
d. 0.740 atm.

42. What volume will 500 ml of gas initially at 25° C and 750 mm Hg occupy when conditions change to 25° C and 650 mm Hg?
a. 477 ml
b. 400 ml
c. 577 ml
d. 570 ml

43. Which law predicts that if the temperature (in Kelvin) doubles, the pressure will also double?
a. Boyle's law
b. Charles's law
c. Gay-Lussac's law
d. Dalton's law

44. Which of the following laws is related to this expression: $P_T = P_1 + P_2 + P_3$?
a. Boyle's law
b. Charles's law
c. Gay-Lussac's law
d. Dalton's law

45. Which of the following is NOT characteristic of gases?
a. They have a definite volume and shape.
b. They are low in density.
c. They are highly compressible.
d. They mix rapidly.

46. Gases that conform to the assumptions of kinetic theory are referred to as
a. kinetic gases.
b. natural gases.
c. ideal gases.
d. real gases.

47. What does the term *pressure* mean when applied to a gas?
a. weight
b. how heavy the gas is
c. mass divided by volume
d. force exerted per unit area

48. A sample of helium at 25° C occupies a volume of 725 ml at 730 mm Hg. What volume will it occupy at 25° C and 760 mm Hg?
a. 755 ml
b. 760 ml
c. 696 ml
d. 730 ml

49. A sample of nitrogen at 20° C in a volume of 875 ml has a pressure of 730 mm Hg. What will be its pressure at 20° C if the volume is changed to 955 ml?
a. 750 mm Hg
b. 658 mm Hg
c. 797 mm Hg
d. 669 mm Hg

50. A mixture consisting of 8.0 g of oxygen and 14 g of nitrogen is prepared in a container such that the total pressure is 750 mm Hg. The partial pressure of oxygen in the mixture is
a. 125 mm Hg.
b. 500 mm Hg.
c. 135 mm Hg.
d. 250 mm Hg.

Answers

41. b. 760 mm Hg is equal to 1 atmosphere; $\frac{740 \text{ mm}}{760 \text{ mm}} = 0.974$.

42. c. Since temperature is constant, use Boyle's law: $P_1V_1 = P_2V_2$. In this case $P_1 = 750$ mm; $P_2 = 650$ mm; $V_1 = 500$ ml; $V_2 = x$.
$750 \times 500 = 650x$
$375{,}000 = 650x$
$\frac{375{,}000}{650} = x$
$577 = x$

43. c. This is Gay-Lussac's law.

44. d. Dalton's law states that $P_T = P_1 + P_2 + P_3$.

45. a. Gases have low density, are highly compressible, and mix rapidly, but they do not have a definite volume and shape.

46. c. The assumptions are applied to ideal gases.

47. d. Pressure refers to the force exerted per unit area.

48. c. Use Boyle's law: $P_1V_1 = P_2V_2$.
$730 \times 725 = 760V_2$
$529{,}250 = 760V_2$
$\frac{529{,}250}{760} = V_2$
$696 \text{ ml} = V_2$

49. d. Again, use Boyle's law: $P_1V_1 = P_2V_2$.
$730 \times 875 = P_1 \times 955$
$638{,}750 = 955\ P_1$
$\frac{638{,}750}{955} = P_1$
$669 \text{ mm} = P_1$

50. d. $8.0 \text{ g } O_2 \times \frac{\text{mol } O_2}{32.0 \text{ g } O_2} = 0.25 \text{ mol } O_2$; $14 \text{ g } N_2 \times \frac{\text{mol } N_2}{28.0 \text{ g } N_2} = 0.50 \text{ mol } N_2$; $PO_2 = \frac{0.25}{0.25 + 0.50} \times 750$ mm Hg = 250 mm Hg.

F. Solutions

1. Properties

Solution is a homogeneous mixture.
Solute is a substance dissolved in a solvent.
Solvent is a medium in which a solute is dissolved.
Solvation is the process of dissolving solute molecules in a solvent.

2. Solubility

Solubility is the maximum amount of solute (in grams) that can be dissolved in a certain amount of solvent (in ml) at a particular temperature.

a. Pressure

Solubility increases with pressure for a gas immersed in a liquid. Solubility of solids and liquids does not vary significantly with pressure.

b. Temperature

Solubility of most solids and liquids increases with increasing temperature while decreasing for gases dissolved in liquids (gas molecules tend to escape).

3. Concentration of Solutions

Percent concentration expresses the concentration as a ratio of the weight (or the volume) of the solute over the weight (or the volume) of the solution. This ratio is then multiplied by 100.

$$\frac{\textit{Weight}}{\textit{volume}}\ \% = \frac{\text{grams of solute}}{\text{100 ml of solvent}}$$

$$\frac{\textit{Volume}}{\textit{volume}}\ \% = \frac{\text{volume of solute}}{\text{100 ml volume of final solution}}$$

$$\frac{\textit{Weight}}{\textit{weight}}\ \% = \frac{\text{grams of solute}}{\text{100 g of solution}}$$

4. Molarity

Molarity (M) expresses the number of moles of solute per liter of solution. A 0.1 M NaOH aqueous (water) solution has 0.1 mol of solute (NaOH) in 1 liter of water.

5. Dilution

$M_iV_i = M_fV_f$ (i = initial; f = final) established the equivalence between the initial and final concentrations. In dilution, equivalence must be achieved between the initial and final concentrations.

6. Colloids

Colloids are stable mixtures in which particles, of rather large sizes (ranging from 1 nm (nanometer) to 1 μ (micrometer) are dispersed throughout another substance. Aerosol (liquid droplets or solid particles dispersed in a gas) such as fog can scatter a beam of light. This is called the **Tyndall effect**.

7. Water

a. Properties

Water is the most abundant (and important, besides oxygen) substance on Earth. The O-H bonds are highly polar, and water forms networks of hydrogen bonds. It is found in large amounts in cells and blood. Water is an excellent solvent and has a high boiling point, high surface tension, high heat of vaporization, and low vapor pressure.

b. High Heat Capacity and High Heat of Vaporization

Heat capacity is the amount of energy required to raise the temperature of a substance by one degree Celsius. Water has high heat capacity, absorbing and releasing large amounts of heat before changing its own temperature. It thus allows the body to maintain a steady temperature even when internal and/or external conditions would increase body temperature.

Heat of vaporization is the heat required to evaporate 1 gram of a liquid. Water's large heat of vaporization (540 calories/gram) requires large amounts of heat in order to vaporize it into gas. During perspiration, water evaporates from the skin and large amounts of heat are lost.

c. Reactivity

Water is not reactive with most substances, so it can serve to transport substances in the body. It takes part in most metabolic transformations (hydrolysis and dehydration reactions).

You Should Review

- the characteristics of solutions and the properties of true solutions
- the types of solutions and how they compare
- saturated solutions
- supersaturated solutions
- dilute solutions
- concentrated solutions
- how water dissolves ionic compounds
- how water dissolves covalent compounds
- hydrates

Questions

51. In a dilute solution of sodium chloride in water, the sodium chloride is the
a. solvent.
b. solute.
c. precipitate.
d. reactant.

52. To prepare 100 ml of 0.20 M NaCl solution from stock solution of 1.00 M NaCl, you should mix
a. 20 ml of stock solution with 80 ml of water.
b. 40 ml of stock solution with 60 ml of water.
c. 20 ml of stock solution with 100 ml of water.
d. 25 ml of stock solution with 75 ml of water.

53. How many grams of NaOH would be needed to make 250 ml of 0.200 M solution? (molecular weight of NaOH = 40.0)
a. 8.00 g
b. 4.00 g
c. 2.00 g
d. 2.50 g

54. The number of moles of NaCl in 250 ml of a 0.300 M solution of NaCl is
a. 0.0750.
b. 0.150.
c. 0.250.
d. 1.15.

55. Which of the following properties of water is not dependent on the polar nature of water?
a. color
b. high boiling point
c. solvent power
d. high heat of vaporization

56. A substance has the formula $MgSO_4 \times 7H_2O$. How many grams of water are in 5.00 moles of this substance?
a. 7.00
b. 35.0
c. 126
d. 630

57. How many grams of sugar are needed to make 500 ml of a 5% (weight/volume) solution of sugar?
a. 20
b. 25
c. 50
d. 10

58. Which of the following types of bonds forms when a hydrogen atom binds to a highly electronegative atom and also partially binds to another atom?
a. coordinate covalent bond
b. hydrogen bond
c. ionic bond
d. covalent bond

59. Which of the following is NOT true of a solution?
a. Each component of a solution retains its original properties.
b. A solution is a heterogeneous mixture.
c. A solution is composed of a solute and solvent.
d. A solution involves two or more pure substances.

60. Which of the following is NOT a factor that affects solubility?
- **a.** temperature
- **b.** pressure
- **c.** particle size
- **d.** properties of the solvent

Answers

51. b. The substance being dissolved is the solute, by definition.

52. a. You need 20 ml of stock solution; you would fill the container with water to the 100 ml mark (80 ml H_2O).
$M_i \times V_i = M_f \times V_f$
$1.0\ M \times V_i = 0.2\ M \times 100\ ml$
$1.0\ V_i = 20$
$V_i = \frac{20}{1}$

53. c. $250\ ml \times \frac{0.2\ M\ NaOH}{1{,}000\ ml} = 0.05\ mol$; 0.05 moles $\times$ 40 g = 2.00 g

54. a. $250\ ml \times \frac{0.3\ M\ NaCl}{1{,}000\ ml} = 0.0750\ mol.$

55. a. The other properties listed are due to the polar nature of water.

56. d. There are 5 moles of $MgSO_4 \times 7H_2O$. There are 7 moles of water of $MgSO_4 \times 7H_2O$; $7 \times 5 = 35$ moles; $35 \times 18\ g = 630\ g$.

57. b. $5\% \frac{w}{v} = \frac{5\ g\ solute}{100\ ml\ solution}$
$\frac{5\ g}{100\ ml} = \frac{x\ (\text{solute needed})}{500\ ml\ (\text{final volume})}$
$\frac{5 \times 500}{25} = x$
$25\ g = x$

58. b. Hydrogen atoms are capable of forming a partial bond between a highly electronegative atom and another atom.

59. b. A solution is a homogeneous mixture.

60. c. Temperature, pressure, and the properties of the solvent all affect solubility.

G. Reaction Rates and Equilibrium

1. Equilibrium

Equilibrium is when two opposing reactions occur at the same rate. No change is observed in the system.

2. Activation Energy

Activation energy is the minimum amount of energy required for reactants to be transformed into products (i.e., to overcome the energy barrier between reactants and products). The higher the activation energy, the slower the reaction.

3. Endothermic vs. Exothermic Reactions

Endothermic reactions are reactions that consume energy in order to take place. Anabolic reactions are examples.

Exothermic reactions are energy-releasing reactions. Most catabolic and oxidative reactions are examples.

4. Factors Affecting the Rate of Reaction

a. Temperature

Rates of reactions increase with temperature, as more collisions between particles occur at higher temperatures.

b. Particle Size

Smaller particles react faster, as they collide often at any given temperature and concentration.

c. Concentration

A high concentration of reacting particles increases the rate of chemical reactions between them.

d. Catalysis

Catalysts speed the reaction rate by lowering the activation energy of the reaction. They are not consumed in the reaction.

5. Reversible Reactions

A double arrow ($\leftarrow \rightarrow$) designates reversible (two-way) chemical reactions. If arrows differ in length, the longer arrow indicates the major (faster) direction in which the reaction proceeds.

You Should Review

- Le Chatelier's principle and the different stresses that can be placed on chemical processes
- equilibrium constants
- energy diagrams

Questions

61. Which of the following is NOT true of reversible chemical reactions?
- **a.** A chemical reaction is never complete.
- **b.** The products of the reaction also react to reform the original reactants.
- **c.** When the reaction is finished, both reactants and products are present in equal amounts.
- **d.** The reaction can result in an equilibrium.

62. Which is an example of an exothermic change?
- **a.** sublimation
- **b.** condensation
- **c.** melting
- **d.** evaporation

63. Which is NOT an example of an endothermic change?
- **a.** melting
- **b.** sublimation
- **c.** freezing
- **d.** evaporation

64. The following reaction is exothermic: $AgNO_3$ + NaCl $\leftarrow \rightarrow$ AgCl + $NaNO_3$. How will the equilibrium be changed if the temperature is increased?
- **a.** Equilibrium will shift to the right.
- **b.** Equilibrium will shift to the left.
- **c.** The reaction will not proceed.
- **d.** Equilibrium will not change.

Answers

61. c. The fact that a reaction is complete does not mean that both reactants and products are present in equal amounts.

62. b. Condensation is an example of a reaction in which energy is given off.

63. c. Freezing does not absorb energy.

64. b. When the temperature is increased, the equilibrium shifts to the left.

H. Acids and Bases

1. Definitions

Acids are proton donors (according to Bronsted Theory) or electron acceptors (according to Lewis Theory). Strong acids are completely dissociated in water. These acids release protons (H^+) and form anionic conjugate bases (negatively charged ions). Acids have a sour taste.

Bases are proton acceptors (Bronsted) or electron donors (Lewis). When dissolved in water, strong bases such as NaOH dissociate to release hydroxide ions and sodium cation. Bases have a bitter taste and feel slippery like soap.

2. Reactions of Acids

Common reactions include:

- metal + acid $\rightarrow$ salt + hydrogen
  $Zn + 2HCl \rightarrow ZnCl_2 + H_2\uparrow$
- base + acid $\rightarrow$ salt + water
  $NaOH + HNO_3 \rightarrow NaNO_3 + H_2O$
- metal oxide + acid $\rightarrow$ salt + water
  $CaO + 2HNO_3 \rightarrow Ca(NO_3)_2 + H_2O$
- metal carbonate + acid $\rightarrow$ salt + carbonic acid (unstable)
  $NaHCO_3 + HCl \rightarrow NaCl + H_2CO_3$ ($H_2CO_3 \rightarrow H_2O + CO_2\uparrow$)

3. Autoionization of Water

In pure water, $2H_2O \leftrightarrow H_3O^+ + OH^-$.

Molar concentration of H_3O^+ = molar concentration of OH^-.

The ion product of water is Kw; $Kw = [H_3O^+] \times [OH^-] = 1 \times 10^{-14}$. Thus, in pure water: $[H_3O^+] = [OH^-] = 1 \times 10^{-7}$ moles/liter.

4. pH

pH = – log [H⁺] The **pH** measures the negative logarithm (for presentation of very small numbers in a large scale) of the hydrogen ion concentration (in moles/liter). The pH scale runs from 0 to 14 with acids in the lower end of the scale (smaller than pH 7), whereas bases are at the higher end (greater than pH 7).

5. Buffers

Buffer is a solution of a weak base and its conjugate acid (weak also) that prevents drastic changes in pH. The weak base reacts with any H^+ ions that could increase acidity, and the weak conjugate acid reacts with OH^- ions that may increase the basicity of the solution.

a. Carbonic Acid/Bicarbonate Buffer

Blood pH must be maintained at pH 7.40 by a buffer system consisting of the couple H_2CO_3 and HCO_3^-.

Neutralization of acid:
$HCO_3^- + H^+ \rightarrow H_2CO_3$

Neutralization of base:
$H_2CO_3 + NaOH \rightarrow NaHCO_3 + H_2O$

b. Phosphate Buffer

The principal buffer system inside cells in blood consists of the couple [$H_2PO_4^-$ and HPO_4^{-2}.]

Neutralization of acid:
$HPO_4^{-2} + H^+ \rightarrow H_2PO_4^-$

Neutralization of base:
$H_2PO_4^- + OH^- \rightarrow HPO_4^{-2} + H_2O$

6. Titration

a. Equivalent

Equivalent is the gram equivalent weight of any base is the amount in grams that can be neutralized by 1 mole of H^+ ions.

The gram equivalent weight of any acid is the amount in grams that can be neutralized by 1 mole of OH^- ions.

b. Normality (N)

Normality is the number of equivalents of the solute per liter of solution. 1N solution of acid (or base) contains 1 equivalent of an acid (or base) per liter of solution.

You Should Review

- monoprotic, diprotic, and triprotic acids
- organic and inorganic acids
- Arrhenius acids and bases
- Bronsted-Lowry acids and bases
- reactions of acids
- activity series of metals
- solubilities of salts
- ionic equations
- buffer systems in the body
- metabolic acidosis and alkalosis
- respiratory acidosis and alkalosis

Questions

65. What is the formula of sulfuric acid?

a. HNO_3
b. H_2SO_4
c. HCl
d. H_2CO_3

66. What is the formula of the hydronium ion?
a. H^+
b. NH_4^+
c. H_3O^+
d. H_2O^+

67. The pH of a blood sample is 7.40 at room temperature. The pOH is therefore
a. 6.60.
b. 7.40.
c. 6×10^{-6}.
d. 4×10^{-7}.

68. As the concentration of hydrogen ions in a solution decreases,
a. the pH numerically decreases.
b. the pH numerically increases.
c. the product of the concentrations $[H^+] \times [OH^-]$ comes closer to 1×10^{-14}.
d. the solution becomes more acidic.

69. The pH of an alkaline solution is
a. 14.
b. less than 7.
c. more than 14.
d. more than 7.

70. A base is a substance that dissociates in water into one or more ________ ions and one or more ________.
a. hydrogen . . . anions
b. hydrogen . . . cations
c. hydroxide . . . anions
d. hydroxide . . . cations

71. An acid is a substance that dissociates in water into one or more ________ ions and one or more ________.
a. hydrogen . . . anions
b. hydrogen . . . cations
c. hydroxide . . . anions
d. hydroxide . . . cations

72. A pH of 4 denotes ________ times fewer ________ than a pH of 3.
a. 10 . . . hydrogen ions
b. 4 . . . hydrogen ions
c. 10 . . . water molecules
d. 20 . . . hydroxide ions

73. Which of the following is considered to be neutral on the pH scale?
a. pure water
b. pure saliva
c. pure blood
d. pure urine

74. A substance that functions to prevent rapid, drastic changes in the pH of a body fluid by changing strong acids and bases into weak acids and bases is called a(n)
a. salt.
b. buffer.
c. enzyme.
d. coenzyme.

75. Complete the following equation: $NaHCO_3 + HCl \rightarrow NaCl +$
a. HCO_3.
b. H_2CO_3.
c. HCl.
d. H_2PO_4.

Answers

65. b. The formula is H_2SO_4.
66. c. The formula is H_3O^+.
67. a. The ion product contrast of H_2O is 1×10^{-14}; $[H^+]\ [OH^-] = \frac{1 \times 10^{-14}}{1 \times 10^{-7.40}} = 1 \times 10^{-6.60}$; pOH = 6.60
or
pH + pOH = 14.00
pOH = 14.00 – 7.40 = 6.60
68. b. As the concentration of hydrogen ions decreases, the pH increases.

69. d. On the pH scale, 1–7 is acidic, 7 is neutral, and 7–14 is alkaline.

70. d. By definition, when a base dissociates in water, it produces one or more OH^- and one or more cations.

71. a. By definition, when an acid dissociates in water, it produces one or more H^+ and one or more anions.

72. a. An increase of one pH unit is a tenfold decrease in hydrogen ions.

73. a. The pH of pure H_2O is 7. $[H^+] = [OH^-]$

74. b. This is the definition of a buffer.

75. b. Metal bicarbonate + an acid ➔ salt + carbonic acid.

I. Oxidation-Reduction

1. Oxidation State

Oxidation state (or **oxidation number**) is the number of charges carried by an ion in an atom, or the number of charges that an atom would have in a [neutral] molecule if electrons were transferred completely. Oxidation numbers enable the identification of oxidized (increase in oxidation number) and reduced (reduction in oxidation number) elements.

The sum of the oxidation numbers of all atoms in the formula of a neutral compound is zero (or equal to the charge on the ion for a polyatomic ion).

2. Oxidation-Reduction (Redox) Reactions

Oxidation corresponds to a loss of electrons.

Reduction corresponds to a gain of electrons.

Redox (reduction-oxidation) reaction involves an electron transfer between the oxidizing (oxidizes another by accepting its electrons) and the reducing (reduces another by donating electrons) agents.

Example:

$$Na \rightarrow Na^+ + e^-$$

Oxidation Number: 0 +1 –1 (Na is oxidized to Na^+)

Example:

$$Cl + e^- \rightarrow Cl^-$$

Oxidation Number: 0 –1 –1 (Cl is reduced to Cl^-)

Sum: $Na + Cl \rightarrow Na^+ + Cl^-$

You Should Review

- redox reactions: cellular respiration, combustion, rusting
- oxidizing agents
- reducing agents

Questions

76. The number of electrons lost during oxidation must always equal the
a. charge of the ion.
b. total change in oxidation number.
c. number of electrons gained in the reduction.
d. number of electrons gained by the reducing agent.

77. What is the oxidation number for nitrogen in HNO_3?
a. –2
b. +5
c. –1
d. –5

Answers

76. c. The number of electrons lost during oxidation must always equal the number of electrons gained in the reduction.

77. b. $H = +1; O_3 = 3 \times -2 = -6$
$+1 + N - 6 = 0$
$N = +5$

J. Nuclear Chemistry

1. Characteristics of Radioactivity

Radioactivity is the process by which unstable nuclei breakdown spontaneously, emitting particles and/or electromagnetic radiation (i.e., energy) also called **nuclear radiation.**

Heavy elements (from atomic numbers 83 to 92) are naturally radioactive and many more (the transuranium elements: atomic number 93 to 118) have been generated in laboratories.

2. Alpha Emission

An **alpha particle** (symbol: $_2He^4$ or $_2\alpha^4$) corresponds to the nucleus of a helium atom (having two protons and two neutrons) that is spontaneously emitted by a nuclear breakdown or decay.

α-particles are of low energy and therefore low penetrating (a lab coat is sufficient to block their penetration), but dangerous if inhaled or ingested.

3. Beta Emission

A **beta particle** (symbol: $_{-1}e^0$ or $_{-}\beta^0$) is an electron released with high speed by a radioactive nucleus in which neutrons (in excess) are converted into protons and electrons (β-particles). β-particles are medium-penetrating radiation requiring dense material and several layers of clothing to block their penetration. They are dangerous if inhaled or ingested.

4. Gamma Emission

Gamma rays (symbol: γ) are a massless and chargeless form of radiation (pure energy). They are the most-penetrating form of radiation, similar to X rays, and can only be stopped by barriers of heavy materials such as concrete or lead. They are extremely dangerous and can cause damage to the human body.

5. Transmutation

Nuclear **transmutation** is another type of radioactivity occurring when nuclei are bombarded by other particles (protons or neutrons) or nuclei. By this process, lighter elements can be enriched and thus converted to heavier ones or vice versa with emission of alpha or beta particles and gamma rays.

During nuclear reaction, there is

1. conservation of mass number
2. conservation of atomic number

6. Half-Life

Half-life (symbol: $t_{\frac{1}{2}}$) is the time required for the concentration of the nuclei in a given sample to decrease to half of its initial concentration. Half-life is specific to a radioactive element and varies widely (from a fraction of a second for Tc-43 to millions of years for U-238).

7. Nuclear Fusion

Nuclear fusion is the process in which small nuclei are combined (fused) into larger, more stable ones with the release of a large amount of energy. Fusion reactions take place at very high temperatures. They are also known as thermonuclear reactions. Examples are our Sun and H-bombs.

8. Nuclear Fission

Nuclear fission is the process in which a heavier, usually less stable, nucleus splits into smaller nuclei and neutrons. The process releases a large amount of energy and neutrons that can set up a **chain reaction** (or self-sustaining nuclear fission reaction) with a more and more uncontrollable release of energy (a highly exothermic reaction) and neutrons.

9. Radioactive Isotopes

Radioactive isotope (radioisotope) is an unstable isotope of an element that decays into a more stable isotope of the same element. They are of great use in medicine as tracers in the body to help monitor particular atoms in chemical and biological reactions. In this way, they aid with diagnosis and treatment. Doctors use Iodine (-131 and -123) and Technetium-99 because of their short half-lives. A short half-life means a radioisotope decays into a stable (nonradioactive) substance in a relatively short time.

You Should Review

- nuclear reactions
- writing balanced nuclear equations
- radiocarbon dating
- the principles of nuclear power
- the use of radioisotopes and their detection in nuclear medicine
- the dangers of ionizing radiation
- radiation sickness/biological effects of radiation
- units of radiation measurement

Questions

78. The time required for $\frac{1}{2}$ of the atoms in a sample of a radioactive element to disintegrate is known as the element's
a. decay period.
b. life time.
c. radioactive period.
d. half-life.

79. The least penetrating radiation given off by a radioactive substance consists of
a. alpha particles.
b. beta particles.
c. gamma rays.
d. X rays.

80. The half-life of a given element is 70 years. How long will it take 5.0 g of this element to be reduced to 1.25 g?
a. 70 years
b. 140 years
c. 210 years
d. 35 years

81. If element A below gives off an alpha particle, what is the atomic number and mass of the resulting element B? $^{210}A_{83}$
a. $B^{210}{}_{81}$
b. $B^{206}{}_{81}$
c. $B^{206}{}_{83}$
d. $B^{204}{}_{81}$

82. If element B below gives off a beta particle and gamma rays, what is the resulting element?
$B^{238}{}_{92}$
a. $B^{238}{}_{93}$
b. $B^{234}{}_{90}$
c. $B^{239}{}_{92}$
d. $B^{239}{}_{91}$

83. What is the missing product?
$X^{42}{}_{17} \rightarrow Y^{42}{}_{18} + ?$
a. $He^{4}{}_{2}$
b. γ
c. $e^{0}{}_{1}$
d. $\beta^{0}{}_{-1}$

84. What is the missing product?
$A^{60}{}_{24} \rightarrow B^{60}{}_{24} + ?$
a. $He^{4}{}_{2}$
b. γ
c. $e^{0}{}_{-1}$
d. $\beta^{0}{}_{1}$

Answers

78. d. The question gives the definition of half-life.

79. a. Alpha particles give off the least penetrating radiation.

80. b. In 70 years, there will be $\frac{1}{2} \times 5.0 = 2.5$ g. In 70 more years (140 total), there will be $\frac{1}{2} \times 2.5 = 1.25$ g.

81. b. Giving off an alpha particle is equivalent to giving off a helium nucleus.
$A^{210}{}_{83} - He^{4}{}_{2} = B^{206}{}_{81}$

82. a. When a beta particle is given off, the nucleus has the same mass number, but the atomic number is greater by one since a neutron is converted to a proton and an electron.

83. d. A beta particle allows the mass to remain the same and increases the atomic number by 1.

84. b. Gamma rays are not particles and therefore do not change the atomic number or atomic mass.

K. Organic Compounds

1. Definition

Organic compounds are compounds made of carbon and hydrogen (hydrocarbon) and heteroatoms such as oxygen, nitrogen, the halogens, phosphorus, sulfur, and others.

2. Stereoisomers

Stereoisomers are two molecules having the same molecular formula and structure but different spatial orientation with respect to the median axis or plane of the molecule. Their three-dimensional shapes are, therefore, very different.

3. Carbohydrates

a. Function

Carbohydrates (or sugars) serve as the main source of energy for living organisms. They are made of one, two, or more rings of carbon, hydrogen, and oxygen. The names of carbohydrates end with the suffix, *-ose* (for example, glucose and fructose).

b. Monosaccharides

Monosaccharides are the simplest carbohydrate structures made of one ring that can contain five C atoms, called a **pentose**, or six C atoms, called a **hexose**. An example of a pentose is ribose which is a constituent of RNA. One example of a hexose is galactose, that is derived from milk-sugar lactose.

c. Disaccharides

Disaccharides are dimeric sugars made of two monosaccharides joined together in a reaction that releases a molecule of water (dehydration). The bond between the two sugar molecules is called glycosidic linkage and can have either an axial (β-glycoside) or an equatorial (α-glycoside) orientation with respect to the ring conformation.

Examples:

Maltose is two glucose molecules joined together, found in starch.

Lactose is one galactose joined to one glucose, found in milk.

Sucrose is one fructose joined to one glucose, found in table sugar.

d. Polysaccharides

Polysaccharides are polymers or a long chain of repeating monosaccharide units.

- **Starch** is a mixture of two kinds of polymers of α glucose (linear amylose and amylopectin). Amylose contains glucose molecules joined together by α-glycosidic linkages while amylopectin has an addition of branching at C-6. They are storage polysaccharides in plants.
- **Glycogen** consists of glucose molecules linked by α-glycosidic linkage (C-1 and C-4) and branched (C-6) by α-glycosidic linkage. Glycogen is the storage form of glucose in animals (in liver and skeletal muscle).

- **Cellulose** consists of glucose molecules joined together by β-glycosidic linkage. Cellulose is found in plants and is not digested by humans (since they lack the necessary enzyme).

e. Condensation and Hydrolysis

Condensation is the process of bonding together separate monosaccharide subunits into a disaccharide and/or a polysaccharide. It is also called **dehydration synthesis**, as one molecule of water is lost in the process. It is carried out by specific enzymes.

Hydrolysis is the reverse process of condensation as a water molecule and specific enzymes break all the glycosidic linkages in disaccharides and polysaccharides into their constituting monosaccharides.

4. Lipids

a. Function

Lipids are a diverse group of compounds that are insoluble in water and polar solvents but soluble in nonpolar solvents. Lipids are stored in the body as a source of energy (twice the energy provided by equal amounts of carbohydrates).

b. Triglycerides

Triglycerides are lipids formed by condensation of glycerol (one molecule) with fatty acids (three molecules). They can be saturated (from fatty acid containing only C-C single bonds) or unsaturated (presence of one or more C=C double bonds). Triglycerides are found in the adipose cells of the body (neutral fat) and are metabolized by the enzyme lipase (an esterase) during hydrolysis, producing fatty acids and glycerol.

c. Ketone Bodies

There are three **ketone bodies** formed during the breakdown (metabolism) of fats: acetoacetate, β-hydroxybutyrate, and acetone. They are produced to meet the energy requirements of other tissues. Fatty acids—produced by hydrolysis of triglycerides—are converted to ketone bodies in the liver. They are removed by the kidneys (**ketosuria**), but if they are found in excess in the blood (**ketonemia**), ketone bodies can cause a decrease of the blood pH and **ketoacidosis** may result. In **ketouria**, acetone is exhaled via the lungs. The whole process is called **ketosis**. Ketosuria and ketonemia are common in patients with diabetes mellitus and cases of prolonged starvation.

d. Phospholipids

Phospholipids are lipids containing a phosphate group. They are the main constituents of cellular membranes.

e. Steroids

Steroids are organic compounds characterized by a core structure known as **gonane** (three cyclohexane—six carbon rings and one cyclopentane—or five C rings fused together). Steroids differ by the functional groups attached to the gonane core. Cholesterol is an example of a steroid and is a precursor for the steroid hormones such as the sex hormones (androgens and estrogens) and the corticosteroids (hormones of the adrenal cortex).

5. Proteins

a. Functions

Every organism contains thousands of different proteins with a variety of functions: structure (collagen, histones), transport (hemoglobin, serum albumin), defense (antibodies, fibrinogen for blood coagulation), control and regulation (insulin), catalysis (enzymes), and storage.

b. Structure

Proteins (also called polypeptides) are long chains of amino acids joined together by covalent bonds of the same type (peptide or amide bonds). There are 20 naturally occurring amino acids, each characterized by an amino group at one end and a carboxylic acid group at the other end. Different proteins have different numbers and kinds of additional functional groups.

The sequence of amino acids in the long chain defines the **primary structure** of a protein.

A **secondary structure** is determined when several residues, linked by hydrogen bonds, conform to a given combination (for example, the α-helix or β-turns).

Tertiary structure refers to the three-dimensionally folded conformation of a protein. This is the biologically active conformation (crystal structure).

A **quaternary structure** can result when two or more individual proteins assemble into two or more polypeptide chains.

Conjugated proteins are complexes of proteins with other biomolecules (for example, glycoproteins, also called sugar proteins).

c. Enzymes

Enzymes are biological catalysts whose role is to increase the rate of chemical (metabolic) reactions without being consumed in the reaction. They do so by lowering the activation energy of a reaction by binding specifically (in the active site) to their substrates in a "lock and key" or "induced-fit" mechanism. They do not change the nature of the reaction (in fact, any change is associated with a malfunctioning enzyme, the onset of a disease) or its outcome. (See below.)

Enzyme activity is influenced by:

- temperature; proteins can be destroyed at high temperatures and their action is slowed at low temperature.
- pH; enzymes are active in a certain range of the pH.
- concentration of cofactors and coenzymes (vitamins)
- concentration of enzymes and substrates
- feedback reactions

Enzyme names are derived from their substrate names with the addition of the suffix, *-ase*. An example is *sucrase* (substrate is sucrose). There are categories of enzymes according to the reactions they catalyze (for example, the kinases, or phosphorylation).

Enzymes are often found in multienzyme systems that operate by simple negative feedback.

enzyme 1	enzyme 2	enzyme 3	enzyme 4
A ↔ B	B ↔ C	C ↔ D	D ↔ E_1
			→ E_2
			enzyme 5

d. Protein Denaturation

Protein denaturation occurs when the protein configuration is changed by the destruction of the secondary and tertiary structures (reduced to the primary structure). Common denaturing agents are alcohol, heat, and heavy metal salts.

You Should Review

- stereoisomers
- the structure of monosaccharides and hemiacetals
- the structure of disaccharides and acetals, glycosides
- reducing sugars
- stereoisomers and enzymes in carbohydrate metabolism
- digestion and synthesis of carbohydrates
- ketoacidosis, ketonemia, acetone breath, chemical structures of ketone bodies, gluconeogenesis
- functions of proteins
- protein synthesis and amino acid structures
- organic functional groups in proteins
- enzyme-catalyzed reactions
- vitamins, metal ion activators
- enzyme nomenclature
- multienzyme systems, simple negative feedback

E	+	S	→	ES	→	E	+	P
enzyme		*substrate*		*enzyme-substrate complex*		*enzyme*		*product*

Questions

85. The elements found in carbohydrates are
- **a.** oxygen, carbon, and hydrogen.
- **b.** zinc, hydrogen, and iron.
- **c.** carbon, iron, and oxygen.
- **d.** hydrogen, iron, and carbon.

86. Steroids are classified as
- **a.** carbohydrates.
- **b.** nucleic acids.
- **c.** lipids.
- **d.** proteins.

87. The primary function of food carbohydrates in the body is to
- **a.** provide for the storage of glycogen in cells.
- **b.** maintain the constancy of the blood sugar.
- **c.** maintain energy production within the cells.
- **d.** contribute to the structure of the cells.

88. A high level of ketone bodies in urine indicates marked increase in the metabolism of
- **a.** carbohydrates.
- **b.** fats.
- **c.** proteins.
- **d.** nucleic acids.

89. Which polysaccharide is a branched polymer of α-glucose found in the liver and muscle cells?
- **a.** amylase
- **b.** cellulose
- **c.** glycogen
- **d.** amylopectin

90. An enzyme that catalyzes the hydrolysis of a triglyceride (fat) is
- **a.** a catalose.
- **b.** an esterase.
- **c.** an amidose.
- **d.** lactose.

91. The site on an enzyme molecule that does the catalytic work is called the
- **a.** binding site.
- **b.** allosteric site.
- **c.** lock.
- **d.** active site.

92. In the multienzyme sequence shown below, molecules of E are able to fit to the enzyme E_1 and prevent the conversion of A to B. What is this action of E called?

$$A \xrightarrow{E_1} B \xrightarrow{E_2} C \xrightarrow{E_3} D \xrightarrow{E_4} E$$

- **a.** effector inhibition
- **b.** allosteric inhibition
- **c.** feedback inhibition
- **d.** competitive inhibition by nonproduct

93. The carbohydrate sucrose is broken down by the enzyme sucrase into
- **a.** glucose and fructose.
- **b.** galactose and glucose.
- **c.** two glucose molecules.
- **d.** glucose and zylose.

94. The bonds between amino acids in a polypeptide are
- **a.** glycosidic bonds.
- **b.** ester bonds.
- **c.** peptide bonds.
- **d.** hydrogen bonds.

Answers

85. a. By definition, carbohydrates are made of oxygen, carbon, and hydrogen.

86. c. Steroids are a subcategory of lipids.

87. c. Glucose, the monosaccharide, is the primary energy source in the body.

88. b. Ketone bodies are formed from free fatty acids.

89. c. Glycogen is a branched polymer of α-glucose, which is found stored in limited amounts in the liver and muscle cells.

90. **b.** A fat is formed from one molecule of glycerol and three fatty acids, which are combined by three ester bonds. To break these bonds, an esterase is needed.
91. **d.** The active site is where the substrate is broken down.
92. **c.** E stops E_1 from converting A to B.
93. **a.** The disaccharide sucrose is broken down into glucose and fructose by sucrase.
94. **c.** Peptide bonds are formed between adjacent amino acids in a polypeptide chain.

III. Other Concepts You Should Be Familiar With

A. The Scientific Method

1. General

The scientific method is based upon **observations** that lead to the formulation of a **hypothesis** in an attempt to make a comprehensive guess. Only **experiments** (reproducible ones) will confirm the hypothesis and develop into a **theory** supported by all the facts.

2. The Science of Chemistry

Chemistry is the study of the structures, properties, and transformation of atoms and molecules.

B. Metric System

Metric system is the standard system for recording measurements. It is a decimal system (the basic unit and its subunits are separated by increasing and decreasing powers of ten). Some of the basic units of measurement are:

- Length: meter (m)
- Volume: liter (l)
- Mass: kilogram (kg)
- Time: the second (s)
- Temperature: Kelvin (° K)
- Amount of substance: mole (mol)

C. Unit Conversion: The Factor Label Method

Conversion factor establishes a relationship of equivalence in measurement between two different units. It is expressed as a fraction. For instance, for 1 kg = 2.2 lb., the conversion factor is: $\frac{1\text{ kg}}{2.2\text{ lbs.}}$ or $\frac{2.2\text{ lbs.}}{1\text{ kg}}$.

Example:
Convert 50 cm to m:

Since 100 cm = 1 m, the conversion factor is

$\frac{1\text{ m}}{100\text{ cm}}$ or $\frac{100\text{ cm}}{1\text{ m}}$

So, 50 cm $\times$ ($\frac{1\text{m}}{100\text{ cm}}$) = 0.50 m

Example:
How many grams are in 0.45 lbs.? (1 lb. = 453.6 g)
Conversion factor: $\frac{1\text{ lb.}}{453.6\text{ g}}$ or $\frac{453.6\text{ g}}{1\text{ lb.}}$
Since we need an answer in grams, we will use the conversion factor that has the grams in the numerator.
So, 0.45 lb. $\times$ ($\frac{453.6\text{ g}}{1\text{ lb.}}$) = 204.1 g.

D. Significant Figures

The number of significant figures in any physical quantity or measurement is the number of digits known precisely to be accurate. The last digit to the right is inaccurate. The rules for counting significant figures are the following:

- Zeros sandwiched between nonzero digits are significant figures. For example, both 400.005 and 400,005 have six significant figures.
- Zeros that locate the decimal place (place holder) on the left are not significant. For example, 0.045 ml, 0.0045 ml, and 0.00045 ml each have two significant figures.
- Trailing zeros to the right of the decimal point are significant if the number is greater than 1. For example, 4.56000 has six significant figures.

- For numbers smaller than 1, only zeros to the right of the first significant digit are significant. For example, 0.020 has two significant figures.
- Trailing zeros are not significant in a non-decimal number. For example, 5,500 has two significant figures.

E. Error, Accuracy, Precision, and Uncertainty

Error is the difference between a value obtained experimentally and the standard value accepted by the scientific community.

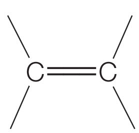
Accuracy establishes how close in agreement a measurement is with the accepted value.

Precision of a measurement is the degree to which successive measurements agree with each other (average deviation is minimized).

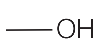
Uncertainty expresses the doubt associated with the accuracy of any single measurement.

F. Functional Groups in Organic Chemistry

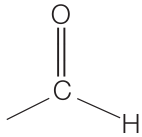
1. Alkene



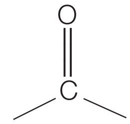
2. Alcohol



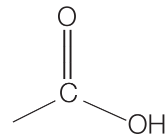
3. Aldehyde



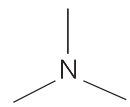
4. Ketone



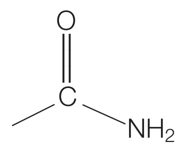
5. Carboxylic Acid



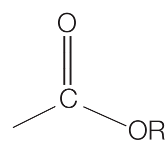
6. Amine



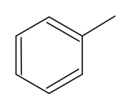
7. Amide



8. Ester

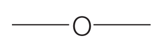


9. Aromatic

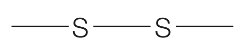


10. Alkyne

11. Ether



12. Disulfide



IV. Suggested Sources for Further Study

Study Guides

Klein, David R. *Organic Chemistry as a Second Language*. (New York: John Wiley & Sons, 2004).

Varma-Nelson, Pratibha and Mark S. Cracolice. *Peer-Led Team Learning General, Organic, and Biological Chemistry*. (New York: Prentice Hall, 2001).

Textbooks

Chang, Raymond. *General Chemistry: The Essential Concepts,* 3rd Edition. (New York: McGraw-Hill, 2003).

Kotz, John C., and Paul M. Treichel. *Chemistry and Chemical Reactivity,* 5th edition. (Pacific Grove, CA: Brooks/Cole, 2003).

Timberlake, Karen C. *General, Organic, and Biological Chemistry: Structures of Life,* Platinum Edition. (Redwood City, CA: Benjamin-Cummings, 2004).

Wade, Leroy G. Jr. *Organic Chemistry, Fifth Edition* (New York: Prentice Hall, 2003).

CD-ROM

Francis A. Carey's Digital Content Manager, *Organic Chemistry* 5th Edition. (New York: McGraw-Hill, 2003).

CHAPTER

9 General Science Review

CHAPTER SUMMARY

This chapter highlights the core concepts that you need to know for the general science section of most health occupations entrance exams—essential topics such as the scientific method, formation of the universe, evolution, and biodiversity. Use this chapter as a study aid to review important concepts and test yourself with sample questions.

▶ General Science Review: Important Concepts

I. General Introduction

A. Description of How Health Occupations Entrance Exams Test General Science

Health occupations entrance exams do not measure scientific knowledge in the same way. The natural sciences section of the Health Occupations Aptitude Exam (HOAE), made up of approximately 65 multiple-choice questions, tests your knowledge of general science. Other entrance exams, like the Health Occupations Basic Entrance Test (HOBET), require only that you can read and understand college-level scientific material. It does not have a separate science test section.

The following subject areas are important for you to know for your exam: history and methods of science, the cosmos, basics of matter, evolution and life, earth works, biodiversity, ecology, and global environmental challenges.

B. How to Use This Chapter

This chapter covers all the subject areas listed above. Use the information about core topics and the practice questions in this chapter to guide you as you prepare for your exam, but remember that this chapter should not be your only resource. Review scientific concepts more comprehensively in the suggested materials listed at the end of this chapter or in your own textbooks.

After you read each subject heading in this chapter, answer the practice questions that follow. These questions are designed to reflect the type of questions you will find on your health occupations entrance exam. Once you have answered the sample questions, you can target the content areas where you need the most review.

Plan your study time effectively so that you have enough preparation for the test. Familiarizing yourself with real test questions and brushing up on important natural science topics in a good college-level textbook will build your confidence and lessen your test anxiety.

II. Main Topics

A. History and Methods of Science

Everywhere you look, science is evident in our present world, from the technology of medicine to our understanding of how stars are made. Here you have an overview of what science is and how it works.

1. Giants of Science

How did science begin? Who were the early discoverers of this way of exploring nature? It is important to look back and review some of the giants.

a. Ancient Greeks

(Some dates are approximate.)

Thales (624–546 BCE), called the "father of philosophy" said the universe was ultimately made of water (one of the three ancient Greek elements of water, fire, earth, and air).

Pythagorus (560–480 BCE) discovered the mathematics of musical harmony and the properties of right triangles (triangles with one 90–degree angle in them).

Hippocrates (460–370 BCE) was called the "father of medicine."

Plato (427–347 BCE) was a major philosopher who wrote the dialogues of Socrates, championing logical thinking.

Aristotle (384–322 BCE) was a student of Plato and tutor of Alexander the Great. He wrote volumes on the knowledge of everything, from plants to the heavens and politics.

Euclid (325–270 BCE) created major work in geometry.

Archimedes (287–212 BCE) was famous for running down the street naked after discovering the law of buoyancy and density during a bath, which allowed a king to verify the amount of gold in a crown. He accomplished major work in geometry and was first to calculate the surface area and volume of a sphere.

b. Originators of Modern Science

Nicholas Copernicus (1473–1543), Polish. His book showed that the motions of Sun, Moon, and planets in the sky could be explained by assuming that the planets go around the Sun and that the Earth is a planet as well. The book had so much influence that we still talk about the "Copernican Revolution."

Francis Bacon (1561–1626), English. He wrote early books on how to do science, emphasizing experiment and inductive reasoning (to make generalizations).

Galileo Galilei (1564–1642), Italian. Galileo studied the swing of a pendulum, found that bodies of different masses fall at the same rate, and distinguished acceleration from velocity. He first saw the moons of Jupiter and craters on the Earth's Moon.

Johann Kepler (1571–1630), German. Kepler described the laws of planetary motion and declared that the paths of planets around the Sun are ellipses, not circles.

René Descartes (1596–1650), French. This father of modern philosophy invented coordinate geometry (the *x–y* axis) and said "I think therefore I am."

Robert Hooke (1635–1703), English. Hooke published the book, *Micrographia*, with detailed drawings of life under a microscope. He named the little units he saw in cork "cells," which became the general word used in biology.

Anton von Leeuwenhoek (1632–1723), Dutch. He perfected the microscope and made many discoveries, such as human sperm cells.

Sir Isaac Newton (1643–1727), English. Newton discovered the law of gravity, discovered how a prism splits light into colors, invented the calculus, and set forth the laws of motion (such as "every action has an equal and opposite reaction").

Pierre Simon Laplace (1749–1827), French. Laplace applied math to the solar system in a new level of detail and correctly surmised that the solar system was formed by condensation from a gas nebula.

c. Science Goes Full Tilt

James Hutton (1726–1797), Scottish. This "father of geology" realized the antiquity of Earth.

John Dalton (1766–1844), English. Dalton was a chemist whose theory of atoms explained why elements combined into molecules in constant proportions.

Sir Charles Lyell (1797–1875), Scottish. This geologist championed "uniformitarianism," the idea that small constant changes over time created the Earth today.

Baron von Humboldt (1769–1850), German. Baron von Humboldt was a geologist and world traveler. The "Humbolt Current" off South America is named after him.

Matthias Jacob Schleiden (1804–1881), German. Schleiden contributed the cell theory for plants that says that all plants are made of cells.

Charles Darwin (1809–1882), English. Darwin's book, *The Origin of Species by Means of Natural Selection,* started a new field of science, evolutionary biology. He traveled extensively in South America and discovered many new species both modern and extinct.

Theodor Schwann (1810–1882), German. Schwann contributed the cell theory for animals that says that all animals are made of cells and coined the term "metabolism."

Gregor Mendel (1822–1884), Austrian. Mendel studied the heredity of pea plants, which led to genetics.

Louis Pasteur (1822–1895), French. Pasteur invented biochemistry, discovered right-handed and left-handed crystals, worked with yeast and proved that life only came from other life, and developed the germ theory of disease.

Thomas Huxley (1825–1895), English. Huxley championed the theory of evolution for technical and popular audiences, and became known as Darwin's "bulldog."

Lord Kelvin (1824–1907), Scottish. Kelvin made new calculations on heat, and analyzed the history of the Earth.

James Clerk Maxwell (1831–1870), Scottish. Maxwell developed mathematical laws of electromagnetism, now known as "Maxwell's equations."

Dmitri Mendeleyev (1834–1907), Russian. Mendeleyev discovered the arrangement of elements in repeating sequences of properties, and thereby created the first periodical table of chemistry. He predicted new elements, which were, in fact, found.

Ernst Mach (1838–1916), Austrian. Mach was a physicist honored by our use of the name "Mach 1" for the speed of sound, "Mach 2" for twice the speed of sound, and so forth.

Sigmund Freud (1856–1939), Austrian. Freud developed a theory of dreams and the unconscious.

d. The Last 100 Years

Albert Einstein (1879–1955), German-Swiss. Einstein computed the size of atoms. He developed the special and general theories of relativity, for light and gravity, respectively. He also described the concept of four-dimensional space-time and made famous the equation $E = mc^2$.

Alfred Wegener (1880–1930), German. Wegener proposed that all continents were once a single large one and had drifted apart in a "continental drift."

Niels Bohr (1885–1962), Danish. He described the "Bohr" model of the atom, in which electrons rotate around a nucleus like planets around the Sun.

Werner Heisenberg (1901–1976), German. Heisenberg developed the uncertainty principle of quantum physics.

Erwin Schrödinger (1887–1961), Austrian. Schrödinger developed wave mechanics to explain the structure of atoms.

Francis Crick (1916–2004), English. Crick was codiscoverer of the double helix structure of DNA.

James Watson (1928–), American. Watson was also codiscoverer of the double helix structure of DNA, and a leader in the recent Human Genome Project.

2. Methods

What makes science special among ways of knowing are its specific methods that uncover the truths of nature, in ways that can be repeated by anyone. For example, after Galileo saw the moons of Jupiter, anyone could look at Jupiter through a telescope and see them. Science does not accept any revelations said to be available only to visionary individuals.

a. Scientific Method

Occam's razor: named after a fourteenth-century English scholar, this concept holds that one should aim for the simplest possible explanations of phenomena.

Experiment: The practice of science focuses on experiments, which have certain steps. First, formulate the idea for an experiment, something to be tested. Second, conduct the experiment. This consists of, at minimum, two parts: the formal **experiment** and the **control** (note that the word experiment is used both for the larger system of the two parts and for one of the parts itself). The experiment varies a crucial aspect of the system under study. In the control, that aspect is left constant.

Example: Louis Pasteur took two flasks of sterilized meat broth and configured their long necks so air could go into both. But for one (the experiment), dust normally in the air was blocked. In the other (the control), the dust along with the air could get in (as would usually be the situation, note the baseline is the control).

Analysis: The next step is to analyze the experiment, which involves recording observations and calculations. In Pasteur's experiment, he observed that the meat broth spoiled in the control flask open to both air and dust but not in the other experiment flask where dust was excluded. Experiments consist of independent variables, which are usually consciously varied by the experimenter (in Pasteur's case, the presence or absence of dust). Experiments also have the dependent variable, which, in our example, is state of the broth, which is affected by (and therefore is dependent upon) the independent variables. Often, experiments are not a simple two-part system, but include some variable that is shifted across a range of values, to be compared to the control.

Predictions: Use the results to make predictions for additional testing. If you were Pasteur, for example, you might predict that using a different kind of meat broth would give the same results, thus confirming the original experiment. More remarkably, you might predict the existence of small, invisible organisms in the dust of air as the cause of the spoiling of the meat broth (microbes in air were in fact discovered). Einstein used his theory of general relativity to predict that starlight would bend as it passed close to the gravitational field of the Sun, which was then observed during a solar eclipse.

Hypothesis and theory: These words are sometimes used interchangeably, but usually a theory is a bigger deal. Thus a theory contains many hypotheses. An example of a big idea is the theory of evolution. Hypotheses and theories usually come after many experiments, but before predictions and more rounds of new and often different experiments.

The process of experiment is cyclic. That is, the experiment leads to new ideas for further experiments. The cycle of the scientific method is repeated.

b. How Truth Is Forged

The ancient Greeks never formalized the process of experiment in the way that happened in Europe after Galileo's time.

Laws versus rules. When phenomena eventually become explained, they become laws of science. This term is most appropriate in physics and chemistry. Biology, in contrast, includes so many creatures and types of ecosystems, that there are often exceptions to the norm. Biologists refer to rules instead of laws.

What determines scientific truth? The famous philosopher of science, Karl Popper, said experiments never prove, they only fail to disprove. He therefore said one should design experiments with the aim to falsify. Popper's concept has been influential. So how is truth known? As more and more experiments fail to falsify a specific hypothesis, the hypothesis comes to be known as true.

Paradigm shift is a term coined by the philosopher of the process of science, Thomas Kuhn, that refers to what happens when new scientific discoveries overturn an entire body of knowledge. Einstein's theories of relativity were a paradigm shift.

Reductionism occurs when smaller entities interacting as a system explain a phenomenon. **Holism** is sometimes contrasted to reductionism—it looks to the context, the larger system surrounding the phenomenon being studied, as key to the explanation.

Truth changes as science progresses. Does that mean that anything goes, that anything is possible? All scientific truth is tentative but not arbitrary. Truth is won by many practitioners, checking each other's results and trying new ideas for experiments, over and over.

c. Graphs, Calculations, and Models

Detailed data from experiments are often plotted as points or lines on **graphs** with *x*- and *y*-axes.

***x*-axis:** the horizontal axis, that by convention, varies along the numerical range of the independent variable (either time or some other property being changed by the experimenter, such as temperature).

***y*-axis:** the vertical axis that contains the result being measured, which is called the dependent variable.

Three-dimensional graphs are graphs that use two horizontal axes for two independent variables (x,y) and a vertical axis called the z-axis.

Calculations are crucial to science. Important tools are measurements, which then might be analyzed by algebra (to relate variables), calculus (to look at changes in time, and changes in rates of processes in time), and statistics (to look at large amounts of data that have inherent variability).

Models are conceptual or mathematical systems that serve as explanations for phenomena. Models can be simple, such as Copernicus's model of the solar system. But usually the term model refers to conceptual systems that are more complex, such as today's computer models of the weather that include hundreds of equations.

3. Measurements

Measurements are so important to science that a practitioner once said that "the only things that count are things that can be counted." This goes too far, but it captures the importance of measurement. For example, the Egyptians knew how to lay out right triangles to measure areas of land and to site the pyramids. The word *geometry* comes from ancient Greek, meaning "Earth-measurement."

a. Units Are Crucial

Two types of units are used in the world: the metric system and the English system (used only in the United States). The units in the English system include pounds, quarts, feet, inches, miles, and degrees Fahrenheit. The metric system, used by most of the world and by scientists, is the universal language of science. Here are some units in the metric system, which uses factors of ten smaller or larger to develop the names.

Length: meter (m)
- micrometer (μm), also called a micron (.000001 m)
- millimeter (mm) (.001 m)
- centimeter (cm) (.01 m)
- kilometer (km) (1,000 m)

Time: second (s). Time in the metric system does not use factors (or powers) of ten, except for units under a second (hundredths of a second, milliseconds, microseconds, and so forth).
- minute (min.)
- hour (h. or hr.)
- day (d.)
- year (y. or yr.)

Note that there is another "second" in use as well. Consider: For degrees latitude and longitude, the 360 degrees of the circle is divided into smaller units called "minutes" (60 to each degree, note this is not a minute of time) and "seconds" (60 seconds to a minute of degree).

Mass: gram (g)
- micrograms (μg) (.000001 g)
- milligrams (mg) (.001 g)
- gram (g)
- kilograms (kg) (1,000 g)
- metric tons (t, 1,000 kilograms to a metric ton)

Volume: liter (L)
- milliliters (mL) (.001 L)
- the cubic meter (1,000 L = 1 m^3)

Temperature: The degree Centigrade (° C, sometimes also called degree Celsius). An interval of one degree C is $\frac{9}{5}$ times larger than the interval of one degree F. To convert the numerical scale of ° F into the numerical scale of ° C, use the equation $x°\text{ C} = \frac{5}{9}(y°\text{ F-32})$. The freezing point of water is 0° C or 32° F.

Energy: The joule (J), or calorie (cal); 1 cal = 4.184 J. Note that 1 calorie of energy in food (Cal) is actually a kilocalorie of energy in the metric system. Therefore, 1 Cal = 1,000 cal = 1 kcal. Also, power is energy summed up over time. Therefore, another term for energy is the kilowatt-hour (kW-h) [or joule second (J.S.)].

Power: watt (W)
milliwatts (mW)
kilowatts (kW)

b. Powers of Ten and Constants

Powers of ten with prefix names in the metric system:

10^{-12} pico (p), one-trillionth
10^{-9} nano (n), one-billionth
10^{-6} micro (μ), one-millionth
10^{-3} milli (m), one-thousandth
10^{-2} centi (c), one-hundredth
10^{3} kilo (k), thousand
10^{6} mega (M), million
10^{9} giga (G), billion
10^{12} tera (T), trillion
10^{15} peta (P), quadrillion

Constants: Relating properties in the calculations of science has resulted in universal constants for major laws. These constants are units that work out to multiply the other properties in a way that makes the total units equal on both sides of scientific equations. You do not have to memorize the numbers, but you should be familiar with the existence and use of these constants.

Avogadro number: $\frac{6.0 \times 10^{23}}{\text{mole}}$. In a "mole" of atoms of any element, for example, there is an Avogadro's number of atoms. This number can also be used for the number of molecules of a substance in a chemical mix.

Speed of light in a vacuum (*c*): $3.0 \times 10^{8}\ \frac{\text{m}}{\text{s}}$.

Universal gas constant (*R*): used to relate pressure, temperature, and volume of a gas in the gas law. [8.314 J\mol × K or 0.08206 L × atm\mol × K]

Stefan-Boltzman constant $\Sigma\ \frac{5.67 \times 10^{-8}\ \text{J}}{m^2 - \text{K}^{4-s}}$. It is used to relate the energy of radiation of a material body (say, the Sun) to its surface temperature.

You Should Review

- major scientists
- major experiments and findings
- units of metric system
- powers of ten

Questions

1. This man wrote *The Origin of Species by Means of Natural Selection,* which established the theory of evolution.
a. Charles Darwin
b. William Gilbert
c. Aristotle
d. René Descartes

2. If you are measuring how water chemistry changes in a river in the days after a flood, the time measurement is the
a. independent variable.
b. independent constant.
c. dependent variable.
d. dependent constant.

3. The prefix *tera-* refers to which unit in the metric system?
a. thousand
b. trillion
c. ten thousand
d. three

4. This codiscoverer published one of the giant papers in the history of science in 1953, on the double helix of DNA.
a. Albert Einstein
b. Francis Crick
c. Ernst Mach
d. Niels Bohr

5. Mathematics provides science with analytical tools. The branch of mathematics that deals with changes in the rates of changes of variables in time is
a. algebra.
b. calculus.
c. statistics.
d. tensor analysis.

6. To compute the number of molecules in 2 moles of oxygen gas, you would use
a. Avogadro's number.
b. Einstein's speed of light.
c. the Stefan-Boltzman constant.
d. Planck's constant.

7. Who discovered the circulation of the blood?
a. Galileo
b. Archimedes
c. Schleiden
d. Harvey

8. Which sequence best described the sequence of the classical scientific method?
a. experiment, prediction, idea, hypothesis
b. idea, experiment, hypothesis, prediction
c. prediction, idea, hypothesis, experiment
d. hypothesis, prediction, idea, experiment

9. How many milliwatts are in 10 watts?
a. 10,000
b. 1,000
c. 100
d. 10

10. What famous equation did Einstein write?
a. $F = ma$
b. $E = mc^2$
c. $PV = nRT$
d. $A = \pi r^2$

Answers

1. a. Darwin's world-shaking book on evolution was published in 1859, in England. William Gilbert (1544–1603), also English, theorized correctly that the Earth was a giant magnet, thereby explaining why compass needles work as they do. See pages 230–232 for the others.

2. a. The independent variable in this case is time, because that is what is changing by itself. On the other hand, the river chemistry is the dependent variable, changing as a function of time. Answers **b** and **d** are made up.

3. b. The prefix *tera-* refers to trillion. For example, a teragram is a trillion grams.

4. b. Francis Crick not only discovered the double helix of DNA, but went on to figure out the genetic code that coded for amino acids that are assembled into proteins. He just recently died (2004). See pages 230–232 for the others.

5. b. Calculus can take derivatives of variables, which gives rates of changes in the variables.

6. a. Avogadro's number is a unit of a specific number of atoms or molecules (a very large number!). Planck's constant is a constant of quantum physics. See pages 230–232 for the others.

7. d. William Harvey (1578–1657) was an English physician who discovered that blood makes a closed circuit around the body. See pages 230–232 for the others.

8. b. First, you have an idea, then create an experiment, derive an hypothesis of why the experiment worked (or did not work), and finally make predictions, leading to another experiment. Language can be tricky, because "idea" and "hypothesis" can have similar meanings. However, the sequences in the other answer choices do not make sense.

9. a. Because there are 1,000 milliwatts in one watt, in 10 watts there are 10,000 milliwatts.

10. b. $E = mc^2$ computes the energy (E) inherent in mass (M) itself, which is multiplied by one of the important constants of physics, the speed of light (c), in this case squared. The equation in **a** was by Newton. The equation in answer **c** is the universal gas law, using the constant R and pressure (P), volume (V), temperature (T), and the number of moles (n). The equation in answer **d** is for the area of a circle.

B. The Cosmos

1. First Billion Years of the Universe

Nearly fourteen billion years ago, our universe began with an event called the Big Bang and by a billion years or so later, galaxies had formed.

a. Evidence for the Expanding Universe

In the 1920s, American astronomer Edwin Hubble measured the distances to a number of galaxies and their spectra of light, which provided crucial evidence that the universe is expanding.

Spectra: All elements, if above 0° K (absolute zero, the K or Kelvin scale of temperature, which is referenced to absolute zero, approximately –273° C), glow at particular wavelengths. These are along different wavelengths of the electromagnetic (E-M) spectrum, which spans from the very long wavelengths of radio waves to the ultra short wavelengths of X rays. The wavelengths that our eyes see are called visible light. Visible red is a longer wavelength than blue. The particular wavelengths for each element form patterns, which are characteristic of that element, and which might be called *photon-prints*, after the patterns of the E-M photons. As the numerous E-M emissions from a star passes through gases that contain particular elements, elements also absorb wavelengths in their characteristic patterns. Thus both emission spectra and absorption spectra can provide astronomers with information about the elements out in space.

By examining spectra, Hubble found that compared to the photon-prints of elements on Earth, those elements found in the galaxies of deep space are shifted toward the red, in other words, the wavelengths are longer. This could only occur if the galaxies were moving away from the Earth. (If the galaxies were moving toward us, the shift in the wavelengths of the patterns would have been toward the blue, which was not observed.)

Hubble had discovered the expanding universe. By extrapolating the expansion back in time, astronomers concluded that the expansion started with a single explosive event known as the Big Bang.

If all galaxies are moving away from us, does that imply that we are at the center? No, because inhabitants of any galaxy would also observe that they appear to be at the center. It is like raisins in an expanding raisin cake. To each raisin, all the others are moving away.

We can look back in time, as we look out into space, because the light reaching us was emitted long ago. Because the speed of light is finite (fast but finite), the light from stars in our own galaxy hundred of thousands of years ago or stars in other galaxies billions of years ago is just now reaching us.

b. The Big Bang

The Big Bang occurred about 13.7 billion years ago (with an uncertainty of a few hundred million years).

At one microsecond (following the Big Bang): The universe as a whole had a temperature of about a trillion degrees K. Matter as we know it, as stable atoms, does not exist at this temperature.

Between the first microsecond and one second: Matter and antimatter nearly annihilated each other.

Antimatter is a form of matter that is the mirror opposite of matter in all aspects. For a positively charged particle, for example, the antiparticle is negatively charged. There are also opposite values for other quantum properties, such as **quantum spin** (not really a spin, but a quantum property). Particles and their antiparticles have the same masses. The key point is that when particles and antiparticles meet, they explode into pure energy, in an amount according to Einstein's famous equation $E = mc^2$. We know that antiparticles exist because they can be made in high-energy physics experiments.

In the early universe, there was an imbalance between matter and antimatter, to the extent of about one part in 200 million. Therefore, in the matter-antimatter annihilation, only one part in 200 million remained as matter, and the rest became energy.

At one second: The universe was about a billion degrees K. This was "cool" enough for protons, neutrons, and electrons to exist as stable particles, what physicists call "subatomic" particles, because they are basic constituents of atoms.

Note that the proton by itself is the nucleus of a hydrogen atom.

c. Formation of First Atoms

At around 300,000 years after the Big Bang, the temperature of the universe had dropped to about 3,000° K (close to the temperature of our Sun's surface). This was cool enough for electrons to remain bound to nuclei of protons and neutrons, creating atoms. (In contrast, at hotter temperatures, electrons are stripped off nuclei and atoms cannot exist.)

Astronomers talk about this event by saying that the "universe became transparent." Before this point, freely moving electrons (in the state of matter known as **plasma**, a kind of matter-energy "fog") blocked the propagation of electromagnetic radiation (such as light and other wavelengths). This crucial event separated matter and energy. Except for small amounts absorbed over time by interactions with matter, this ongoing energy has been traveling throughout the universe ever since, stretching and cooling with the ongoing expansion.

In 1965, this radiation was detected. It is called the **cosmic background radiation**. Its temperature, which represents the average temperature of the current state of the universe, is 2.7° K, very close to absolute zero. (Locally, places like the Earth and the Sun, of course, are much hotter.)

At this point of formation of atoms, both theoretical calculations and actual measurements have shown that matter consisted of 76 percent hydrogen and 24 percent helium (with a trace of lithium). No other elements existed.

d. Formation of Stars and Galaxies

Stars and galaxies formed between 1 million and a billion years after the Big Bang. Stars are created when gas clouds in space condense, pulled together by gravity. During the condensation, the gas becomes hotter and hotter. If the density and temperature are high enough, the protostar ignites and is sustained as a glowing star by nuclear fusion.

Stars are within large gravitationally bound groupings called **galaxies**. Our Milky Way galaxy has about 100 billion stars, which go through births and lifetimes. In special cases, extremely large masses can contract so much that light itself cannot escape; they are called **black holes**. Many galaxies are believed to have black holes in their centers. Our galaxy has a central black hole.

The contraction of the matter of the universe into galaxies could only have occurred from some initial lumpiness in the universe, which was predicted to be still present in the cosmic background radiation. Satellites such as the Cosmic Background Explorer did indeed find such **inhomogeneities**, which indicate differences in the distribution of energy in space from the time the universe became transparent. These differences are small, only + or –27 microdegrees warmer and cooler than the average 2.7° K, but they are a crucial confirmation for the Big Bang theory. Our universe now contains about 100 billion galaxies.

2. Birth of Chemical Elements in Stars

All elements heavier than the primordial triplet of elements, primarily hydrogen and helium with a trace of lithium, are created in stars.

a. Nuclear Fusion

Stars are hot and are able to throw radiation into space because of fusion reactions deep within their cores. For atoms from hydrogen up to the atomic weight of iron, energy is released when atoms are fused to make larger atoms. This is because the protons and neutrons inside the nuclei of the larger atoms (again, up to iron) contain less mass per subatomic particle and therefore less energy according to Einstein's equation. The excess energy of fusion is released as heat and radiation.

b. Sequence of Births of Elements

Inside stars, the first element to be fused is hydrogen, the most abundant primordial element. Under intense temperature and pressure, two hydrogen atoms are fused into one atom of helium, releasing energy and making stars hot, thus sustaining further fusion reactions. When the hydrogen is used up, helium is fused into carbon, and then the carbon and some helium are fused into oxygen. All the elements up to iron can be made in this way. Note the sequence of how elements are made: Hydrogen (H) ➔ Helium (He) ➔ Carbon (C) ➔ Oxygen (O). All these fusion reactions release energy.

c. Supernovas and the Dispersal of Elements

Stars can run out of matter to fuel fusion; they can "die." Some stars die by throwing off gases, then withering into small, smoldering white dwarfs.

Very massive stars, on the order of ten times the mass of our Sun, can create supernova explosions at their deaths. One supernova, for example, occurred in our galaxy in A.D. 1066, which is now the Crab Nebula. Ancient people observed this bright new star in the sky before it faded.

Supernovas are important parts of how our universe works. They do two special things. First, all elements heavier than iron (such as gold and uranium) are made in the intense heat and pressure of the supernova. Second, the supernovas disperse all the elements inside the former star out into space. We can see these elements in the emission and absorption spectra in the regions surrounding former sites of supernovas. In the dispersal of elements by supernovas, there are elements made earlier in fusion reactions during the long, ordinary lifetime of the star, as well as the new elements made only in the supernova itself.

The elements dispersed into space can eventually gather into gas clouds and might contract, after mixing with remnants of other supernovas, into totally new stars and their planets.

3. Formation of Earth

a. Age of Sun and Earth

About five billion years ago, a gas cloud condensed into the star that is now our Sun, which has been burning since that birth.

Around the Sun, the gas cloud condensed into smaller bodies (picture small whirlpools of contraction around a large, central one). What started as dust grains coalesced into rocks, then boulders, then objects the size of mountains. By collisions and gravitational attraction, which held the bodies together, the objects grew. Sometimes, the collisions created smaller bodies but, on the whole, growth in size ruled. Earth formed about 4.5 billion years ago.

b. Methods of Dating

To date the formation of stars and planets, scientists use radioactive clocks. Very large atoms, such as those of uranium, can have unstable nuclei. These unstable nuclei restructure into nuclei that are slightly smaller by giving off radioactive particles (there is also a kind of radioactive decay that only gives off energy). The new atom might also be radioactive, and thus, the process continues until it reaches an atom that is perfectly stable. Lead-206, for example, is the stable daughter-product of what started as Uranium-238 (the numbers refer to the atomic weights). When molten or gaseous, the lead-206 is driven off; the radioactive clock is thereby "reset." We can use the clock to date when rocks formed. The oldest Earth rocks are 3.9 billion years old, the oldest Moon rocks 4.1 billion years old, and most meteorites about 4.6 billion years old. Because the Earth and Moon would have been molten even after they formed (see below), the date of the meteorites is taken to be that time that the Earth condensed (4.6 billion years ago, or, rounded to the nearest half billion, about four and a half billion years ago).

c. Formation of the Moon

Though it was once thought that the Moon might have condensed separately around the Earth, the following scenario is now known to be true (from multiple lines of evidence). A few hundred million years after the formation of the Earth, a rogue body about the size of Mars, which had an odd orbit around the Sun, smashed into the Earth. Material from both the colliding body and the Earth flew off and condensed around the Earth to form the Moon. The Moon was much closer and has been slowly moving away from the Earth ever since.

4. Exploration of the Solar System

From the dawn of time, humans have looked up at the stars. Only in the past half century have we been able to look back on Earth itself with satellite cameras and even human eyes.

a. From Satellites to Humans in Space

Sputnik, which means "fellow traveler" in Russian, was launched by the U.S.S.R. in 1957. It was the first artificial satellite in orbit.

Vanguard was the first U.S. satellite, in 1958.

In the manned U.S. space program, the *Mercury* program put solo humans in orbit, the *Gemini* program put teams of two into orbit, and the *Apollo* program, with teams of three, aimed for the Moon. The first manned Moon landing came in 1969. The Russians had the first space station, called Mir (for "peace"), but eventually it could not be maintained and fell to Earth. The International Space Station, led by the efforts of the United States, is currently in orbit, and every half year or so, there are changes of crew. Russia has supplied the rockets for these changes in recent years, following the grounding of the U.S. space shuttles, after the second total loss of a space shuttle crew in 2003, during a disastrous reentry into Earth's atmosphere.

b. Discoveries from Venus

Astronomers cannot see surface features of the planet Venus because of its thick clouds. Several U.S. and Russian probes have measured properties of the Venusian atmosphere and even mapped the surface from orbit, using various wavelengths that can penetrate the clouds. Despite its similar size to Earth, Venus is very different from Earth. It is extremely hot, partly because it is closer to the Sun, but mostly because the atmosphere is about 600 times more massive than that of the Earth, and is mostly carbon dioxide. This amount of CO_2 produces an intense greenhouse effect, keeping the planet hot. There is no water vapor or oxygen in the atmosphere.

c. Discoveries from Mars

In the mid-1970s, the Viking probe successfully landed on Mars and measured properties of the soil, seeking signs of life. None was found, but scientists now believe there is a possibility for life in cracks in rocks, well beneath the surface. Unusual bacteria are found in similar sites deep under the surface of Earth.

In 2004, the United States successfully deployed two more rovers on the surface of Mars. They have analyzed minerals and have concluded, through multiple lines of evidence, that Mars was once wet. Rivers flowed; there was possibly a shallow ocean. Again, compared to Earth, the atmosphere of Mars is very foreign. The thin atmosphere (about 7% that of Earth) is, like that of Venus, mostly carbon dioxide. There is only a faint trace of oxygen and little nitrogen (the two most abundant gases in the Earth's atmosphere).

5. Mysteries of the Cosmos

a. Dark Matter

When astronomers use the law of gravity to compute what the spin of galaxies (such as ours) should be, given the presence of a known amount of matter, they find that there must be a significant amount of matter that is "dark," unseen, and unknown.

The dark matter is about six times the mass of the known, ordinary matter of stars and gas clouds.

b. Dark Energy

Certain kinds of supernovas explode with a fixed real brilliance. Astronomers have mapped these "standard candles," and, knowing their real brilliance, their apparent brilliance to us on Earth, and their red shifts, can calculate their distances and ages. A startling fact has emerged, which has been borne out by other lines of evidence as well: The expansion of the universe has been accelerating since the Big Bang.

What is causing the expansion? It is some kind of energy that we cannot currently see. It is therefore known as **dark energy**.

Using Einstein's equation $E = mc^2$, any amount of energy can be computed as an equivalent mass. Therefore, scientists can ask about the amounts of dark energy, dark matter, and the universe's third constituent of known, ordinary matter and energy. Here are the results:

Dark energy: 73% (the most of the substance of the universe)
Dark matter: 23%
Ordinary matter and energy: 4%

c. Life and Intelligence Elsewhere

Are we alone? The research program called *SETI (the Search for Extraterrestrial Intelligence)* seeks answers to this question. It assumes that other intelligent civilizations might send out signals to space. So far, no definite signals have been found.

By measuring wobbles in stars, which are caused by planets circling the stars and perturbing the stars with their gravity, astronomers do know that many stars have planets around them. To date, this technique only locates very large planets, assumed to be similar to the gas giants of our solar system, Jupiter and Saturn. More than 100 planets around other stars are currently known. The first stars of the universe could not have had planets of heavy elements, such as iron. Early planets could not have had carbon, a crucial element for life as we know it. This is because iron and carbon are made in the fusion reactions inside stars. Therefore, the density of carbon increases over time, as stars go through lifetimes and more stars form. Is there a critical density of carbon needed for life? Perhaps we are alone (or nearly so), because just around the time of formation of the Earth the density of carbon reached a value high enough to form life. This is a possible explanation for our apparent aloneness, but more work on the history and composition of the cosmos needs to be done.

You Should Review

- Big Bang theory
- formation of stars and galaxies
- dating methods
- supernovas
- formation of Earth and Moon
- characteristics of planets in the solar system
- discoveries from space exploration
- dark matter and dark energy

Questions

11. What feature of our universe is demonstrated by the "red shift"?
- **a.** an increase in supernovas
- **b.** the contraction of black holes
- **c.** the expansion of the universe
- **d.** the decrease in gravity

12. What of the following did not occur at about 300,000 years after the Big Bang?
- **a.** Matter was left over from matter-antimatter annihilation.
- **b.** The universe became transparent.
- **c.** The first atoms formed.
- **d.** Electrons started orbits around atomic nuclei.

13. What is the current temperature of the universe, as indicated by the cosmic background radiation?
- **a.** 2.7° C
- **b.** –2.7 K
- **c.** –2.7° C
- **d.** 2.7 K

14. In the stages of nuclear fusion inside stars, which element in the list, compared to the others, is the ultimate building block for all the others?
- **a.** hydrogen
- **b.** helium
- **c.** carbon
- **d.** oxygen

15. A supernova is observed in a star that is a distance of 500 light years from Earth. That means we now see the star
- **a.** as it was 500 years in the past.
- **b.** as it was 500 years after the Big Bang.
- **c.** as it will be 500 years in the future.
- **d.** as it is, basically, today.

16. We can date very old rocks because of what fact?
- **a.** Uranium turns into platinum.
- **b.** Uranium turns into lead.
- **c.** Lead turns into uranium.
- **d.** Gold turns into uranium.

17. How did the Moon form?
- **a.** A large body crashed into the Earth soon after its own formation.
- **b.** A gas cloud condensed around the Earth at the same time the Earth itself condensed.
- **c.** The early Earth was unstable and split into the Moon and what became the Earth.
- **d.** The Moon was captured by the Earth early on.

18. Which planet is about the same size as Earth, has a blanket of thick clouds, and has a surface temperature that could melt lead?
- **a.** Mercury
- **b.** Jupiter
- **c.** Titan
- **d.** Venus

19. Which country was the first to launch a satellite?
- **a.** Union of Soviet Socialist Republics (U.S.S.R.)
- **b.** United States
- **c.** China
- **d.** European Union

20. What is the main piece of evidence for dark energy?
- **a.** black holes found in the centers of most galaxies
- **b.** discovery of cosmic background radiation
- **c.** rotations of galaxies not explained by our known, ordinary matter and energy
- **d.** acceleration of the expansion of the universe

Answers

11. c. All galaxies have red shifts in the signatures of elements in their spectra of light, which shows us that the galaxies are all moving away from each other and therefore that the universe is expanding.

12. a. This event (matter left over from matter-antimatter annihilation) occurred in less than a second after the Big Bang. Answers **c** and **d** are two ways of describing the same event, which happened at about 300,000 years following the Big Bang. Answer **b** describes what happens during atom formation, which occurred at the same time period as choices **c** and **d**.

13. d. 2.7 K. K for Kelvin refers to the temperature scale that uses absolute zero as the "zero" point. Note that it is written as just "K" not "° K." You can figure this out if you know that 0 K refers to absolute zero and that the average temperature of the universe is very close to absolute zero. Negative K makes no sense. The answers **a** and **c** are too warm, given that 0° C is about 273 K.

14. a. Hydrogen is the building block for other elements inside stars. It is the simplest element, with one proton and one electron.

15. a. We see the star as it was 500 years in the past, because light can only travel at a finite speed (fast but finite, the *c* in Einstein's famous equation). A light year is the distance that light travels in a year. When we look out into space, we also are looking back in time.

16. b. Uranium, a radioactive element, turns into lead, which is stable. The amount of a particular isotope of lead gives the amount of time that has passed since the rock formed and any lead prior would have been purged during a gaseous or molten state.

17. a. A large body crashed into the Earth soon after its own formation. From this collision, material went into space and recondensed to form the Moon as well as restructuring the surface of the Earth. This was after the Earth had already condensed.

18. d. Venus has a super-thick atmosphere of carbon dioxide that creates high surface temperatures. Answer **c** is not a planet but a Moon of Saturn.

19. a. The Union of Soviet Socialist Republics first launched a satellite into Earth orbit. (This country has broken up into a number of countries today, but the largest part of the U.S.S.R. is Russia.) Answer **d**, the European Union, did not exist at the time of the first satellite.

20. d. The existence of dark energy is evidenced by the accelerating expansion of the universe. We know this by measuring the distances to certain types of supernovas in distant galaxies, which serve as standard candles of known brightness.

C. Basics of Matter

1. Physics

Physics is the study of the constituents and forces that govern matter at its most elementary level.

a. Atoms

The word **atom** comes from the ancient Greek, meaning "indivisible." Atoms are the most finely divided parts of matter that possess the characteristics of a particular element, such as copper, gold, carbon, or hydrogen.

Atoms are not actually indivisible. Atoms not in molecules or ions are electrically neutral and contain equal amounts of positive and negative electrical charges. The positive charge is concentrated in a tiny central massive region called the **nucleus**. The negative charge is in one or more tiny electrons, which "whir" around the nucleus, bound to it by electrical attraction.

The nucleus, too, has parts: **protons** and **neutrons**. Protons are positively charged, neutrons are neutral. Their masses are nearly (but not exactly) the same. The mass of a proton or neutron is about 2,000 times the mass of an electron.

Quantum theory made the picture of the atom more complete though more difficult to visualize. According to quantum mechanics, the electrons do not orbit the nucleus like planets around a star, but are more like clouds of probability, in which an electron can exist anywhere in its cloud (its range of possible places), popping in and out of existence in different sites within its cloud, which fades out with distance from the nucleus.

The atoms of a particular element all have the same number of protons in their nuclei (which determines the charge of the nucleus, thus the number of electrons around the nucleus, and thus the chemistry of the element). But atoms of elements can vary in the number of neutrons in their nuclei. Therefore atoms of an element can vary in their masses. These different atomic masses of the same element are called **isotopes**.

Example:
Most atoms of the element carbon contain 6 protons and 6 neutrons in their nuclei. This is carbon-12 (atomic number 6, atomic weight 12). About 1 in 100 atoms of carbon have 6 protons and 7 neutrons in their nuclei. This is carbon-13 (atomic number 6, atomic weight 13). An even smaller fraction of carbon is carbon-14. It has 6 protons and 8 neutrons in the nucleus. Also, it is radioactive, which means it is inherently unstable and will decay in the following manner. One neutron converts to a proton plus an electron that is shot out at great energy from the nucleus (note that the electron was created by the conversion, it was not "in" the nucleus.) This is **beta decay**, governed by the weak nuclear force. After beta decay, the atom is no longer carbon, it is nitrogen, with 7 protons and 7 neutrons, and now is perfectly stable. Other radioactive isotopes, such as those of uranium, can decay in another manner called **alpha decay**, when a bound particle of 2 protons and 2 neutrons is ejected.

b. Quarks and Charges

From the discoveries of quantum mechanics, protons and neutrons were found to be made of **quarks**. The proton is made of two "up" quarks and one "down" quark. The neutron is one "up" quark and two "down" quarks. Other numbers of quarks create other kinds of particles in a quantum mechanical "zoo," such as **mesons**. This zoo also contains chargeless particles called **neutrinos** with much less mass than electrons. There are other types of quarks, too, such as **strange** and **charm**.

c. Essential Concepts

Velocity (*v*) is distance (s) covered per unit time (t): $v = \frac{s}{t}$.

Acceleration is the change in velocity over an interval of time. It can be written as $a = \frac{\Delta v}{\Delta t}$ Δd = difference, or, in the terms of calculus, **derivative**). If velocity is a change in position, acceleration is the change in velocity.

Newtonian concept of force (*F*): $F = m \times a$. It takes force to accelerate a mass (m) (stepping on the gas pedal of a car, which causes more gasoline to be burned and converted into the car's forward motion). Honoring Newton, the metric unit of force is called a Newton (N). Its units are $\frac{kg \times m}{s \times s}$ (the force it takes to accelerate one kilogram by one meter by second over the course of one second).

Momentum is mass times velocity. A car traveling at 60 mph has twice the momentum of a car of the same mass traveling at 30 mph.

Objects traveling not in straight lines but in curved paths have properties called **angular**, because in the governing equations one must also account for the change in the angle; thus, **angular velocity**, **angular acceleration**, and **angular momentum**. The Earth has a huge angular momentum because of its huge mass.

Forces can be **static** as well as **dynamic**. **Pressure** (for example the pressure that exists inside a balloon blown up with air) is expressed as $\frac{N}{m^2}$, a force per area on the inner surface of the balloon. But once it is blown up, the balloon does not keep expanding. This is because there is an equal and opposite force exerted by the stretched skin of the balloon. The balloon remains at the same size (except for slowly leaking) because the two forces, from air and skin, exactly balance each other.

Electricity is an entire special topic in physics.

Voltage is the difference in electrical force that can drive electrons from one place to another; the unit is the volt.

Amperage is the actual amount of flow of electricity, or electrons; the unit is the amp or ampere.

Resistance is the resistance to the flow of electricity, which varies among materials; the unit is the ohm. The watt (*W*) is the amount of power that flows when 1 amp flows by an electrical force of 1 volt.

Another important topic in physics is waves. **Waves** are characterized by frequency (cycles per time) and by wavelength (distance traveled by one cycle). Amplitude (strength) is another characteristic. For example, sound consists of traveling waves of compression and expansion in air (or water). Light waves (standing waves) are electromagnetic, which can travel in a vacuum.

d. Basic Forces

Physicists recognize four forces that are ultimately fundamental.

1. **Gravity** attracts two masses toward each other. Newton wrote the main equation of gravity, and Einstein's general theory of relativity more completely explained gravity as a warping by matter of space-time. The force of gravity obeys an inverse-square law: The force falls off as the square of the distance from the source.
2. **Electromagnetism (*EM*)** is the force that exists between charged particles. It is attractive when the charges are opposite (positive and negative) and repulsive when the charges are the same (both positive or both negative). Electromagnetism holds atoms together—the EM force in various forms is the secret to the chemical bond. The EM force, like gravity, obeys an inverse square law. Its main theoretical formulation is in Maxwell's equations.
3. **Weak nuclear force**, which has a very short range and is responsible for certain kinds of interactions in the atom, governs a particular kind of radioactive decay called **beta decay**, in which a neutron converts to a proton plus an electron and antineutrino.
4. **Strong nuclear force** is the major stabilizer of the atomic nucleus, governing interactions among the quarks that make up the protons and neutrons. Unlike forces such as gravity and EM that diminish with distance, strong nuclear force strengthens with distance. The more quarks are separated, the more strongly they are bound to each other. This is why free quarks have never been observed.

2. Chemistry

Chemistry studies the interactions of atoms, how they form molecules, and the interactions of those molecules, which range from simple ions to complex organic molecules.

a. Atoms and the Periodic Table

The naturally occurring elements contain from 1 proton (hydrogen) to 92 protons (uranium) in the nuclei of their atoms. Elements with more protons have been made artificially in experiments of high-energy physics.

The electrons around each nucleus fill, in sequence, what are called **shells**. These shells, and the number of electrons in them, determine the chemical properties of the elements, such as crystal geometry, electrical conductivity, and, most importantly, their bonding properties with other atoms into molecules.

The first shell, K, can hold 2 electrons. The second shell, L, can hold 8 electrons (in two subshells of *s* with 2 and *p* with 6). The third shell, M, can also hold 8 electrons (in two subshells of *s* with 2 and *p* with 6), and so on. Things become more complicated as the elements move into higher **atomic numbers** (the number of protons in their nuclei), with, for example, phenomena such as a lower subshell filling after a more outer shell contains electrons. But basically, for most chemistry we need to consider, the outermost shell will have 8 electrons when it is "full." (Note that the first shell only holds 2 electrons.)

These shells of electrons, and the fact that shells can be full or less than full, creates **cycles** in the properties of elements. For example, elements with full shells include helium, neon, and argon. These elements are in the family of elements called **noble gases**, which tend not to combine with other elements (they don't need the other elements to create a full shell of electrons, because they already are full).

There is a tendency, driven by energy considerations, for atoms to achieve complete shells of electrons. They may do this by either losing or gaining electrons, depending on which direction makes creating the full shell "easier."

For example, elements with one electron in an outer shell will tend to give up that electron in a chemical bond with a different atom. Elements with 7 electrons in the outer shell will tend to grab an electron in a chemical bond with another atom. An example is table salt, NaCl. By themselves, atoms of sodium (Na) have one outer electron, whereas those of chlorine (Cl) have seven outer electrons. In chemical contact, sodium gives up an electron to chlorine, thereby both achieving full shells. They bond into a solid crystal (salt) of an alternating, three-dimensional lattice of Na ions and Cl ions.

The outer shell that is chemically active by virtue of this tendency to give up or gain electrons is called the **valence shell** of atoms.

Depending on the strength of the tendency to gain or lose electrons, and on the "needs" of chemical partners, **chemical bonds** can occur in different types. **Ionic bonds** are when one element gives up electrons and the other element gains. An example is table salt, where the sodium atoms, having lost electrons, become ions with a positive charge (of 1), and the chlorine atoms, having gained electrons, become ions with a negative charge (of –1). In another kind of bond, called a **covalent bond**, electrons are shared in pairs. In a covalent bond, the resulting atoms in the bond do not become ions, but still can have a slight charge polarization. The complexities of forces between atoms in chemical bonds and between molecules with charged surfaces create other types of bonds (for example, hydrogen bonds and the bonds from van der Waal forces).

b. Chemical Reactions

Chemical reactions occur when chemical reactants change into products. Reactions can be as simple as salt dissolving its ions into water, or as complex as two organic molecules brought together into a larger one in the presence of an enzyme. Parts on the left-hand side of a reaction are called the **reactants**. Parts on the right-hand side are called the **products**. By convention, reactions are written with an arrow taking reactants into the state of products.

Chemical reactions must be balanced according to the **law of conservation of matter**: Matter can be neither created nor destroyed. (Changes in the nucleus, for example, from nuclear fusion, nuclear fission, or radioactive decay are not considered here in these ordinary chemical reactions that involve only the electrons of atoms, not their nuclei.) For instance, the number of atoms of oxygen in the reactants has to equal the number of atoms of oxygen in the products.

Reactions can give off energy (**exothermic**). These tend to occur spontaneously (but not instantaneously). Some reactions can require energy supplied from the environment—these are called **endothermic**.

Many important chemical reactions are known as **oxidation-reduction reactions**. One element gains electrons (is reduced). A different element loses electrons (is oxidized). The word **reduced** refers to the fact that the gain in electrons reduces the charge of the element to a more negative value.

Acids are substances whose dissolution in water creates hydrogen ions (H+) in water. **Bases** are substances whose dissolution accepts hydrogen ions (H+) ions in water. The **pH scale** is the measure of acidity.

c. States of Matter

Solid: the state of matter in which the atoms or molecules are bound tightly and move together as a unit. Some solids are mathematically regular in their atomic structure (such as crystals). Other solids can be more amorphous (such as coal).

Liquid: the state of matter in which the atoms or molecules can glide past each other, loosely bound but not attached to specific neighbors. However, in liquids, the molecules still have some degree of coherence to each other.

Gas: the state of matter in which atoms or molecules are totally free of each other. In air, for example, the molecules of nitrogen and oxygen travel as independent units, only bumping into other molecules (this bumping creates the gas pressure).

The different states of matter contain different amounts of energy. The energy required to change a substance from solid to liquid is called the **heat of fusion** (fusion here means melting). The energy required to change a substance from liquid to gas is called the **heat of vaporization**. The heats of fusion and vaporization occur at constant temperatures. It requires energy to heat water to the boiling point, but then more energy is needed—at that constant boiling point temperature—to turn the water into steam. Only after the water has become steam can more energy raise the temperature of the steam itself. These heats of fusion and vaporization are unique for all substances, as are the freezing and boiling temperatures.

For water, for example, the heat of vaporization is 549 calories per gram. This is the same amount of energy it takes to raise 10 grams of water by 54.9° C (or one gram by 549° C, but that is not possible, given that the freezing point is 0° C and the boiling point is 100° C).

When temperatures are extreme (as in the center of the Sun), electrons are stripped from their nuclei. The resulting state of matter is called a **plasma** (often plasma is called a fourth state of matter).

d. Organic and Inorganic Molecules

Basically, organic molecules contain a reduced form of carbon, in other words, carbon with a slightly negative charge from the stronger attraction (electron affinity) of electrons in sharing with other atoms, notably hydrogen. Carbon has four electrons in an outer energy level, thus requiring four more to complete the shell of eight. It is special. Carbon can bond with itself in chains, a virtually unique feature of its atomic structure (silicon also has this special characteristic). Pure forms of carbon include diamonds, graphite, and the recently discovered form of carbon in hollow spheres of 60 atoms called "buckyballs."

Organic molecules are the stuff of life. Therefore, organic chemistry is the chemistry of life itself. There are important classes of organic molecules in living things.

Proteins are organic molecules made from smaller organic components called **amino acids**. Amino acids contain the element nitrogen. **Enzymes** and many structural parts of cells are all types of proteins. **Hemoglobin** in our blood is a protein.

Carbohydrates are organic molecules of carbon in chains that are fairly short, with side groups that branch off the chains and consist of hydrogen and hydrogen-oxygen pairs. The chemical formulae for carbohydrates often look like they consist of carbon plus multiples of water (for example, $C_6H_{12}O_6$)—thus, the name **carbo-hydates**. Examples are sugars such as sucrose and lactose, and starch. The important structural molecule of plants—cellulose—is also a carbohydrate.

Lipids are very long chains of carbon atoms, with side groups that are primarily single hydrogen atoms. Other side groups also occur. Examples of lipids are the molecules in various kinds of oils (saturated versus unsaturated). Lipids are crucial in the membranes of cells, which all consist of complex lipids called **phospholipids**, because they have a phosphate group at one end. Most lipids are insoluble in water.

Nucleic acids, such as DNA and RNA, form important coding molecules inside cells for the genetics of living things.

Inorganic chemistry deals with the chemistry of everything that is not organic. This includes, for example, the chemical reactions between simple charged ions dissolved in water, and the structures of crystals, with their different planes of cleavage. Inorganic chemistry includes many kinds of reactions among molecules in Earth's atmosphere.

3. Energy

a. First Law of Thermodynamics

Work is force times distance, which has the same units as energy. The metric unit of energy is the joule (J, therefore 1 J = 1 $N-m$). The unit is named after James Prescott Joule (1818–1889), one of the founders of the concept of the conservation of energy.

In the first law of thermodynamics, energy is neither created nor destroyed, but only transformed.

One of the amazing discoveries in the history of science was the gradual realization that types of energy can be equivalent in value (the manifestation of the first law). How can the warmth of our body or the strength of our arms come from the food we eat? Joule discovered the mechanical equivalent to heat, that, indeed, mechanical motion and heat could be put into equivalent terms as forms of energy. In heat, the unit is the calorie. In the mechanical equivalent of heat, 4.18 J = 1 calorie. One feature shared by all forms of energy is that they can be converted into heat, or work.

b. Second Law of Thermodynamics

All forms of energy can be converted to heat; heat cannot be converted to all other forms of energy with equal efficiency. In a sense, heat is the most degraded form of energy, because it is least convertible into the other forms. This fact—that not all forms of energy are equal in "quality"—led to what is known today as the second law of thermodynamics.

The key property is **entropy**. This is often taken to mean "disorder." Indeed, there is a relationship between the order of matter and its entropy content. Thus, a gas has a higher entropy than a solid, because compared to the molecular chaos of a gas, the solid has atoms and molecules in relatively neat arrangements.

Physicist Ludwig Boltzman (1844–1906) worked out the relationship between entropy and the number of states possibly occupied by a state of matter. He had the equation for entropy put on his gravestone.

In general, entropy will increase over time. Disorder increases. A hot cup of tea placed in an ordinary room will cool off. Its energy went into the room's air. Thus, the tea cooled off by many degrees as the room warmed up a tiny amount of temperature (because it has a bigger mass). Because the heat, as energy, went from a more concentrated state (in the tea) to a more diffuse state (in the room's air), there was an increase in entropy of the tea-and-room considered as a system. A concentrated amount of heat at a high temperature is not as degraded as a diffuse amount of heat at a lower temperature. In fact, the unit of entropy is the heat per unit degree Celsius, in other words, the $\frac{\text{calorie}}{°\text{C}}$. (Note from this definition that one calorie of heat at a lower temperature has a higher entropy than one calorie at a higher temperature.) A state of higher entropy is a more disorderly and a more degraded state of energy. These considerations are essential for the industrial world—for example, in the design and operation of the electrical power plants.

Entropy can sometimes decrease. Energy can become more useful (less degraded). For example, in plant photosynthesis, carbon dioxide and water are transformed into carbohydrates, which are food energy that we can eat. The carbon dioxide and water have a higher entropy than the same atoms arranged into the carbohydrate molecules. In this case, entropy decreased, an apparent violation of the second law. But photosynthesis takes sunlight—solar energy—which itself is a very low form of entropy. One can compute the efficiency of photosynthesis, which is the efficiency of the conversion of solar energy into chemical energy of food. The wasted light (this waste is an unavoidable part of the process) goes off as heat from the plant. This heat is an increase in entropy. When we combine the entropies for the two processes (1. some part of the sunlight, along with carbon dioxide and water go into carbohydrates in an entropy decrease, 2. the other part of sunlight goes into heat in an entropy increase), it turns out that the increase dominates.

Local decreases in entropy have always been found to co-occur with increases in entropy at a larger scale, when more factors are included. Therefore, some prefer to state the second law as the fact that in any process that transforms energy, the entropy of the universe always increases.

c. Types of Energy

Heat (also called **thermal energy**), on a molecular scale, whether for a solid, liquid, or gas, is the motion of molecules. In a solid, the atoms or molecules do not go anywhere, they vibrate in place. In a gas, higher temperatures mean faster velocities for the molecules. As a cup of hot tea cools, the fast molecules of the tea hit the molecules of the tea cup, which causes them to vibrate faster; these, in turn, come in contact with the molecules of air around the cup, causing the air molecules to move faster. The air molecules that are faster collide into the slower ones, causing them to move. Thus, the heat moves outward as the cup cools. In addition to this conduction of heat, heat can also move by **convection**, as when waves of air waft upward from a hot highway during midday in summer. Heat can also move by **radiation**, which is why your hands held even to the sides of a campfire perimeter are warmed.

Mechanical energy is the energy of motion (for example, water in a waterfall that can turn a turbine). As a very high quality (low entropy) form of energy, mechanical motion can be easily converted into other high quality forms, such as electricity.

Light is an electromagnetic wave that travels in a vacuum at the universal constant velocity, the speed of light. The energy of an individual quantum packet of light in this wave (the photon) is higher for shorter wavelengths. Thus, a blue photon has higher energy than a red photon, and an ultraviolet photon has even higher energy. A very high energy photon would be the X ray. A low energy photon is the microwave.

Electricity is moving electrons. In direct current (DC, as from a battery), electrons actually move from the negative pole to the positive pole. Eventually, the battery becomes dead when the electrons that can move have all done so. In alternating current (AC, 60 cycles per second here in the United States), electrons are vibrated back and forth, first toward one direction in the wire, then toward the other direction. So they do not actually travel. We use AC for most power needs, because it is safer at the high voltages needed for long distance transmission from the power plants to individual homes.

Nuclear energy is the energy inherent in the nuclei of certain atoms. For example, nuclear power plants use the nuclear energy of a uranium isotope (U-235), which can be split in a controlled chain reaction of nuclear fission. This source of energy turns water to steam to spin the turbine and thereby generates electricity. In the Sun, the form of nuclear energy is nuclear fusion, in which hydrogen is fused to helium, with the release of energy.

Work is formally defined as force times distance. For example, to lift a heavy box from the ground is work. You exert a force, counter to that of gravity, to lift the mass through a distance. Work has the same units as energy. Work requires the expenditure of energy. Where has the energy gone? Some went into body heat as your muscles were used. Some went into lifting the box, now above the ground, and now a form of potential energy.

Gravitational and mechanical potential energy: There are many forms of potential energy, which usually means that energy is held in a static arrangement of matter in some form, with the potential to be released and turned into some other form of energy, such as kinetic or electrical or heat (thermal). An object lifted above the ground has potential energy (thus, every leaf on a tree has potential energy). Potential energy also resides in the mechanical tension of a pressed or stretched spring.

Chemical potential energy exists when any two or more substances are capable of undergoing a chemical reaction that could potentially release energy in an exothermic reaction. One example is food and the oxygen in the air. That pair has the chemical potential to "burn" together and release energy. We do this when consuming the food. Our cells convert the energy into other molecules that can store energy. This stored energy can then be used to construct the other molecules we need to live.

Kinetic energy is similar to mechanical energy and is called the energy of motion. It is proportional to the square of the velocity of an object.

You Should Review

- laws of motion, gravitation, momentum
- light and magnetism
- electricity
- structure of the atom
- periodic table
- chemical bonds
- forms of energy
- first and second laws of energy thermodynamics

Questions

21. Which variant of the most common type of atom of an element has a different number of neutrons in the nucleus?
a. epitope
b. isotope
c. moletope
d. entrope

22. Which of the following is a true statement?
a. Velocity is the rate of change of time.
b. Acceleration is the rate of change of velocity.
c. Velocity is the rate of change of acceleration.
d. Acceleration is the rate of change of time.

23. A bicycle tire has air pressure inside it. Which concept in physics is the pressure most closely related to?
a. energy
b. momentum
c. wave
d. force

24. Which force gets stronger as the distance increases?
a. strong nuclear force
b. gravity
c. weak nuclear force
d. electromagnetism

25. When a sodium atom gives up an electron to enter into an ionic bond with chorine in table salt, it does so because
- **a.** it requires a electrical charge of +1.
- **b.** it requires an electrical charge of –1.
- **c.** it creates a negative potential energy.
- **d.** it achieves a full electron shell.

26. Dissolving H_2SO_4 in water creates an acid by increasing the
- **a.** sulfate ions.
- **b.** water ions.
- **c.** hydrogen ions.
- **d.** oxygen ions.

27. Which organic molecule contains nitrogen?
- **a.** carbohydrate
- **b.** lipid
- **c.** cellulose
- **d.** protein

28. What is the first law of thermodynamics?
- **a.** Matter can be neither created nor destroyed, but only transformed.
- **b.** Energy moves from higher forms to lower forms.
- **c.** Energy can be neither created nor destroyed, but only transformed.
- **d.** Matter moves from higher forms to lower forms.

29. It is a fact that heat leaving a teacup never goes back in. Some have called this the "arrow of time." This concept is most closely related to
- **a.** energy.
- **b.** entropy.
- **c.** reactions.
- **d.** expanding universe.

30. Moving electrons are best described as
- **a.** electricity.
- **b.** heat.
- **c.** kinetic energy.
- **d.** light.

Answers

21. b. Epitope refers to cell biology; the others are nonsense words.

22. b. Velocity is a change in distance; acceleration is a change in velocity.

23. d. Pressure is, in fact, a force, usually expressed as force per unit of area (force per square inch or force per square centimeter, in the case of the tire).

24. a. The strong nuclear force exhibits this counter-intuitive behavior.

25. d. The sodium atom has 1 electron in its outermost shell; by losing 1 electron, it achieves a full shell (the next innermost one was already full). The sodium atom achieves an electrical charge of +1, which is the result of, not the reason for, giving up an electron.

26. c. Hydrogen ions come directly from putting H_2SO_4 into solution.

27. d. The amino acids that make up proteins all have nitrogen atoms in them. Cellulose is a form of carbohydrate.

28. c. Thermodynamics covers the properties of energy, and the first law is about the conservation of energy.

29. b. In the teacup example, even though it involves the transfer of energy, the governing rule is the law of the increase in entropy.

30. a. Electricity is electrons in motion.

D. Evolution and Life

1. Origin of Life

Life on Earth has persisted for nearly four billion years. How did it begin?

a. Formation of Organic Molecules

In 1953, a Nobel Prize–winning experiment by Harold Urey and Stanley Miller created organic molecules by passing a spark through a mixture of gases, such as methane and ammonia, presumed constituents of an early Earth atmosphere. Zapping inorganic molecules with energy—a possible analogy to lightning in ancient Earth's atmosphere—could create certain constituents for life.

Other possible sources of organic molecules are (1) from space, because organic molecules do occur in certain types of meteorites, and (2) at deep sea vents, where raw chemicals from the inner Earth provide a source of materials and chemical energy.

b. Concentration of Organic Molecules

To form life, organic molecules need to be concentrated. Darwin had the concept of a warm, little pond as a site for the origin of life. Lagoons that periodically flooded and then dried up might have concentrated organic molecules during the dry stages.

Scientists are not sure of the temperature of early Earth at the time of the formation of life. Some say that were early Earth cold enough for ice to at least occasionally form, the freezing of water, which excludes any organic molecules present, could have concentrated organic molecules at the surfaces of ice.

Clay minerals are complex, and some scientists have suggested clay as a template for the concentration and even organization of organic molecules into more complex networks, on the way to life.

As a possible source of organic molecules, deep sea vents are also candidates for their necessary concentration. In fact, in recent years, various lab experiments have increased the odds that the vents—with hot water rich with minerals and abundant complex minerals—were sites for key steps in the origin of life.

c. Membranes

All cells today have membranes that separate inside from outside and regulate the exchange of matter and energy.

Organic molecules (lipids) from certain kinds of meteorites, when added in water, spontaneously form spherical vesicles (liposomes). According to some, these gifts from space could have created the molecular vesicles that became protocells, within which ran self-perpetuating chemical reactions, a step on the way to real life.

The details of how the origin of life went from simple organic molecules, perhaps enclosed in membranes, to real cells with the genetic machinery of proteins and DNA, are still unknown. Many scientists claim that RNA served as the first genetic material, only later supplanted by DNA, at which time RNA then took on the role of helper molecules in that machinery.

d. Evidence in the Rocks

Evidence for early life is of two types.

An isotope of carbon, carbon-13, is set in a special ratio to ordinary carbon-12 when carbon passes through living metabolisms. Some evidence of this isotopic signature of early life has been found in rocks as old as 3.9 billion years old.

Scientists (micropaleontologists) find ancient rocks, slice them, and look then through a microscope to seek direct visual evidence of cells. There are indications of cells in rocks from 3.5 billion years ago.

To gain clues to the origin of life, scientists seek organisms generally known as **extremophiles** across the Earth. These are bacteria or archaea adapted to (and requiring) extreme conditions of acid or temperature to live (acidophiles, thermophiles, and others).

2. Recipe for Evolution

a. Inheritance, Variation, and Selection

Inheritance is when organisms in each generation share many of the same features of their predecessors, because the DNA is copied from parent to offspring.

Variation: Often, offspring are not exactly like the parents. Variation is key because this serves as the raw material that can be molded by evolution into new types of creatures.

Selection (natural selection) is defined as survival of the fittest. Not all offspring live long enough for themselves to put forth the next generation. Those that can withstand drought, or seek out food most efficiently, or run the swiftest, survive. The filtering process of death upon life selects certain types of creatures to carry on.

In summary, evolution is modification by natural selection. The process repeats: inheritance, variation, selection. It operates over and over, as generations roll along, and it has been doing so for nearly four billion years.

b. DNA and Mutations

The molecule **DNA (deoxyribonucleic acid)** is key to inheritance and variation. It is the famous double helix, with double strands of alternating sugar and phosphate units, between which are set rungs of the genetic code. The code is made of four bases: adenine (A), cytosine (C), tyrosine (T), and guanine (G). Base A always pairs with base T, base C always pairs with base G. The double helix allows a way for DNA to make copies. In the copying process, DNA unravels, and because of the rule of pairing (A-T, C-G), the code on both individual strands can be completed and both made double again, as the complementary bases are added, rung by rung. This copying creates faithful inheritance.

Mistakes, or mutations, in the copying sometimes occur randomly. Most mutations are detrimental to the offspring. But some can be beneficial (for example, a mutation might create a more effective pore in the cell membrane for the transport of nutrients into the cell).

The simplest type is **base substitution**, in which, say, a T is removed and an A, C, or G is substituted. In another kind of mutation, entire genes can be duplicated and put somewhere else into the DNA. If the original gene continues with its function, the duplicated gene is free to mutate into possibly a new and beneficial function.

There can be insertions and deletions from sections of the code.

All the types of mutations potentially serve as variation in the process of evolution.

How does the genetic code become the stuff of life, the metabolism of proteins? Triplets of bases are read off and code for single amino acids (there are about 20 of these). Amino acids are assembled in chains that then fold into complex, bulbous shapes of final proteins. Many proteins are active enzymes, others are structural. Enzymes facilitate the assembly of other types of molecules through chemical reactions inside cells.

c. "Blind Watchmaker" of Natural Selection

Before evolution was accepted, a story about a watch found on a beach was used as a parable to suggest the presence of a creator for all life forms. A watch, being so complex, obviously had a watchmaker. The scientist and master writer of evolution, Richard Dawkins, coined the phrase the "blind watchmaker." Evolution creates wondrous organisms, even though there is no maker, because the process is "blind," it doesn't know where it is going.

3. Types of Cells

a. Prokaryotes

Prokaryotic cells were the earliest type of cell. They are small and simple. The word *prokaryote* means "before" (*pro*) and "kernel" (*karyote*), signifying that the prokaryotes are single cells with no central nucleus (in other words, no kernel). Prokaryotes have their DNA floating inside, and do not contain membrane-bound organelles. Today, there are two types of prokaryotic organisms: **archaea** and **bacteria**. Prokaryotes reproduce primarily by fission of the cell into two equal daughter cells in a process called **mitosis**. Bacteria also have ways to exchange parts of their genomes with different bacteria of the same species or even other species.

b. Eukaryotes

Eukaryotes are larger cells that make up animal and plant matter and fungi. Some types of single-celled creatures, such as amoebas and paramecia, are also eukaryotes. The word *eukaryote* means "good" (*eu*) and "kernel" (*karyote*), signifying that eukaryotic cells have a central, membrane-bound nucleus, which houses the DNA for these complex cells. Eukaryotic cells also have other membrane-bound organelles inside them, which support special functions for the cells. All eukaryotic cells have **mitochondria**, power-plant organelles that take food nutrients and create high-energy molecules used elsewhere in the cell for various metabolic tasks. Plant cells have another organelle, called the **chloroplast**. It is also membrane bound and contains the photosynthetic machinery for the plant cell. Eukaryotic cells have internal structures, like wires and tent posts, called, respectively, **microfilaments** and **microtubules**. These allow the big cells to take on complex shapes (even creep along as the amoeba does).

Eukaryotic cells can reproduce by mitosis (for example, paramecia or our skin cells). In addition, multicellular eukaryotes (animals, plants, fungi) have sexual reproduction for the entire organism, which uses **meiosis** to generate sex cells with half the genetic components (sperm and egg).

c. Cell Evolution by Symbiosis

The eukaryotic cell evolved about two billion years ago, at about the same time that Earth's atmosphere shifted from anaerobic (with virtually no oxygen) to a level of oxygen about ten percent of today's amount. The eukaryotic cell evolved from a symbiotic merger between a large prokaryote and a smaller prokaryote, which eventually became the mitochondrion of the new, eukaryotic type of cell. **Symbiosis** means working together, and the two cells that merged had specific ways to help the other (probably sharing metabolic products that were needed by the other). Eventually, this merger became permanent. Genes were transferred from the small, embedded cell into the genome of the larger host. One strong piece of evidence of this ancient merger is the fact that today's mitochondria still have a remnant of still useful DNA inside them. Also, the mitochondria are about the same size as typical bacteria.

The chloroplast also came about from a symbiotic merger between something like today's **cyanobacteria** (a type of photosynthesizing, chlorophyll-containing bacterium). As in the case of the mitochondrion, most of the DNA from the symbiotic cyanobacteria migrated into the genome of the larger host cell, but there still exists a remnant DNA for a few proteins in the modern cell's chloroplast. Again, the size is also about right for the theory.

Because all eukaryotic cells have mitochondria but only some have chloroplasts, the symbiotic event that created the mitochondria came first. Scientists do not know how the nucleus itself evolved.

d. The Universal Tree of Life

All life possesses DNA and much the same genetic machinery. This is strong evidence that all current life shares a universal ancestry. In addition, all organisms manufacture proteins at cell sites called **ribosomes** (where the amino acids are linked into chains, on the way to forming proteins). The ribosome contains some structural RNA as a permanent subunit. All organisms thus contain rRNA (for ribosomal RNA). This rRNA varies from creature to creature, because the rRNA mutated over time. The closer in structure the rRNA is between two creatures, the more closely related they are.

Scientists can construct a tree of all life, using the degree of similarity of rRNA as the metric to distinguish and group organisms. The rRNA tree of life reveals three major lobes: the eukaryotes, the archaea (a type of prokaryote), and the bacteria (another type of prokaryote). Eukaryotes most likely gained some of their genetic material from the archaea and some from the bacteria.

The universal tree of life constructed from the patterns of rRNA shows that most of the organisms near the trunk (prokaryotes living today that presumably are similar to those that lived long ago, when the tree was near its trunk stage in evolutionary time) are **hyperthermophilic** (they require high temperatures). These creatures might indicate a very high temperature origin for life. Such temperatures would have occurred at the deep sea vents, or possibly over the entire Earth.

4. Multicellular Life

The eukaryotic cells gave rise in evolution to true multicellular life forms: fungi, plants, and animals.

a. Earliest Evidence

Evidence of the first multicelled creatures is obscure because their soft bodies meant they were only rarely preserved as fossils. Scientists use fossil and genetic evidence (the universal tree of life) to estimate the date of origin of multicellularity at about one billion years ago. That means that for nearly three-fourths of the history of life, all creatures were single-celled.

Ediacaran fauna was an early type of multicellular life, which lived about 600 million years ago (MYA). Scientists named these strange, flat creatures found in many shapes and sizes after the Ediacara Hills of Australia, where their fossils were first found. Some scientists believe that the Ediacarans went extinct when predators evolved.

b. Cambrian Explosion

The **Cambrian explosion** was the geological time period of ten million years that began around 540 million years ago, in which suddenly all kinds of animals with hard parts (that is why they were preserved) "exploded" into the fossil record. The hard parts—shells of various types—used calcium from ocean water. Except for the absence of vertebrates, the Cambrian explosion formed most of the basic body plans of animals. The action was all underwater, with **arthropods** (such as **crustaceans** called **trilobites**) and bizarre creatures crawling on the sea floor while others swam and sported formidable jaws. Scientists have not yet determined the trigger for this blossoming of life.

c. Evolution of Trees and Fungi

The **Devonian period** was a period roughly between 300 and 400 million years ago, in which new types of creatures emerged. Important adaptations made this evolution possible. For land plants, these changes included: (1) molecules such as **cellulose** and **lignin** that could give structure to stems and trunks and lift plants up into the air and (2) **vascular tissues** in the stems, trunks, and roots that could transport water and mineral ions up from the roots to the photosynthetic parts (via tubes called the **xylem**) and could transport manufactured food downward from the photosynthetic parts to the roots (via tubes called the **phloem**).

The fossil record shows that plants evolved from tiny, moss-sized beings into tall trees over a period that was only about 20 million years long. No flowering plants (**angiosperms**)—like deciduous trees—existed yet. Fossil evidence shows that fungal cells (visible as microscopic fossils) occurred inside the roots of ancient plants. Apparently, these fungi lived like some kinds of fungus do today, in a symbiotic partnership with plants. Most fungi live as microscopic underground threads, called **hyphae**.

d. Animals

What makes an animal? One defining characteristic is a **blastula stage** (a hollow ball of cells) during early embryonic development.

Vertebrates evolved in the ocean as fish.

Animal life came ashore during the Devonian, as fishlike creatures with four legs (tetrapods). Besides the legs, lungs were another key development for what became **amphibians**.

To become fully terrestrial, vertebrates had to solve the problem of living in the desiccating air. **Reptiles** became terrestrial with adaptations like a water-retaining amnion (sac) in their embryo stages, a waterproof egg, and a watertight skin of scales.

Mammals evolved by around 200 million years ago, from mammallike reptiles, which had split off as a branch of reptiles about 260 million years ago. Adaptations of mammals include hair and nursing the young with mammary glands.

5. Mass Extinctions

In just the last 20 years, we have discovered what caused the extinction of the dinosaurs. The answer has given new understanding to what factors contributed to the story of life.

a. Origin of the Dinosaurs

Dinosaurs are a group of reptiles that diverged from early reptiles by 220 million years ago. An adaptation of dinosaurs was a new kind of hip joint that allowed many early (and late) dinosaurs to run bipedally. Species of dinosaurs came and went over more than one hundred and fifty million years of time, until their sudden extinction at 65 million years ago.

b. Evidence for Impacts from Space

Objects from space occasionally strike the Earth—evidence includes the meteor crater in northern Arizona and the Sudbury crater in Canada (the result of a much larger impact occurring about two billion years ago). The longer the time period between impacts, the more chance for a devastating impact. (Small objects enter Earth's atmosphere every night, and burn up—shooting stars.) On the Moon and Mars where little or no geological change occurs, scientists see evidence (craters) of large impacts. On Earth, as wind and water shift sediments, as continents rise and fall, most craters are buried or erased.

c. End of Cretaceous and End of Dinosaurs

In the 1980s, an unusually large amount of a rare element called iridium (Ir) was discovered in a centimeter-thick clay layer in rocks in Italy, dating from the time of the dinosaur extinction. This anomaly of iridium was subsequently found all over the world.

Iridium only occurs at such concentrations in meteorites. This discovery pointed to a large impactor (comet or asteroid) as the cause of the iridium and the mass extinction. Such an object would have smashed into the Earth at a speed of 20 km/sec, and is estimated to have been about the size of Manhattan (say 10 km or 6 miles in diameter).

A few years later, evidence from gravity patterns (mapped by a Mexican oil company, during prospecting) revealed a crater buried under sediments in the Yucatan Peninsula of Mexico. About 200 km in diameter (about the estimated size of the crater made by a 10–km object), it dates to exactly 65 million years ago, the end of what geologists call the **Cretaceous** (K) and the beginning of the **Tertiary** (T). A wealth of other types of evidence for the **K-T impact** has been found, including material ejected close to the impact and shocked minerals, as well as chemical evidence for worldwide fires and other environmental disruptions.

At the K-T boundary, 65 million years ago, many other types of life also went extinct, on all scales, all the way down to the plankton. One group of creatures survived that had been alive at the time of the K-T extinction and were directly descended from the dinosaurs. These are the birds. And, fortunately for us, mammals survived, too, probably because the mammals back then were only the size of rats, and could weather the catastrophe underground in burrows.

d. End of Permian

Another large extinction occurred 250 million years ago, at the end of the **Permian era**, and beginning of the **Triassic** (the P-T boundary). It came just before either dinosaurs or mammals existed, during an age of giant amphibians and early reptiles. Some paleontologists have called this the mother of all mass extinctions. What caused it is not yet known.

e. Other Mass Extinctions

Species are always going extinct. But once in a while comes a mass extinction, which we know from the fossil record. In some cases, scientists name climate change or large impacts as the cause.

Though the stories of individual mass extinctions are still being assembled from field data, the discovery of the K-T impact and the mass extinction of the dinosaurs has given us new insight into how precarious life on Earth has been and how evolution has been subjected to random shocks from space. What if the impact had been larger? And what if it had not taken place? Before the dinosaurs went extinct, mammals had remained small for over a hundred million years. In the millions of years following the demise of the dinosaurs, mammals evolved into a huge variety of species, some of them as big as hippopotamuses and elephants. In terms of evolutionary biology, the mammals radiated. Without the K-T extinction, this radiation would not have occurred.

6. Human Evolution

a. Chimps, Gorillas, and the Hominid Tree of Life

The molecular clock, the rate at which certain proteins mutate over time, has been used to date the divergences of evolutionary lineages of humans from the great apes: orangutans, gorillas, and chimpanzees. These are all modern creatures. The point is to know the time of the common ancestors.

At about 12–15 MYA, the lineage leading to orangutans diverges.

At about 8–10 MYA, the lineage leading to modern gorillas diverges.

At about 5–7 MYA, humans and chimps share a common ancestor. Many lines of evidence—from morphology to genetics—show that chimpanzees are our closest living animal relative.

b. Many Species of Hominids

Australopithecus is the genus that evolved in Africa after the hominids' divergence with chimps.

Australopithecus africanus is the species thought to be a human ancestor; the fossil called "Lucy" was this species, which lived about 3.5 million years ago. It had a brain size equivalent to the modern chimp's (humans' famed evolutionary brain growth had not yet begun), but the species stood upright and its legs, feet, spine, pelvis, and skull were adapted to upright living. Some paleontologists suggest that living upright freed the hands to carry objects (but no real stone tools yet), and that caused selective pressure for more braininess.

Homo is the genus of modern human, which evolved by 1.5 million years ago. An early important species in genus *Homo* is *Homo erectus*, which evolved in Africa but spread over wide parts of the world, as far as China and other parts of Asia. Some paleontologists think a closely related species, *Homo ergaster*, is more likely our direct ancestor. Compared to *Australopithecus*, the brains and bodies of *Homo erectus* and *Homo ergaster* are larger. Scientists have found evidence of the first stone tools—crudely chipped rocks—which were likely made for cutting meat, scraping, and pounding.

There were other species of genus *Homo* in the time between 500,000 to 200,000 years ago. Paleontologists are still sorting out (and discovering) evidence. Some of these species reached Europe and evolved, by 150,000 years ago, into *Homo neanderthalis*, the Neanderthals. They were large and powerfully muscular, with brow ridges above their eyes, and slightly bigger brains than humans have today. Though the word Neanderthal is sometimes used to mean "dumb," these creatures are considered intelligent. Why did they go extinct? Was it from competition with our species? Was it climate change? They did survive in Europe and Russia during a deep ice age.

Homo sapiens, the species of modern humans, originated in Africa by about 150,000 years ago. *Homo sapiens* migrated from Africa into the mideast and even shared land with Neanderthals in some cases. Over this span of human evolution, from *Australopithecus africanus* to *Homo sapiens*, brain size increased about threefold. Human brains (relative to body size) are way above the mammalian average and enormous even for the brains of primates.

c. The Creative Explosion

A creative explosion occurred between about 60,000–30,000 years ago and included complex tool making (using animal bones for needles, harpoons, and other craft items), clothing, and elaborate burial practices. An early sculpture from Germany shows what seems to be a standing man with a lion's head. Was this a shaman? Does this signal the birth of myths? (Some scholars claim we will find evidence for art even earlier, when the time period of 100,000 years ago is examined more carefully in Africa.) By 30,000 years ago, we have evidence of paintings deep within caves, elaborate color paintings of animals, usually the animals that were hunted. Were these the sites for rituals? For initiation ceremonies?

A find in the Ukraine, dated at about 15,000 years ago, shows that these people constructed dome homes out of mammoth bones, probably covered with mammoth hides. Thus, they had architecture.

What was their language? Scholars tend to agree that by the time of cave art and elaborate bone tools and carvings, language was used to educate the young and to organize complex social dynamics. But did language come even earlier? And was the creative explosion due to a final genetic advance or was it all cultural? Scientists do not yet have the answers.

d. Evolutionary Psychology

Evolutionary psychology is the study of the evolution of human behavior; considered controversial by some because scientists are limited in studying the minds and emotions of ancestral humans. No other mammal species wages war—although male chimps have been observed in similar behavior, forming a band to kill a solitary individual in a competing band. Humans also cooperate to an unprecedented degree. In a central African jungle lives another kind of chimp called the bonobo. Unlike the male-dominated chimp, the bonobo has a female-bonded society and uses sex as a social lubricant. Chimps and bonobos genetically diverged 2–3 million years ago, after their shared lineage diverged from the lineage that led to us. Evolutionary psychologists study chimps and bonobos to investigate how the behavior of humans may have evolved.

The human brain contains an organ that senses danger and creates the emotion of fear (the brain organ is the **amygdala**). Humans share this with other mammals and most vertebrates. But humans can also project into the future more than any other creature. We know we are going to die. Evolutionary psychologists investigate whether this knowledge is lined with the origin of religion.

You Should Review

- cell evolution
- prokaryotic and eukaryotic cells
- major events of evolution
- major adaptations leading to new kinds of organisms
- steps in human evolution
- mass extinctions

Questions

31. The four bases of DNA are

- **a.** ACEG.
- **b.** CMEP.
- **c.** TAGC.
- **d.** MGPA.

32. Considering the problem of the origin of life on Earth, which is not a possible source of organic molecules?
a. dissolution of rocks
b. lightning in the atmosphere
c. deep sea vents
d. meteorites from space

33. Which cell type has a nucleus?
a. bikaryotic
b. prokaryotic
c. eukaryotic
d. postkaryotic

34. For what fraction of the span of life's existence on Earth was life only microbial?
a. $\frac{1}{1}$
b. $\frac{3}{4}$
c. $\frac{1}{2}$
d. $\frac{1}{5}$

35. A lichen is a symbiosis between which two organisms?
a. animal-plant
b. algae-fungi
c. plant-fungi
d. animal-algae

36. What was the mass extinction that ended the reign of the dinosaurs?
a. Cretaceous-Tertiary
b. Permian-Triassic
c. Triassic-Jurassic
d. Carboniferous-Permian

37. The most direct ancestor of the mammals was a
a. mammal-like amphibian.
b. mammal-like reptile.
c. mammal-like fish.
d. mammal-like crocodile.

38. Which animal today is the direct descendant of the dinosaurs?
a. ostrich
b. white shark
c. African lion
d. humpback whale

39. About how many times larger are brains of humans today, compared to our Australopithecine ancestors about three million years ago?
a. $2\times$
b. $5\times$
c. $8\times$
d. $3\times$

40. Which is the second oldest, in terms of evolution?
a. *Homo erectus*
b. *Homo sapiens*
c. Neanderthal
d. *Australopithecus*

Answers

31. c. The four DNA bases are tyrosine, adenine, guanine, and cytosine.
32. a. Dissolution of rocks creates ions in water, but this has nothing to do with actually forming organic molecules. All the other choices are definite possibilities.
33. c. Eukaryotic cells have a nucleus in each cell. The word means "good (or true) kernel."
34. b. Life became single celled nearly four billion years ago but multicellular life did not evolve until about one billion years ago. Therefore, the time period over which life was only microbial was $\frac{3}{4}$ of the total time of life.
35. b. A lichen on a rock (often flat) is a working partnership (a symbiosis) between a green algae and a nutrient-gathering fungi.
36. a. The Cretaceous-Tertiary event caused the extinction of the dinosaurs, about 65 million years ago. (This is also called the K-T boundary—K for Cretaceous, in geologist's terminology.)

37. b. Because fish evolved into amphibians, which evolved into reptiles, the ancestor of mammals was a mammallike reptile. Crocodiles came much later.

38. a. The ostrich, like all birds, is a descendent of the dinosaurs.

39. d. 3× is the amount that brain size increased during human evolution.

40. a. *Homo erectus* came after *Australopithecus* but well before Neanderthal and *Homo sapiens*.

E. Earth Works

1. Continental Drift and Plate Tectonics

a. History

In 1912, German scientist Alfred Wegener proposed that continents could move around, they could "drift." One of Wegener's clues to the drift was the fact that the east coast of South America could fit into the lower half of the west coast of Africa, almost like puzzle pieces. Wegener also pointed to evidence in South America, Africa, India, and Australia for ice sheets at about the same time, 300 million years ago, which made no sense with the continents in their present positions, because some of these sites are at today's equator.

Modern geologists have evidence that continents have shifted positions radically throughout Earth's history. For example, when molten rock (**magma**) cools to become solid rock, if the rock is slightly magnetic, it takes on the magnetic field of the Earth, which depends on latitude. Rocks near the poles have signatures of ancient latitudes near the equator and vice versa.

b. Seafloor Spreading

In the 1960s, new lines of evidence supported the idea of shifting continents, but the focus changed to the spreading ocean floor. Ships drilled and brought to the surface cores from the ocean's rocky floor and analyzed them for periodic reversals in Earth's magnetic fields in the lava that came to the surface.

On both sides of the Atlantic Ocean's mid-ocean ridge, stripes showed times when Earth's magnetic field was normal and reversed. The ocean's floor had been growing over time, and the Atlantic Ocean slowly increasing in size. This ocean floor was like a tape recorder of the history of seafloor spreading. The Atlantic Ocean spreads at a rate of 1–2 inches per year (consider that rate over tens of millions of years).

Finally, scientists had a mechanism for continental drift. It wasn't that the continents drifted but they were moved by changes in the ocean's floor. Seafloor spreading replaced continents drifting.

c. Subduction Zones and Plate Tectonics

If the Atlantic Ocean is growing, what about the other oceans? Because the Earth is a constant size, the other oceans cannot be growing, too. However, there is a north-south underwater volcanic ridge in the Eastern Pacific, and that is spreading even several times faster than the Mid-Atlantic Ridge. Eventually, the solution was found in the discovery of what are called **subduction zones**. These are regions ("lines") where ocean crust disappears by diving down into the deep Earth, by subducting. The loss of ocean floor (crust) in subduction zones balances the creation of new ocean floor (crust) in mid-ocean ridges.

The modern theory of **plate tectonics** was thus born. Earth's geological activities have always been called **tectonism**. What about the term **plate**? Think of an egg shell with patterns of cracks in it, creating zones of the shell. That's the crust of the Earth. Earth's surface is divided into a number of major plates. Sometimes, continents ride within the areas of the plates; sometimes edges of continents coincide with edges of other plates. From some of the edges of the plates emerges new ocean crust from mid-ocean ridges and seafloor spreading. Into other cracks, ocean crust subducts (the western coast of South America and the ocean trench regions of the western Pacific are examples). Plates grow and shrink in size with the geological ages. Thus, continents shift positions.

South America, Africa, and Antarctica were all joined as recently as 200 million years ago.

Plate tectonics is an overarching theory that solves many separate mysteries about geology. What made mountain ranges? Why do earthquakes and volcanoes occur where they do? Why is there a "ring of fire" around the outer edge of the Pacific Ocean, a ring with huge numbers of earthquakes and volcanoes? It turns out that earthquakes and volcanoes tend to occur at the boundaries between two plates, because that is where geological activity happens. The Pacific ring of fire occurs because the Pacific Ocean is ringed by many plate edges. The famous San Andreas fault in California, which is the origin of California's earthquakes, is a plate boundary (here the two plates are sliding past each other, neither subducting nor spreading apart). The towering Andes mountain chain along the western coast of South America has been lifted up by a plate plunging under South America from the west, putting pressure from below to lift the mountains up.

d. Earth Over Time and the Geological Time Scale

Planet Earth coalesced from planetary materials brought together by gravity about 4.6 billion years ago (BYA).

Hadean (4.6–4 billion years ago) was the earliest eon and means "time of hell." The Earth still experienced many bombardments from space.

The **Archean** eon (4–2.5 BYA) was when single-celled life originated.

The **Proterozoic** eon (about 2,500–545 millions of years ago) was the time of the first great rise in oxygen and evolution of eukaryotic cell about 2,000 MYA. Near the end of the eon, multicelled life evolved. There is also evidence for massive ice ages, which came close to covering the entire Earth in ice sheets.

The **Paleozoic** eon (545–250 MYA) started with the Cambrian explosion of life and by its end, plants had evolved into tall trees. Giant amphibians and early reptiles were the dominant life on land.

The **Phanerozoic** is the current eon, further divided into eras. The Mesozoic era (250–65 MYA) is subdivided into three main periods called the Triassic, Jurassic, and Cretaceous. The Jurassic was the reign of dinosaurs. The mass extinction at 65 MYA ended the dinosaurs' existence and the Mesozoic period.

The **Cenozoic** period (from 65 MYA to today) is the age of mammals. The **Pleistocene** epoch (a subdivision of the Cenozoic period) lasting from 2 MYA to 10,000 years ago, is a time of the growth and then retreat of giant ice sheets, in cycles of about 100,000 years each. During the height of the last ice age, for example, ice sheets a mile thick covered all of Canada and extended as far as New York City. Sea level was 100 meters lower, and the ocean was therefore far offshore of its present location. At the final deglaciation, about 10,000 years ago, geologists end the Pleistocene and start a new epoch, called the **Holocene** (for "wholly recent"). Because humans are perturbing so much of the planet, there has been the suggestion that we have inaugurated what should be called a new epoch, perhaps the "anthropocene," the "human-made recent."

2. Earth's Layers

a. Core and Mantle

When the Earth formed 4.6 billion years ago, the heat generated from all the impacts that formed it, and heat from the high levels of radioactive rock, put the Earth into a molten state. Being molten, elements and minerals could separate according to their density. The heavier materials sunk toward Earth's center. The lighter materials floated, so to speak, nearer the surface.

Earth's metallic core is solid near the center and liquid further out. It is about 1,200 kilometers thick and mostly iron, with smaller amounts of nickel and other elements.

Circulation of the liquid iron in the core generates Earth's magnetic field. This field is related to Earth's spin, but the north and south magnetic poles are not in the same locations as the north and south poles of Earth's spin axis.

Outside the core is the layer called the **mantle**. With a thickness of about 2,800 km, the mantle reaches to 10–50 km below the surface. The upper layer of the mantle belongs to the lithosphere (see below). Then, below the lithosphere and about 250 km thick, is a layer of the mantle called the **aesthenosphere**. This is crucial because although made of rock, the aesthenosphere can move like putty over long time periods. The circulation of the aesthenosphere is one main factor in plate tectonics.

When Earth's crust enters subduction zones, the material sinks back down into the aesthenosphere (in other words, into the mantle), melting and joining with the deep Earth material.

b. Lithosphere

Lithosphere (literally "rock-sphere"), the uppermost and lightest layer, consists of the outermost crust and a thin upper part of mantle. Below the lithosphere, the rock is malleable (the putty of the aesthenosphere). The lithosphere itself, being cooler, is brittle. The border between lithosphere and aesthenosphere is defined by this change in behavior of the rock, from brittle to malleable.

The crust under the ocean's water is thin, about 10 km deep.

The crust under the continents is thick, about 50 km deep.

c. Oceans

The average depth of the ocean is about four km. Around the continents, the ocean is shallow, about 100–300 meters deep. This so-called continental shelf is really part of the continental mass. Heading seaward from the continental shelf, the bottom of the ocean drops downward in a steep slope. This region is called the **continental slope**.

Much of the ocean, at its deepest, is in the 3–5 km range of depth. Exceptions are the very deep trenches, formed where slabs of ocean floor are subducting downward into the mantle at plate boundaries. Other exceptions are the mid-ocean ridges, which are mountains ranges underwater where new crust is forming, as described above.

At places on the Earth, plumes of magma in semi-permanent tubes from the mantle rise into the lithosphere. These are the **hotspots**. For example, the Hawaiian islands have been formed by one of these hotspots. As the Pacific plate moves westward (its motion created by plate tectonics), the plate moves over the hotspot (which remains approximately stationary). The Hawaiian islands have been formed, one by one, sequentially, as the Pacific plate moved over the hotspot over tens of millions of years. Therefore, the oldest Hawaiian island is the one furthest to the west, Kauai. The most recent Hawaiian island, with active volcanoes, is the "big island," called Hawaii itself. Because new ocean floor (crust) is continually being formed and then subducted, the average age of the oldest ocean floor is about 100 million years.

d. Continents

The continents are also part of the crust, much thicker than the ocean-floor crust. Continents that are elevated because of mountain ranges also have deep roots below. The continental masses, in a sense, float on the heavier aesthenosphere.

Continents form when relatively light magma bursts from below to the surface, solidifying as rock. Plate movements that rub bits of crust together can cause continents to grow as the lightest material ends up staying on the surface.

Geologists believe that the early Earth had almost no continents or, at most, very small ones. Continents have generally been growing throughout time, because once the light rock reaches the surface it tends to stay there.

A distinctive feature of continents is mountain ranges, which rise and then are eroded over tens of millions of years or more. Rocks on continents can be very old. Some of the oldest, more than three billion years old, are found in Canada and Australia.

3. Rocks and Minerals

a. Igneous

Igneous rock, that was once very hot and molten, makes up most of Earth's crust. Molten magma from under Earth's surface, when it cools and solidifies, becomes igneous rock. Volcanoes create igneous rock (extrusive igneous rock). Molten intrusions under the surface also create igneous rock (intrusive igneous rock). The base of the ocean's floor is igneous rock, having emerged at mid-ocean ridges. Types of igneous rock include granite, rhyolite, gabbro, and basalt.

Igneous rocks have crystals of minerals, which form when the magma cools and becomes rock. The slower the cooling, the larger the crystals. Therefore, crystals are larger in intrusive igneous rocks.

b. Sedimentary

Sedimentary rock is formed by underwater sediments in the ocean. It is derived either from tiny particles physically deposited or from precipitation of chemicals from the seawater. It makes up most of Earth's surface. Fossil evidence for the origin of life comes from sedimentary rocks (3.5–3.9 BYA).

Some types of sedimentary rock are made from physical particles cemented together: conglomerate (from sedimented gravel), sandstone (from sedimented sand), siltstone (from sedimented silt), and shale (from sedimented mud). Note that this sequence progresses from coarse to fine particles.

Some types of sedimentary rock are made primarily from chemical precipitation: limestone (from the mineral calcite) and dolostone (from the mineral dolomite). Calcite and dolomite are calcium carbonate and calcium-magnesium carbonate, respectively. These precipitates are biogenic, created by organisms that precipitate shells. The shells later were fused into rock. Examples of limestone are the white cliffs of Dover in England and much of Indiana, Illinois, and Florida. Other types of sedimentary rock are created from precipitation during the evaporation of seawater: halite (salt) and gypsum (calcium sulfate).

c. Metamorphic

Metamorphic rock is created when either igneous or sedimentary rock is subjected to great heat and pressure. Rock already at Earth's surface can be buried deep, creating heat and pressure, or trapped in a mountain-building event, which squeezes the rock and twists the sediments. The mineral structure is changed though the rock is not melted (that would turn it back into igneous rock). Some types of metamorphic rock include slate (from shale), marble (from limestone), and quartzite (from sandstone).

d. Element Abundances

Rocks are made of specific minerals, with definite chemical compositions and crystal structures. The minerals can be classed by hardness. Diamond, of course, is the most hard, with number ten on Mohs Scale of Hardness. Talc is the softest, at number one on the scale. Other examples include calcite (hardness 3) and quartz (hardness 7).

What elements make up the crust of the continents? Here are the main elements and their percentages, rounded off to whole numbers: Oxygen (45%), silicon (27%), aluminum (8%), iron (6%), calcium (5%), magnesium (3%), sodium (2%), potassium (2%), and titanium (1%). Hydrogen, manganese, phosphorus, and all the others make up the rest.

The large amount of oxygen and silicon in the crust means that many minerals are silicon oxides, or silicates. Other elements join in to create different kinds of silicates, such as magnesium-iron silicates, magnesium-aluminum silicates, and so forth.

Elements are shifted from rock to the ocean by two processes. In physical weathering, bits of rock are sloughed off and transported by rivers to the ocean. In chemical weathering, minerals are actually dissolved in water, and are then transported to the ocean. In this way, one kind of rock contributes to the chemistry of future kinds of rock. Rocks are thereby recycled and reformed.

4. Structure of the Biosphere

The biosphere is the thin, dynamic upper layer of our planet, which includes air, water, soil, and life.

a. Atmosphere

The atmosphere has a mixture of gases: nitrogen (N_2, 78.08%), oxygen (O_2, 20.95%), and argon (Ar, 0.93%). These three gases make up most of dry air; all the other gases are only 0.04% of the total. Of these, the most abundant is carbon dioxide or CO_2 (0.037%). Water vapor is not included in the dry air percentages, because it varies with the humidity, from 0.3% to 4%.

Clouds consist of huge numbers of condensed water droplets, microscopic aerosols. Clouds are important to climate, not only as the sources of precipitation but as reflectors of sunlight. Globally, clouds reflect about 30% of the sunlight back into space.

The atmosphere has four layers:

1. **Troposphere:** the lowest layer, about 15 km high (which varies with latitude and seasons). Weather takes place in the troposphere; almost all clouds are in the troposphere. Temperature decreases with height in the troposphere.
2. **Stratosphere:** next layer, up to about 50 km (between troposphere and stratosphere is a thin transition zone called the **tropopause**). Temperature increases with height in the stratosphere, primarily because in the upper regions the gas ozone (O_3) absorbs much of the ultraviolet energy in the Sun's spectrum.
3. **Mesophere:** layer up to about 80 km (between stratosphere and mesosphere is a transition zone called the **stratopause**). Temperatures again drop with increasing altitude.
4. **Thermosphere:** in this layer, temperatures rise with altitude. The air in this zone is extremely thin.

Air pressure drops exponentially with altitude. For example, at the top of Mount Everest, it is only about 40% that of the pressure at sea level. If one were to compress the atmosphere all to a uniform pressure equal to that at sea level, the atmosphere would only be about 10 km thick (6 miles).

The winds, which move air from surface regions of high pressure to regions of low pressure, mix the entire atmosphere, even between northern and southern hemispheres, in about a year.

The spin off the Earth creates the **Coriolis force**, which makes winds around low pressure systems in the northern hemisphere turn counterclockwise and winds around high pressure systems turn clockwise. The directions are reversed in the southern hemisphere.

b. Hydrosphere

The oceans are also mixed by surface currents, moved by the winds and tides. Large-scale, ocean-wide gyres (a circular ocean current) turn the water, and in places near certain western coasts of the ocean the flow intensifies to true currents: the Gulf Stream off the American Atlantic coast, the Pacific's Kuroshio Current off Japan, and the South Atlantic's Brazil Current off Brazil.

The large, basin-wide ocean gyres circulate clockwise in the northern hemisphere (North Pacific, North Atlantic) and counterclockwise in the southern hemisphere (South Pacific, South

Atlantic). Again, the Earth's spin and the resulting Coriolis force is the cause of these patterns.

The oceans have a second, different kind of circulation: the **thermohaline**, ("temperature" (*thermo*) + "salt" (*haline*)—the factors that determine the density of water). When water gets cold, for example, in winter at high latitudes, it becomes more dense and will tend to sink. When sea ice forms, also in winter at high latitudes, the freezing of fresh water into ice leaves the remaining ocean water more salty. Saltier water is heavier water, and also tends to sink. These two factors create the densest water at certain high latitude regions, particularly in the north Atlantic and around Antarctica, in winter. This dense water plunges downward, flooding the deep basins of the world's oceans with cold water. Thus, surprisingly, if one goes downward from the hot water at the surface of the equator, one finds near the bottom a thick layer of water that is just a couple degrees above freezing. This cold water has come from the polar regions.

Considering the surface gyres and the deep thermohaline circulation, the world's oceans circulate in about 1,000 years. In that time period, all is mixed from surface to deep.

Oceans cover about 71% of Earth's surface.

The dominant ions in seawater are chloride (55% by weight), sodium (30%), sulfate (8%), magnesium (4%), and calcium (1%). When precipitated, the sodium and chloride form salt, though the other elements are present as well.

c. Soil

Soil is derived from two factors: rock that has been physically weathered to small particles and biological material such as dead leaves. The amount of organic matter in the soil (from leaves and parts of organisms, for example) decreases with depth in the soil. Soil is typically about a meter thick, but this varies tremendously from place to place.

The amount of organic matter in the soil depends on the vegetation and, most crucially, on the temperature. Bacteria and fungi in the soil feed upon and thus break down the organic matter. This rate of breakdown changes with temperature. At higher temperatures, the bacteria are more active, at lower temperatures, less so. Very cold climates, then, tend to have thick soils with a high content of organic matter. Famous for this are the peats of northern Canada and Siberia. Tropical soils, despite the rich vegetation, tend to be thin with low amounts of organic matter, because the breakdown (decomposition) is so rapid.

Soils hold water, to greater or lesser degrees. This water dissolves elements from the mineral grains in the soil (the material that came from parent rocks). The resulting dissolved ions serve as new sources of nutrients for the plants. The dissolved ions can also move away from the soil and into groundwater. These ions are carried by the flow of groundwater into streams and then rivers, eventually depositing them into the ocean.

The soil is key to the recycling of elements from vegetation to ions and then back to vegetation. As bacteria and fungi feed on the detritus from vegetation (leaves, dead roots, branches), they return elements to ionic forms in the soil water, making these nutrients again available for the plants.

Organisms in the soil must breathe. They can do so because air circulates between atmosphere and soil, via pores in the soil.

d. Life

Life is an active part of the biosphere, and it makes a huge difference to the surface state of the planet—in fact, to soil, ocean, and atmosphere.

Without life, there would be essentially no soil, only sand piles here and there between large zones of bedrock. The roots of plants and the organic matter from the detritus of plants create a matrix that holds soil together, a matrix that can retain water. Furthermore, the acids put forth by certain forms of soil life increase the rate of chemical weathering of soil minerals.

Regarding the oceans, algae photosynthesize at the surface where the sunlight is. Other creatures feed on the algae. Their waste and also the dead bodies of algae sink downward. This removes elements from the surface of the ocean and places them into deep water. The elements circulate back up to the surface via the currents and the thermohaline circulation. Life, therefore, affects the chemistry of the ocean.

Life affects the atmosphere. Oxygen would be virtually nonexistent without photosynthesis. Other gases, such as carbon dioxide and methane are also altered by the presence of life. Compared to the CO_2-rich atmospheres of Mars and Venus (with hardly any oxygen), Earth's atmosphere is low in CO_2 and high in O_2.

You Should Review

- basic geological structure of Earth
- theory of plate tectonics
- geological time scale
- types of rocks
- structure and composition of atmosphere, ocean, and soil

Questions

41. The Atlantic Ocean is
  a. growing at several kilometers per year.
  b. shrinking at several kilometers per year.
  c. shrinking at several centimeters per year.
  d. growing at several centimeters per year.

42. The San Andreas fault in California is a
  a. subduction zone.
  b. spreading ridge.
  c. place of magnetic reversal.
  d. site of plate slippage.

43. Key evidence for the modern theory of plate tectonics came from
  a. the apparent fitting together of continents.
  b. mapping of depth contours on the ocean bottom.
  c. magnetic field stripes in the Atlantic ocean's floor.
  d. chemical analysis of volcanoes.

44. The Earth has layers because
  a. all planets have layers when they form.
  b. elements were in layers in the gas nebula that formed the solar system.
  c. it was once molten.
  d. plate tectonics causes geological shifts.

45. The Hawaiian islands are in a chain because
  a. the volcanism that made them came from a long crack.
  b. they were made over millions of years.
  c. the Pacific plate has moved over a hotspot.
  d. they are part of the East Pacific rise.

46. Which type of rock emerges from a volcano?
  a. igneous
  b. sedimentary
  c. metamorphic
  d. hadean

47. What kind of rock is marble?
  a. igneous
  b. sedimentary
  c. metamorphic
  d. hadean

48. When magma cools slowly,
  a. its mineral crystals are small.
  b. it has streaks.
  c. its mineral crystals grow large.
  d. it has bubbles.

49. Which is the second most abundant gas in Earth's atmosphere?
  a. carbon dioxide
  b. oxygen
  c. nitrogen
  d. water vapor

50. The thermohaline circulation is
- **a.** the way the polar atmosphere mixes.
- **b.** the way the deep ocean mixes.
- **c.** the way the lithosphere mixes.
- **d.** the way the soil mixes.

Answers

41. d. The Atlantic Ocean is growing in width, as magma at the mid-ocean ridge spreads the ocean floor, at a very slow rate.

42. d. At the San Andreas fault, two continental plates are slipping past each other. This happens in occasional jolts, causing the earthquakes in that region.

43. c. Magnetic field stripes in the Atlantic ocean's floor showed that the floor was growing in size, spreading away from the Mid-Atlantic Ridge.

44. c. Earth, in its early "years," was molten which caused heavier materials to sink toward the center, segregating the Earth into layers.

45. c. The chain of Hawaiian islands demonstrates what happens when a tectonic plate moves over a stationary plume of magma (a hotspot) in the underlying mantle.

46. a. Rock that solidifies from the molten state is igneous rock. Hadean (choice **d**) does not at all apply here.

47. c. Marble is a classic metamorphic rock, having been transformed from limestone.

48. c. The crystals grow relatively large when the magma cools slowly. Whether it has streaks or bubbles cannot be determined from the information given.

49. b. At about 21%, oxygen is number two, after nitrogen. Even under the most conditions, water vapor does not become as high as oxygen.

50. b. The thermohaline (referring to temperature and salt) creates dense water that sinks in the polar regions of the ocean, thereby mixing the deep ocean.

F. Biodiversity and Ecology

1. Species and Biodiversity

One can note biodiversity on a number of scales, from genes to ecosystems. But the focus at some point always comes down to that of species.

a. What Is a Species?

In its classic sense, a **species** is a group of genetically related organisms with the potential for mating and producing offspring who are themselves capable of successfully mating. For example, robins can only reproduce with other robins. A species is thus reproductively isolated.

Reproductive isolation is brought about by any number of evolved mechanisms: physical mating apparatus, mating rituals, genetic compatibility. Geographical separation often plays a role in allowing different populations of a species to genetically diverge and separate into two different species over time.

A **subspecies** is a taxonomic level within a species that is genetically distinct but not reproductively isolated. In other words, members of different subspecies can reproduce. For example, the Florida panther is a subspecies of the mountain lion, which lives in the western United States (but formerly lived all across the United States).

In 1973, the Endangered Species Act was passed to protect any species whose population is declining to such a level that the existence of the species is threatened.

b. How Many Species?

Today, we have catalogued and defined about 1.5 million species. Total species estimates range from 3–30 million. Most ecologists think the number is somewhere in between, perhaps ten or more million. Occasionally, a new primate is discovered (for example, a new monkey was discovered recently in South America), but most undiscovered species are insects.

Estimates are made by surveying regions where new species are found. One technique kills all the insects on a specific tree, say in the tropics. The insects are surveyed for new species that seem to be specific for that tree. Then, knowing how many trees are in the area, one can estimate the number of unknown insects in that area.

Here are some different groups of organisms and the number of species currently known: plants (250,000), insects (750,000), fungi (50,000), mammals (4,000), and birds (8,000).

c. Classification

Organisms are classified according to a nested hierarchy of named groups. Each species has a double name of genus and species. Humans are *Homo sapiens*. The word **species** gets applied in two different ways: The species is *Homo sapiens*, which consists of a genus (*Homo*) and the species name (*sapiens*). Within any genus, there can be many species. The ancient Neanderthals, *Homo neanderthalensis*, are the same genus as modern humans, but a different species.

Levels of classification (in increasing levels of inclusivity):

family (more inclusive than genus)
order
class
phylum
kingdom

d. Tropical Biodiversity

The tropics, in particular the rain forests, are famed for their biodiversity. Maps of the numbers of species, from poles to tropics, for amphibians, trees, and others show species diversity increasing in almost all cases toward the tropics. A single forest plot in South America could have as many species of butterfly or tree as all of England. There are many possible reasons for the high diversity in the tropics.

The high amount of Sun in the tropics supplies energy to the plants, which, in turn, supports more animals. The larger the amount of mass that can be supported, the larger is the potential number of species.

Stability of climate allows species to enter into highly specific arrangements with each other. Species of fig tree, for instance, are pollinated with a single species of fig wasp. Both depend on each other. Also, during the recent ice ages, the tropical rain forests might have dried up into zones called **refugia**, where pressures to evolve made many new species.

The high latitudes experience large seasonal changes, which makes those species more adapted to wide geographical ranges, creating less diversity.

e. Biomes

Biomes are large geographical regions within which are relatively similar basic types of plant and animals. A biome is larger than an ecosystem. The main determining factors that give shape to biomes are temperature and rainfall.

Tundra is characterized by polar regions with tiny plants produced during short summer growing seasons. It has thick soils of peat because of slow decomposition.

Boreal forest is characterized by evergreen trees such as spruce and fir across Canada and Russia. It has cold winters but warm summers.

Temperate deciduous forest is characterized by trees such as maple, birch, and oak, which lose their leaves each winter. It has cold winters and hot summers with adequate rainfall for trees. Despite the loss of the leaves, deciduous trees in these regions fare better than evergreen trees because flat leaves are more efficient solar collectors than needles.

Prairies and grasslands are characterized by warmer summers than areas of deciduous forests, but less rainfall. Hot dry summers create conditions for fires, which is often an important part of the structure of these biomes. Clearing native grasslands has created some of the great "breadbasket" farmlands of the world.

Deserts are very dry biomes with little rain. Plants and animals have special adaptations. Many plants are bulbous (cacti) to store water in their bodies for times of extended drought.

Tropical seasonal forests and rain forests: Some areas of the tropics have wet and dry seasons. In these areas, many trees can also be deciduous because they lose their leaves during the dry seasons. In the rain forests, enough year-round moisture supports green vegetation all year. Species diversity is at a maximum.

2. Principles of Biodiversity

a. Island Biogeography

In the 1960s, MacArthur and Wilson developed the theory of island biogeography, by studying the relationship between numbers of species and areas of islands. They found that larger islands held a greater number of species, when specific groups were examined, such as birds or amphibians.

The theorists went farther. What determines the number of species on islands? Species die (go locally extinct) and species originate (they migrate from the mainland, fly over in the case of insects and birds, are blown over by the winds in the case of small insects, and come aboard from floating logs and other debris, in the case of lizards).

For islands of the same size, islands closer to the mainland have a greater number of species because the immigration rate is higher. Islands with diverse habitats (such as mountains and swamps) have a great number of species. For all else equal, smaller islands have a greater rate of extinctions, because the smaller populations are more susceptible to environmental stressors or disease, which leads to a smaller number of species.

For example, in the Caribbean, Cuba, the largest island, has the greatest number of species of reptiles and amphibians. Furthermore, plotting the sizes of islands versus their number of species shows a mathematical law, allowing scientists to count on some theory behind the distributions.

Data roughly along lines compatible with the theory of island biogeography from other regions on continents show that the theory has some applicability to what will happen to species as humans fragment the landscape more and more. The theory will help in the design of nature preserves. For example, butterflies increase in English woodlands as the sizes of the woodlands increase.

b. Predators and Prey

A key kind of interaction in nature is the **food chain**, the chain of eating: mouse eats seed, snake eats mouse, hawk eats snake. In real nature, we find not simple chains but webs, more complex networks because predators often (not always) feed upon many different kinds of prey, and prey often can be fed upon by many different kinds of predators. Are there principles to the food webs?

Level 1—**trophic levels** can be distinguished because they turn sunlight, carbon dioxide, and nutrients into their bodies upon which all other terrestrial life depends.
Level 2—herbivores, creatures such as deer and many insects that feed on plants
Level 3—carnivores that prey on the herbivores
Level 4—also carnivores, which in the idealized situation, feed on other carnivores of level 3

As food passes from trophic level to trophic level (from gut to gut), it is converted into new animal bodies with an efficiency that is typically about 10%. In other words, it might take 10 kg of plant matter to make 1 kilogram of herbivore, and then 10 kg of herbivore to make 1 kg of carnivore. This is why the spectacular predators of ecosystems are rare and why there will always be far fewer eagles, for example, than mice.

c. Sex

Many creatures reproduce without sex between males and females. Bacteria, for instance, can reproduce by cell splitting, creating two clones in a process called **mitosis**. Each daughter cell has the same DNA as the mother cell.

Many plants can reproduce by **vegetation propagation** (for example, taking a cutting from a houseplant, rooting it in water, and then planting it in soil), making a clone of the original plant. Some trees, such as aspens, reproduce with underground runners. So what looks like a patch of individual trees is actually a family of clones. Certain invertebrates, such as hydra, can also reproduce asexually, by budding off small replicas, which fall off or swim away to form new individuals. Some insects and even some vertebrates (several species of lizards, for example) are capable of asexual reproduction in which the females lay eggs that are capable of growing into new adults.

For the individual of an asexual species, reproduction is more efficient than in the sexual mode, because, in sex, each parent is only putting half its genes into the offspring. In the asexual mode, the sole parent is putting one hundred percent of its genes into each offspring.

However, sexual reproduction has the benefit of mixing genes, which creates variation, one of the stages in the recipe for evolution. Mitosis relies on mutations for variation (except in some cases in which bacteria exchange genes)—but sex creates variation by its very nature. Parasites and diseases can evolve quickly, putting populations of clones at risk. But when sex mixes genes, offspring are all different. There is good evidence that sexual species can have lower susceptibility to parasites and other diseases. What is gained in producing lots of genetic variation seems to make up for what is lost in efficiency of gene transfer for each individual during sex.

In higher organisms, such as plants and animals, sex cells (pollen and egg in plants, sperm and egg in animals), have half the chromosomes and therefore half the genes of the cells of the adults they derive from, in a special process of cell division called **meiosis**.

d. Invasive, Umbrella, and Keystone Species

Keystone species are species that play a key role (like the keystone in an arch) by holding the structure of the ecosystem together. Many top predators are keystone species because they affect the populations of their prey, which affects the populations lower in the trophic levels. For example, the starfish along rocky coastlines can be a keystone species because starfish affect the populations of many species of mollusks and barnacles.

Umbrella species are species that have a role in conservation. Preserving an umbrella species that needs a particular habitat will automatically act like an umbrella to save many other species that also use that habitat. A classic example is the northern spotted owl of the old-growth forests of the Pacific Northwest. (An old-growth forest is forest that has never been cut.) The owl requires holes in old growth trees for its nests and will not nest elsewhere.

A **poster** or **flagship species** is a particularly charismatic species that people tend to naturally rally around for its preservation. The giant panda of China is an example.

Invasive species are also called **alien** or **introduced species**, because they come from other regions of the world, transported by humans. The introduction could have been intentional (European starlings into Central Park in New York City), but is often unintentional, as species hitch rides on ships or even in airplane wheel cases. A classic example is the zebra mussel, originally from waters in Russia, now all over the Great Lakes of the United States and even up stretches of the Missouri River. Its huge, dense populations clog pipes of factories and power plants, and cause billions of dollars of damage each year.

Introduced species can be successful invaders when they come into an area with no natural predators and where the prey lacks evolved defenses against the new species. Invasive species are a serious problem for the world's healthy maintenance of biodiversity and economies.

Extinct species are a natural part of Earth's past. But humans are causing extinctions at a far greater rate than the "background" rate of nature (not counting mass extinctions from impacts, for instance, like the one that took out the dinosaurs). The passenger pigeon and the dodo bird are two bird species that humans (or the animals humans introduced) caused to go extinct.

Endemic species are species that occur in a rather small region and nowhere else. Islands often have large numbers of endemic species. Lemurs, for example, are endemic to the island of Madagascar. Special regions where there are a large number of endemic species that are under threat (and which are unusually rich in overall biodiversity) are called hotspots.

3. Basics of Ecology

Ecology is the study of the interactions of organisms with each other and with their physical and chemical environments.

a. Definitions

A **population** is the system of locally interacting members of the same species. When individuals in a local population have substantial interaction among them (say, as potential mates) but only occasional links to other populations (say, in another valley), the populations are then said to be **metapopulations** in the context of the larger, more loosely linked species system.

A **community** is the locally interacting system of organisms of different species, usually considered as the plants, animals, and fungi. But there can also be soil communities that include species of bacteria.

An **ecosystem** can be a pond, swamp, local area of prairie, local woods, and so forth. It usually does not have defined boundaries (except in cases like ponds), but consists of the community or communities of creatures and the nonliving parts of the environment they are in contact with, such as water and soil.

Ecosystems can become disturbed, by natural events such as volcanoes or by humans. If left to restore themselves, they undergo a process of succession. Early, colonizing species come in first, followed by later species that often require the conditions created by the earlier species. Eventually, a stable endpoint community of organisms is reached, called a **climax community**.

Carrying capacity is the maximum number of organisms of a particular species that an ecosystem can support.

Reserves are parts of nature set aside by humans for the preservation of species or wilderness in general. Reserves include National Parks and National Wildlife Refuges in the United States and various regions with different names in other countries.

Fragmentation occurs when a force (primarily human) fragments the natural landscape into patches (examples: construction of interstate highways and other roads, housing and urban developments, draining parts of wetlands, or cutting down parts of forests for farmlands).

A **watershed** is a region that includes all the drainage of tributaries that feed a larger stream or river. For example, the very large Mississippi watershed would include the watershed of the Missouri River, because the Missouri River empties into the Mississippi.

b. Soil Ecology

When leaves die from trees in autumn or grasses die for winter, they fall to the ground. This material contains carbon and other elements that start to decompose and become part of the soil.

The new material is called **detritus**. Organisms in the soil that perform decomposition are called **detritus feeders**, and include various insects, worms, fungi, and bacteria. Though we normally know fungi as their visible forms of mushrooms (the reproductive bodies), they normally occur as invisible threads (called **hyphae**) throughout the soil.

Organisms in the soil breathe because air enters and leaves the soil through openings between its grains. The deeper one goes in the soil, the air has less oxygen, because the oxygen has been used by the soil organisms.

Soil has layers. The uppermost, rich layer is topsoil, which is important to preserve in farmlands. Farmers must beware of losing topsoil to erosion by wind and water.

c. Marine Ecology

The continental shelf regions of oceans tend to be richer in life because they obtain increased nutrients from rivers and from the winds and tides that stir the shallow water, thereby mixing up nutrients from below to the surface. The open ocean is sometimes considered a marine desert; life is more sparse there.

At the top of the ocean is a zone called the **mixed layer**, varying in depth but usually about 100 meters thick. It is well mixed, having been stirred by the winds. The upper part that receives light is called the **pelagic zone**, which varies depending on how far light penetrates down. The deep parts are called the **benthos**. Thus, marine biologists distinguish organisms as pelagic species and benthic species.

Special areas called **upwelling zones** occur off certain coasts, such as Chile and the coast of northwest Africa. Here, deep, nutrient-rich waters are brought up and fish are hugely abundant.

Tiny organisms in the ocean constitute the **plankton**, which generally drift with the currents. There are **phytoplankton**, which are green because they have chlorophyll and perform photosynthesis (eukaryotic algae and prokaryotic cyanobacteria), and **zooplankton** (“animal-plankton”). Zooplankton include tiny multicellular swimming crustaceans as well as the swimming larvae of creatures that will grow to adult sizes out of the plankton range, such as jellyfish and mollusks. Zooplankton feed on phytoplankton, and all are fed upon by a variety of fish and other organisms, making a marine food web.

A **fishery** is a species of fish that occurs in a certain region and is abundant enough to be commercially fished (examples: northwest salmon fishery, the New England cod fishery). Many fisheries are in decline as the stocks of fish have been depleted.

Aquaculture is the commercial raising of fish, shrimp, or oysters in tanks or fenced off areas of the ocean.

d. Ecology and Energy

Sunlight is captured by plants using the chlorophyll molecule. Plants are green because chlorophyll absorbs the red and blue wavelengths of light, reflecting some of the green. The energy thus captured is used to drive the process of photosynthesis, which creates simple sugar molecules from carbon dioxide and water. Plants get water from the soil (through their **xylem**) and carbon dioxide from the air, through pores in their leaves called **stomata** (or stomates). Marine algae are also green because of chlorophyll, but they get the carbon dioxide from the water.

Terrestrial plants and marine algae are called **autotrophs**, for “self-feeders,” because they create their own food, in a sense, from inorganic molecules. Insects and humans are **heterotrophs**, requiring autotrophs for food.

The molecules of organisms are high energy molecules, because they can be “burned” by the metabolisms of organisms to maintain their bodies and exert force upon the environment, for movement and food capture. The energy comes from the

Sun. Thus, when we walk, we are using transformed and stored solar energy. Life runs on solar energy.

The mass of a living thing or a collection of living things is called **biomass**, or biological mass. One can ask about the biomass of trees in a forest, or the insect biomass of an ecosystem.

When plants convert their simple sugars made by photosynthesis into more complex organic molecules that they need, such as proteins and starches, they use some of the sugar as a source of carbon for this next generation of organic molecules. They also "burn" some of the sugar for energy, to drive the chemical reactions inside their cells that create the next generations of molecules. This burning uses up some of the sugars and requires oxygen, and results in the chemical products of carbon dioxide and water, thus reversing the process of photosynthesis. This is called **respiration**. Heterotrophs perform respiration, too (but not photosynthesis).

The amount of sugar created by the photosynthesis in a plant is called **gross primary production (GPP)**. It is usually expressed in terms of carbon. The carbon that actually goes into the full metabolism of molecules inside a plant is less—that is called **net primary production (NPP)**.

GPP = NPP – respiration

NPP can be calculated at the level of ecosystem and biome, as well. It varies across ecosystems and biomes, being highest in tropical rain forests and lowest in deserts.

Limiting factors limit the amount of net primary production. Depending on the ecosystem or biome, limiting factors could include water, nitrate, phosphate, and other nutrients. Farmers overcome limiting factors—in particular, in soils—by adding fertilizers.

4. Biogeochemical Cycles

Biogeochemical cycles are the cycles of elements essential to life. These cycles are thus biological (*bio*) and include geological processes (*geo*) and chemical reactions (*chemical*).

a. Carbon on Land

The most important biogeochemical cycle is that of carbon, the essential element in the organic molecules of life. Carbon moves in and out of various forms. Photosynthesis and respiration form a coupled pair of processes that convert carbon from carbon dioxide into organic molecules and back again. Most respiration takes place in the soil, as respiration from bacteria and fungi releases carbon dioxide. The cycle is more complex with other forms of carbon as well. Some bacteria release waste carbon in the form of methane (CH_4). Other types of bacteria consume methane.

b. Carbon in the Biosphere

The atmosphere contains about 700 billion tons of carbon, primarily in the form of carbon dioxide. The carbon in all biomass is about the same amount. The carbon in the world's soils is about three times that amount. The oceans contain the largest pool or reservoir of carbon, because seawater has carbon in yet other forms: bicarbonate and carbonate ions. Atmosphere, plants, algae, soil, and ocean—these are all considered **pools**, between which carbon is shuffled in and out of various forms, in amounts known as **fluxes**. Global net primary productivity is the flux of carbon from the atmosphere into all photosynthesizers, for example.

c. Nitrogen in the Biosphere

Nitrogen, which is important in the proteins of organisms, is another element that has a biogeochemical cycle. Like carbon, there are pools (or reservoirs) of nitrogen, in the atmosphere (as N_2 gas), in organisms (primarily in proteins), in the soil (in the detritus), and in water (as nitrate and ammonium ions). Fluxes convert the nitrogen from one form to another.

Nitrogen fixation occurs when soil or marine bacteria take nitrogen gas and convert it into the useful ammonium ion for their bodies. Some ecologically and agriculturally important soil bacteria live within the roots of plants, in a symbiotic relationship. When we say that bean plants or clover can fix nitrogen, it is really the bacteria in the nodules on their roots that perform that function, not the plants themselves.

Ammoniafication is also done by bacteria, in the soil, as the bacteria process proteins in detritus and converts the organic nitrogen into ammonium ions.

Nitrogen assimilation occurs when organisms take up nitrogen as ammonium ions or nitrate ions from the environment of soil or water.

In **denitrification**, other kinds of bacteria specialists convert nitrate ions in soil or water into nitrogen gas. Denitrifiers live in places of no or little oxygen. Finally, nitrifying bacteria take ammonium ions and make nitrate ions.

d. Phosphorus in the Biosphere

Phosphorus is another crucial element for all living things. It has a cycle, too, which is relatively simpler than the cycles of carbon and nitrogen, because phosphorus does not have a gaseous form. It primarily cycles between its ion (phosphate ions in soil and water) and its form in life (various molecules inside cells). Phosphorus is used as part of the ladder of DNA and is essential for energy molecules inside cells, such as ATP.

e. Bioessential Elements

All the dozen or so elements that are essential to living things have their biogeochemical cycles. The major elements and their approximate mass percentages in a typical plant are: carbon (C, 45%), oxygen (O, 45%), hydrogen (H, 6%), nitrogen (N, 1.6%), sulfur (S, 0.1%), phosphorus (P, 0.2%), potassium (K, 1%), calcium (Ca, 0.5%), magnesium (Mg, 0.2%), and iron (Fe, 0.01%). The elements N, S, P, K, Ca, and Mg are the macronutrients, because they occur in relatively large amounts. Iron and other elements not listed, such as manganese, molybdenum, and copper, are micronutrients. Hydrogen and oxygen, though essential elements, are not considered nutrients because they occur abundantly in water. In humans, the percentages change somewhat but not drastically (not so much that iron is larger than phosphorus, for example). More proteins in humans means more nitrogen, to cite one element's differences between humans and plants.

You Should Review

- principles of biodiversity and ecology
- numbers of species
- classification system
- biome types
- food webs in ocean and on land
- interaction of predators and prey
- asexual versus sexual reproduction
- biogeochemical cycles of carbon and nitrogen

Questions

51. Which category contains the fewest number of species?
a. birds
b. primates
c. mammals
d. fungi

52. Which one is NOT one of the possible theories that at least partially explains the high diversity in the tropics, such as rain forests?
a. high solar energy
b. Pleistocene refugia
c. low seasonal variability
d. Permian-Triassic extinction

53. Fire can be an important part in the structure of an ecosystem. This is particularly true in which of the following biomes?
a. tundra
b. chaparral
c. boreal forest
d. prairie

54. Food chains are parts of food webs, in which we go from plants at the first trophic level (primary producers) to a second trophic level, and so on. Why do food chains in nature rarely exceed 4 or 5 levels?
a. because evolution has not yet created that degree of complexity
b. because organisms die more easily at the higher levels
c. because of inefficiencies, the available energy becomes less and less at higher levels
d. because food chains limit the levels of food webs

55. The California sea otter, native to the coast, controls the populations of starfish, which control the populations of many other marine creatures among the kelp beds. The otter is an example of a(n)
a. umbrellate species.
b. invasive species.
c. keystone species.
d. mammal species.

56. Consider the following food web: oak seedlings eaten by rabbits; rabbits eaten by wolves. What happens to the oak seedlings if the wolf population suddenly declines from a disease?
a. Seedlings decrease.
b. Seedlings are eaten by something else.
c. Seedlings increase.
d. Seedlings are also hit by a disease.

57. Which is NOT true about marine ecology?
a. Phytoplankton are functionally equal to land plants.
b. Fish eat zooplankton.
c. Zooplankton grow up into plankton.
d. Fish are part of the food web.

58. The term *fragmentation* refers to which of the following?
a. invasive species that divide the structure of ecosystems
b. the dispersed nature of marine food webs
c. successive waves of species as an ecosystem develops
d. humans segregating up nature into chunks

59. In considering the pools of the biogeochemical carbon cycle, which has the most carbon in it?
a. ocean
b. soil
c. plants
d. atmosphere

60. Which bacteria thrive in places in the ocean with low oxygen?
a. nitrogen fixers
b. denitrifiers
c. nitrifiers
d. ammoniaficators

Answers

51. **b.** Compared to birds and fungi, mammals have fewer species. Because only a small fraction of all mammals are primates, primates have the fewest in the list.

52. **d.** The Permian-Triassic extinction occurred 250 million years ago, and has nothing to do with the differences today between tropical and high-latitude biodiversity. The other answer choices are all possible contributing reasons to the diversity pattern.

53. **d.** Prairies have dense vegetation and often long intervals of summer drought. Fires started by lightning are a natural part of these grasslands, and many plants have even become evolutionarily adapted by having seeds that germinate after a fire.

54. **c.** Typically, each level only converts 10% of the energy of the previous level. As the levels progress, the energy available is very small, thus limiting the levels reached.

55. **c.** The otter is a keystone species, because like the top stone in an arch, it holds much of the rest of the ecosystem in its structure.

56. **a.** If the wolves decline, the rabbits increase in population. If the rabbits increase, they eat more seedlings, so the seedlings decline.

57. **c.** Zooplankton are a type of plankton; they do not grow up into plankton.

58. **d.** Human activities fragment nature.

59. **a.** The ocean has about 10–50 times more carbon than any of the other pools. In the ocean, carbon is found mostly in the form of the bicarbonate ion (with the carbonate ion number two).

60. **b.** Denitrifiers live in places of low oxygen, and use nitrate as a source of oxygen, creating nitrogen gas.

G. Global Environmental Challenges

1. Population and Land Use

a. Population

Prior to the invention of agriculture, some 10,000 years ago, humans in their hunting and gathering phase were limited to about ten million people worldwide. But by the pyramid days of ancient Egypt, 5,000 years ago, global population had grown tenfold, to about 100 million, an increase due to agriculture.

By 1830, the population had reached the first billion.

By the late 1950s, the world held two billion people.

The third, fourth, and fifth billion marks were reached by the late 1950s, the early 1970s, and the mid-1980s, respectively.

The six billion mark occurred in the late 1990s, and seven billion is expected around 2012, because of a growth rate of about 85 million people a year (ten times the population of New York or Los Angeles). However, the population growth rate is starting to decline. Factors that cause the growth rate to decline include a higher standard of living and better education (for women, in particular). Scientists expect the world population to reach eight billion, but variables may influence how high the population climbs.

b. Land Use

Global land = 140 million square kilometers = 14 billion hectares (about four acres per person).

Usable land: 31% of the world's land (4.4 billion hectares) is unusable, because it is rock, ice, tundra, or desert, leaving 9.6 billion hectares for potential human use.

Agricultural use: The major human land use is for agricultural production, which is currently 4.7 billion hectares. Of that, 70% is permanent pasture and 30% is crop land. So agriculture (pasture + crops) takes 34% of the world's land.

Urbanized land: Globally, only about 1% of land (about 140 million hectares) is considered urbanized, including highways. In some local areas, the urbanized land approaches 100% of coverage.

Therefore, 14 billion hectares – 4.4 (unusable) – 4.7 (agriculture) – 0.14 (urbanized) = 4.8 hectares of potential usable land remains.

This is about 34% of the total land, or about as much as humans currently use for all agriculture. However, much of the prime land for agriculture has already been used, so what remains is not as high in quality.

2. Humans Alter the Biosphere

Unlike other species, humans deploy vast arrays of chemical processes (factories, residences, and forms of transportation). In our use of energy and in the ways we process matter, we create substances that alter the chemistry of the biosphere.

a. Carbon Dioxide and the Greenhouse Effect

Carbon dioxide (CO_2) is typically measured in units of ppm (parts per million), because there are only small amounts of it in the atmosphere. *Million* refers to a million randomly selected molecules of air (such as N_2, O_2, and so forth). Today, CO_2 is somewhat more that 370 ppm (which is equal to 0.037%).

CO_2, though such a small amount of the atmosphere, is of critical importance because it is a greenhouse gas. Oxygen and nitrogen gases are not. A greenhouse gas lets in visible radiation (light, short-wave radiation) from the Sun, which enters the atmosphere, and passes directly through to the ground (therefore we can't see the CO_2). But a greenhouse gas absorbs infrared radiation. Infrared radiation (long-wave radiation) is what the Earth uses to cool to space and to balance the energy received from the Sun. Greenhouse gases are like one-way insulation, letting light in but blocking the escape of infrared radiation. The Earth's surface will warm up to compensate for any extra insulation in the atmosphere.

Without CO_2, the Earth would be very cold, below the freezing point of water. So present conditions require CO_2.

But there can also be too much: CO_2, emitted as a waste gas from the combustion of fossil fuels (coal, oil, natural gas), is rising. Data from bubbles trapped in ice at Antarctica show that for 10,000 years prior to the industrial revolution, CO_2 was fairly constant at about 280 ppm. Now it is above 370 ppm and rising from human activities at the rate of 1.5–2 ppm per year.

b. Ozone and Ultraviolet Radiation

Ozone is O_3, a molecule with three oxygen atoms, unlike the regular oxygen (O_2) that is 21% of Earth's atmosphere. Ozone is made naturally, by cosmic rays that cause chemical conversions in Earth's stratosphere. Ozone readily absorbs the ultraviolet portions of the Sun's spectrum that enters Earth's atmosphere. This absorption also destroys some of the ozone, so a balance is reached between creation and destruction, resulting in a natural amount of ozone that is constantly present.

Without this protective ozone layer, biologically damaging ultraviolet (UV) rays would reach the surface of the planet. UV exposure is a main cause, for example, of skin cancer.

Until recently, ozone was on a worrisome decline across decades. Human-made gases called **chlorofluorocarbons** (CFCs, containing chlorine, fluorine, and carbon) used in refrigerators, air-conditioners, and some aerosol cans, when released, travel up into the stratosphere. There, the chlorine acts as a catalyst to destroy the ozone at a rate much faster than its natural rate of destruction. Humans had altered the balance, and global ozone levels started dropping, particularly in the ozone "hole" area above Antarctica, endangering people in Australia and New Zealand.

In 1987, many nations signed the Montreal Protocol, a global agreement to phase out the production and use of CFCs. Substitute gases were invented to replace the technological uses of CFCs. As a result, the ozone decline has been halted. Over the coming decades, the ozone layer should be able to repair itself and return to its natural level.

c. Acid Rain

Acid rain is yet another human perturbation to the atmosphere, related to the combustion of fossil fuels, coal in particular. Coal, the remains of ancient plants from hundreds of millions of years ago, contains sulfur (one of the bio-essential elements). When the coal is burned in power plants to obtain energy (most of which comes from converting carbon to CO_2), the sulfur also combines with oxygen to create sulfur dioxide (SO_2), a gas that enters the atmosphere. The SO_2 further combines with water vapor and then becomes sulfuric acid (H_2SO_4) in cloud droplets. The rain that falls from these clouds is acidic—acid rain.

Nitrogen also contributes to acid rain, as nitric acid, derived from nitrogen oxides created from the high temperature reactions with air in power plants and automobiles.

Acid rain falls mostly in the regions downwind of power plants. It has been responsible for ecological damage to many streams and lakes.

Laws governing the release of acids from power plants are in place, but could be strengthened further. Acid rain is a problem that potentially could be controlled, with adequate environmental regulation. Emissions of pollutants from automobiles have been improved, for example, with better technology.

d. Toxins

Primary pollutants are chemicals released directly into the atmosphere.

Besides some of the gases already discussed, primary pollutants include the following:

- *Suspended particulate matter* (PM) consists of all kinds of tiny particles from smog stacks and even from metals.
- *Volatile organic compounds* (VOC, hydrocarbons) are organic gases from a variety of sources, such as leaks into the air that you smell when you fill your car with gasoline and even gases from lighter fluids used to start barbeques.
- *Carbon monoxide* (CO) derives from incomplete combustion of fossil fuels (organic carbon is oxidized to CO, rather than CO_2 during complete combustion); odorless, CO is the leading annual cause of death by poisoning in the United States.

Primary pollutants can be altered chemically by interactions with sunlight, and become **photochemical pollutants** (or **photochemical oxidants**).

- **Tropospheric ozone** is one such oxidant. Different from the natural, much-higher-up stratospheric ozone, tropospheric ozone is ozone or pollution in an urban area.
- **Photochemical smog**, another secondary pollutant, is created when car exhaust is acted upon by sunlight to form a brown haze that is highly irritating to the lungs. Smog is particularly troublesome in cities that lie in valleys and are subject to air inversions, in which a lid of air sits over the city and does not move for a long period of time.

After cigarette smoke, **radon gas** is the second leading cause of lung cancer. Radon, a daughter product of uranium in Earth's rocks, is a radioactive gas that leaks from particular kinds of soils. It can accumulate indoors, for example, in basements.

Scrap rocks from uranium mining are a form of radioactive waste. Of even more concern are the waste byproducts from nuclear power plants. These are daughter products of the process of controlled nuclear fission, which uses uranium but then creates radioactive iodine, cesium, plutonium, and others as wastes. This material is secured and stored on the site of the nuclear power plants, but plans are being created for long-term, permanent storage. The most planning has been done for a site in Nevada, at which the material would have to be kept safe from earthquakes and groundwater for many thousands of years.

3. Energy Systems

Our lives are dependent on external sources of energy, as we burn fossil fuels at a total rate that is many times greater than all the metabolisms of all humans.

a. Energy versus Power

Power is the rate of energy flow; unit is kilowatts.

Energy is the summation of power over time; measured in kilowatt-hours or BTU (for British thermal unit, the energy it takes to raise 1 pound of water by 1 degree Fahrenheit).

b. Fossil Fuel Combustion

All fossil fuels contain carbon and hydrogen. When a fossil fuel is reacted (burned) with oxygen (from the air), the chemical products are carbon dioxide and water (as a vapor). Because the produced CO_2 and H_2O together have a lower molecular energy than the reactants of fossil fuel and oxygen, energy is released in the reaction. Fossil fuel energy is the main source of energy for all the processes of civilization.

Types of fossil fuels differ in their relative amounts of carbon and hydrogen. The more carbon a fossil fuel has, the more carbon dioxide it releases for a given amount of energy. In this regard, coal is the worst fuel and natural gas (which is primarily methane) is the best fuel, with oil rating somewhere in the middle.

Fossil fuels come from biological sources of many millions of years ago. Oil is from marine algae, buried and transformed. Coal is from terrestrial plants that lived in vast swampy environments, buried and transformed. Natural gas (methane) is mostly derived as a breakdown product of either coal or oil. All occur underground and must be dug up or piped to the surface, transported, and processed for human use.

A significant factor in world politics is the uneven distribution of fossil fuels, especially oil. This shows how geological processes from hundreds of millions of years ago affect human life today.

c. Energy Today

The global primary energy supply consists of the following (total is 99% because numbers are rounded off):

- oil (35%)
- coal (23%)
- natural gas (21%)
- wood and combustible wastes (11%)
- nuclear (7%)
- hydroelectric (2%)

How is energy used? One-third of it is used for industry, one-third for transportation, and one-third for residential (varies by country).

Hydroelectric energy uses vertical drops in rivers. Water is diverted, usually from behind dams, into turbines, which turn generators to produce electricity. (All mechanical electricity-generating power plants turn turbines to make electricity.)

Nuclear power plants generate intense heat from the controlled splitting (fission) of uranium atoms. The heat creates steam, which turns turbines to make electricity.

Fossil fuel power plants work the same way, except that the source of heat is the combustion of the fuel.

d. Efficiency from Supply to Use

Efficiency is output of useful energy during conversion of energy input, measured in percent. For example, how much of the energy in oil goes into making the automobile travel, and how much is wasted as heat in the exhaust system and from the cooling engine?

For fossil fuel power plants, a typical efficiency is about 33%. Although better engineering can improve this number, it cannot and will not ever be 100%, because the Second Law of Thermodynamics limits how much of one kind of energy can be converted into a different kind of energy.

All devices, from refrigerators to light bulbs to cars, can be quantified in terms of efficiency. Improvements in energy efficiency can cut down on pollutants and the use of fossil fuels, which not only are limited but produce the greenhouse gas carbon dioxide.

e. Future Energy Technologies

Research continues on future energy technologies, on sources of energy that do not emit carbon dioxide and are renewable.

Hydrogen can be burned with oxygen to produce harmless water (vapor). However, hydrogen does not occur naturally. To have a hydrogen economy in the future, therefore, we need to make hydrogen from the splitting of water, which requires an energy source, like fossil fuel or solar energy. (Hydrogen can also be made from natural gas [methane], but this creates CO_2, so to avoid the emission of CO_2, it would have to be sequestered, see the next column.)

Wind energy uses the pressure of air motions to turn turbines to make electricity. Many large wind turbines are going up all over the world, particularly in northern Europe. These have blades 100 feet or more in length. Wind energy is site-specific. In the United States, for example, states such as the Dakotas and the western part of Texas have particular potential for wind development. If set up in farm fields, only a small percent of the land is used, and farmers can still grow their crops under the turbines; the land would then do double duty.

Solar energy has two main types: **solar thermal energy** that uses sunlight to heat water or air for direct use, mainly for domestic water heating or wintertime home heating; and **solar photovoltaic energy** that uses solar cells (silicon cells, originally perfected by NASA for space use) to create electricity directly from the photons of the Sun. Like wind electricity, photovoltaic electricity is increasing, but not as much because the costs are still quite high.

Nuclear fusion would use energy from fusing hydrogen into helium, fusing the nuclei of atoms (which is the process that takes place in the center of the Sun). Fusion requires enormous temperatures and pressures in the fusion reactor's center, which will probably use incredibly high-tech magnetic "bottles" to hold the reactants (because nothing material could withstand those conditions). Fusion has been accomplished in high-energy physics labs, but no fusion energy plants exist yet.

Carbon sequestration is a technology that stops the emission of CO_2 (by trapping and disposing of carbon dioxide waste) and would allow humans to continue burning fossil fuels, depending on supply. One possibility is to pipe carbon dioxide deep into the ocean (but this might make conditions intolerably acidic for some benthic marine life). Another possibility is to pipe it into deep aquifers of salty, unusable water far beneath the land surface. But would the CO_2 leak back up into the atmosphere? A small industrial project off the shores of Scandinavia is currently injecting CO_2 into the ocean. Much remains to be tested with these technologies as well.

4. Systems of Matter and Life

The biosphere is an interacting system of matter and energy, of humans and nature.

a. Waste Disposal

Municipal solid waste describes general garbage. Disposal methods include landfills, combustion, recycling, and the composting of organics.

Sewage describes liquid and solid body wastes treated in sewage treatment plants. A number of steps are involved: Preliminary and primary treatments remove debris and organic particles, respectively. Secondary treatment involves bacteria in aqueous slurries. The bacteria consume the dissolved organics in the sewage. Before the treated waste water is put back into a natural water system, it is disinfected. Many variations exist, and new technologies, often using more advanced biological processes to help, are being explored. In sewage treatment, we are mimicking (and using) the natural recycling capabilities of bacteria in nature, in the soil, and in the deep ocean.

b. Deforestation

Deforestation is the cutting of areas of forest. This occurs at a rate of ten million hectares per year. Deforestation occurs to supply raw material for the lumber and paper industries, or it can also take place when trees are burned to create open land for pasture or crops.

Clear-cutting is the term used when patches of forest are completely cut for industrial use. The other approach is **selective cutting**, when only certain trees (say large trees or a certain species) are harvested, leaving the rest to grow for future harvests or just remain as forest.

Certain regions, such as the New England states, are undergoing **reforestation**. Farming, which was a strong part of their economy up to a hundred years ago, eventually could not compete with the midwestern and western farms. Through reforestation, much land in New England is returning to forest.

Deforestation usually releases CO_2. If trees are burned, CO_2 goes right into the atmosphere. Even if the trees are to be used for paper or lumber, the twigs and dead roots decay fairly rapidly, and thus are a lesser, though still important, source of CO_2 from these areas of deforestation. Reforestation, on the other hand, removes CO_2 from the atmosphere, and thus can help mitigate the rising threat of a greenhouse effect.

c. Nature's Services

Nonrenewable resources are resources that cannot be renewed in anywhere close to the time in which we are depleting them. For example, though oil is formed continuously during the geological ages, the rate is infinitesimal compared to our rate of extraction and burning it. Minerals are also nonrenewable resources.

Renewable resources, on the other hand, can be regenerated by natural processes. For example, fresh water is reformed by the water cycle, in which water from the ocean is evaporated (leaving the salt behind), then forms droplets in clouds, which in turn rain over land. Thus, the fresh water in rivers is renewed. Of course, humans can still exert stress upon the water systems, when deep, underground aquifers are pumped faster than they are being renewed, or when water is drawn from watersheds at rates that do not allow enough water for the fish in the natural stream.

Trees would be considered a renewable resource, because they can regrow. However, old-growth forests are nonrenewable, because they take many hundreds of years to develop to the full climax state.

Nature is our basic life support system. It is important to preserve the services of nature. Much is not yet understood, but it is clear that biodiversity is crucial for the healthy continuation of most natural systems.

You Should Review

- human population
- land use
- greenhouse effect
- acid rain
- toxins
- ozone depletion
- energy technologies
- waste disposal and deforestation
- renewable versus nonrenewable resources

Questions

61. What is the global population today?
- **a.** between seven and eight billion
- **b.** between four and five billion
- **c.** between five and six billion
- **d.** between six and seven billion

62. Which of the following statements about global land use is not true?
- **a.** Cropland is increasing.
- **b.** Old growth forest is decreasing.
- **c.** Unusable land (rock, ice, desert) is greater than urbanized land area.
- **d.** Pasture is less than cropland.

63. Considering the unit *ppm* as parts per million, how many ppm is oxygen in Earth's atmosphere?
- **a.** 21 ppm
- **b.** 21,000 ppm
- **c.** 210,000 ppm
- **d.** 2,100 ppm

64. Stratospheric ozone absorbs
- **a.** infrared radiation.
- **b.** visible light.
- **c.** ultraviolet radiation.
- **d.** green radiation.

65. The Montreal Protocol limited
- **a.** the production of carbon dioxide.
- **b.** the production of acid rain.
- **c.** the production of dimethyl sulfide.
- **d.** the production of chlorofluorocarbons.

66. What requires storage for thousands of years to be safe?
- **a.** radon
- **b.** radioactive waste
- **c.** photochemical waste
- **d.** greenhouse poisons

67. Which is mostly methane?
- **a.** oil
- **b.** natural gas
- **c.** coal waste
- **d.** propane

68. Which is not a future possibility as a primary source of energy?
- **a.** fusion
- **b.** hydrogen
- **c.** wind
- **d.** photovoltaic

69. A good future source of energy for farmers to consider as a source of profit is
- **a.** fission.
- **b.** fusion.
- **c.** wind.
- **d.** hydrogen.

70. The systems in nature that help purify water do not include
- **a.** solar energy.
- **b.** infrared radiation.
- **c.** clouds.
- **d.** the ocean.

Answers

61. d. The population reached six billion in the late 1990s and will not be at seven billion until about 2012.

62. d. Pasture is about twice the area of cropland, for the world average. The other statements are true.

63. c. Oxygen gas is 21% of Earth's atmosphere, which converts to 210,000 ppm; ($\frac{210,000}{1,000,000}$ = 0.21 = 21%).

64. c. Stratospheric ozone is a natural protective shield because it absorbs the ultraviolet wavelengths of solar radiation that would otherwise cause great damage to living things at the surface.

65. d. The Montreal Protocol was a global agreement to phase out the production and release of the ozone-destroying chlorofluorocarbons.

66. b. Radioactive waste, from weapons production and nuclear power plants requires very long-term storage, to allow the radioactivity to decrease to safe levels.

67. b. Natural gas is predominantly methane, piped up from underground reservoirs, sometimes from gas domes at the top of oil pools under the Earth.

68. b. Hydrogen cannot be a primary source of energy because there are no natural supplies of hydrogen. Hydrogen must be made from water, by splitting water (or using methane) via a primary energy source. Hydrogen is therefore best considered a possible energy storage material.

69. c. Wind energy could be particularly attractive to farmers because the wind turbines take up little space and thus the land can still be used for farming as well. Thus, the land does double duty.

70. b. Infrared radiation is how the Earth cools itself to space, which of all the answers has least to do with the water cycle, whereby solar energy evaporates water from the ocean. The water vapor forms clouds, which shower purified water onto the land as rain.

III. Suggested Sources for Further Study

Bryson, Bill. *A Short History of Nearly Everything.* (Broadway, 2003). Bryson is a simply fabulous writer. This book focuses on the history of major discoveries, from physics to geology and evolution. You learn about the characters who made history at the same time that you learn much of the science.

Bush, Mark B. *Ecology of a Changing Planet,* 3rd Edition. (Prentice Hall, 2004). This is an excellent textbook covering ecology, evolution, and biodiversity.

Mathez, Edmond A. and James D Webster. *The Earth Machine: Science of a Dynamic Planet.* (Columbia University Press, 2004). An excellent new book about geology and plate tectonics.

Trefil, James *The Nature of Science: An A-Z Guide to the Laws and Principles Governing our Universe.* (Houghton Mifflin, 2003). Trefil is an accomplished science writer as well as scientist. This book contains many key concepts of science, including how science works.

There are many textbooks on environmental science, and they all cover much the same material relevant to general science: some chemistry evolution, biodiversity, the chemical cycles, human impacts, often with some geology, and the science of atmosphere and ocean. They are fairly expensive, but you should be able to find used books or earlier editions for a fraction of the new book price. Slightly older editions will be fine for your needs. Some popular tects include the following.

Skinner, Brian J., Stephen C. Porter, and Daniel B. Botkin. *The Blue Planet: An Introduction to Earth System Science*, 2nd Edition. (Wiley, 1999).

Daniel B. Botkin, and Edward A. Keller. *Enviromental Science: Earth as a Living Planet*, 3rd Edition. (John Wiley & Sons, 2000).

Wright Richard T. *Enviromental Science*, 9th Edition. (Pearson/Prentice-Hall, 2005).

Raven, Peter H. and Linda R. Berg. *Enviroment.* (Harcourt College Publishers, 2001).

CHAPTER

10 Practice Exam II

CHAPTER SUMMARY

This is the second of three practice exams based on actual health occupations entrance exams used today. Take this test to see how much you have improved since you took the first exam.

THE PRACTICE TEST that follows is closely modeled after real entrance exams used to admit candidates to health education programs throughout the country. This test will help prepare you for admissions tests like the HOAE, the HOBET, and other entrance tests. As with the first practice test in Chapter 3, it covers six essential topics—Verbal Ability, Quantitative Ability, General Science, Biology, Chemistry, and Reading Comprehension—and uses a multiple-choice format, with four answer choices, **a–d**. Although the practice tests in this book will prepare you for *any* health occupations entrance exam, be sure to learn the specifics about the exam that you are facing—it may vary somewhat in content and format (number of questions or sections) from this practice test.

For this second exam, simulate an actual test-taking experience as much as possible. First, find a quiet place where you can work undisturbed for four hours. Keep a timer or alarm clock on hand to observe the time limits specified in the directions. Time each section separately, according to the directions set out at the beginning of each segment. Stop working when the alarm goes off even if you have not completed the section. Between sections, take five minutes to clear your mind, and take a fifteen-minute break after Section 3. These breaks, and the time limits given for each section, approximate the testing schedule of commonly used entrance exams, such as the HOAE and HOBET.

Using a number 2 pencil, mark your answers on the answer sheet on the following pages. The answer key is located on page 326—of course, you should not refer to it until you have completed the test. A section about how to score your exam follows the answer key.

► Section 1: Verbal Ability

1.	a	b	c	d
2.	a	b	c	d
3.	a	b	c	d
4.	a	b	c	d
5.	a	b	c	d
6.	a	b	c	d
7.	a	b	c	d
8.	a	b	c	d
9.	a	b	c	d
10.	a	b	c	d
11.	a	b	c	d
12.	a	b	c	d
13.	a	b	c	d
14.	a	b	c	d
15.	a	b	c	d
16.	a	b	c	d
17.	a	b	c	d
18.	a	b	c	d
19.	a	b	c	d
20.	a	b	c	d
21.	a	b	c	d
22.	a	b	c	d
23.	a	b	c	d
24.	a	b	c	d
25.	a	b	c	d
26.	a	b	c	d
27.	a	b	c	d
28.	a	b	c	d
29.	a	b	c	d
30.	a	b	c	d
31.	a	b	c	d
32.	a	b	c	d
33.	a	b	c	d
34.	a	b	c	d
35.	a	b	c	d
36.	a	b	c	d
37.	a	b	c	d
38.	a	b	c	d
39.	a	b	c	d
40.	a	b	c	d
41.	a	b	c	d
42.	a	b	c	d
43.	a	b	c	d
44.	a	b	c	d
45.	a	b	c	d
46.	a	b	c	d
47.	a	b	c	d
48.	a	b	c	d
49.	a	b	c	d
50.	a	b	c	d

► Section 2: Reading Comprehension

1.	a	b	c	d
2.	a	b	c	d
3.	a	b	c	d
4.	a	b	c	d
5.	a	b	c	d
6.	a	b	c	d
7.	a	b	c	d
8.	a	b	c	d
9.	a	b	c	d
10.	a	b	c	d
11.	a	b	c	d
12.	a	b	c	d
13.	a	b	c	d
14.	a	b	c	d
15.	a	b	c	d
16.	a	b	c	d
17.	a	b	c	d
18.	a	b	c	d
19.	a	b	c	d
20.	a	b	c	d
21.	a	b	c	d
22.	a	b	c	d
23.	a	b	c	d
24.	a	b	c	d
25.	a	b	c	d
26.	a	b	c	d
27.	a	b	c	d
28.	a	b	c	d
29.	a	b	c	d
30.	a	b	c	d
31.	a	b	c	d
32.	a	b	c	d
33.	a	b	c	d
34.	a	b	c	d
35.	a	b	c	d
36.	a	b	c	d
37.	a	b	c	d
38.	a	b	c	d
39.	a	b	c	d
40.	a	b	c	d
41.	a	b	c	d
42.	a	b	c	d
43.	a	b	c	d
44.	a	b	c	d
45.	a	b	c	d

► Section 3: Quantitative Ability

1.	ⓐ	ⓑ	ⓒ	ⓓ
2.	ⓐ	ⓑ	ⓒ	ⓓ
3.	ⓐ	ⓑ	ⓒ	ⓓ
4.	ⓐ	ⓑ	ⓒ	ⓓ
5.	ⓐ	ⓑ	ⓒ	ⓓ
6.	ⓐ	ⓑ	ⓒ	ⓓ
7.	ⓐ	ⓑ	ⓒ	ⓓ
8.	ⓐ	ⓑ	ⓒ	ⓓ
9.	ⓐ	ⓑ	ⓒ	ⓓ
10.	ⓐ	ⓑ	ⓒ	ⓓ
11.	ⓐ	ⓑ	ⓒ	ⓓ
12.	ⓐ	ⓑ	ⓒ	ⓓ
13.	ⓐ	ⓑ	ⓒ	ⓓ
14.	ⓐ	ⓑ	ⓒ	ⓓ
15.	ⓐ	ⓑ	ⓒ	ⓓ
16.	ⓐ	ⓑ	ⓒ	ⓓ
17.	ⓐ	ⓑ	ⓒ	ⓓ
18.	ⓐ	ⓑ	ⓒ	ⓓ
19.	ⓐ	ⓑ	ⓒ	ⓓ
20.	ⓐ	ⓑ	ⓒ	ⓓ
21.	ⓐ	ⓑ	ⓒ	ⓓ
22.	ⓐ	ⓑ	ⓒ	ⓓ
23.	ⓐ	ⓑ	ⓒ	ⓓ
24.	ⓐ	ⓑ	ⓒ	ⓓ
25.	ⓐ	ⓑ	ⓒ	ⓓ
26.	ⓐ	ⓑ	ⓒ	ⓓ
27.	ⓐ	ⓑ	ⓒ	ⓓ
28.	ⓐ	ⓑ	ⓒ	ⓓ
29.	ⓐ	ⓑ	ⓒ	ⓓ
30.	ⓐ	ⓑ	ⓒ	ⓓ
31.	ⓐ	ⓑ	ⓒ	ⓓ
32.	ⓐ	ⓑ	ⓒ	ⓓ
33.	ⓐ	ⓑ	ⓒ	ⓓ
34.	ⓐ	ⓑ	ⓒ	ⓓ
35.	ⓐ	ⓑ	ⓒ	ⓓ
36.	ⓐ	ⓑ	ⓒ	ⓓ
37.	ⓐ	ⓑ	ⓒ	ⓓ
38.	ⓐ	ⓑ	ⓒ	ⓓ
39.	ⓐ	ⓑ	ⓒ	ⓓ
40.	ⓐ	ⓑ	ⓒ	ⓓ
41.	ⓐ	ⓑ	ⓒ	ⓓ
42.	ⓐ	ⓑ	ⓒ	ⓓ
43.	ⓐ	ⓑ	ⓒ	ⓓ
44.	ⓐ	ⓑ	ⓒ	ⓓ
45.	ⓐ	ⓑ	ⓒ	ⓓ
46.	ⓐ	ⓑ	ⓒ	ⓓ
47.	ⓐ	ⓑ	ⓒ	ⓓ
48.	ⓐ	ⓑ	ⓒ	ⓓ
49.	ⓐ	ⓑ	ⓒ	ⓓ
50.	ⓐ	ⓑ	ⓒ	ⓓ

► Section 4: General Science

1.	ⓐ	ⓑ	ⓒ	ⓓ
2.	ⓐ	ⓑ	ⓒ	ⓓ
3.	ⓐ	ⓑ	ⓒ	ⓓ
4.	ⓐ	ⓑ	ⓒ	ⓓ
5.	ⓐ	ⓑ	ⓒ	ⓓ
6.	ⓐ	ⓑ	ⓒ	ⓓ
7.	ⓐ	ⓑ	ⓒ	ⓓ
8.	ⓐ	ⓑ	ⓒ	ⓓ
9.	ⓐ	ⓑ	ⓒ	ⓓ
10.	ⓐ	ⓑ	ⓒ	ⓓ
11.	ⓐ	ⓑ	ⓒ	ⓓ
12.	ⓐ	ⓑ	ⓒ	ⓓ
13.	ⓐ	ⓑ	ⓒ	ⓓ
14.	ⓐ	ⓑ	ⓒ	ⓓ
15.	ⓐ	ⓑ	ⓒ	ⓓ
16.	ⓐ	ⓑ	ⓒ	ⓓ
17.	ⓐ	ⓑ	ⓒ	ⓓ
18.	ⓐ	ⓑ	ⓒ	ⓓ
19.	ⓐ	ⓑ	ⓒ	ⓓ
20.	ⓐ	ⓑ	ⓒ	ⓓ
21.	ⓐ	ⓑ	ⓒ	ⓓ
22.	ⓐ	ⓑ	ⓒ	ⓓ
23.	ⓐ	ⓑ	ⓒ	ⓓ
24.	ⓐ	ⓑ	ⓒ	ⓓ
25.	ⓐ	ⓑ	ⓒ	ⓓ
26.	ⓐ	ⓑ	ⓒ	ⓓ
27.	ⓐ	ⓑ	ⓒ	ⓓ
28.	ⓐ	ⓑ	ⓒ	ⓓ
29.	ⓐ	ⓑ	ⓒ	ⓓ
30.	ⓐ	ⓑ	ⓒ	ⓓ
31.	ⓐ	ⓑ	ⓒ	ⓓ
32.	ⓐ	ⓑ	ⓒ	ⓓ
33.	ⓐ	ⓑ	ⓒ	ⓓ
34.	ⓐ	ⓑ	ⓒ	ⓓ
35.	ⓐ	ⓑ	ⓒ	ⓓ
36.	ⓐ	ⓑ	ⓒ	ⓓ
37.	ⓐ	ⓑ	ⓒ	ⓓ
38.	ⓐ	ⓑ	ⓒ	ⓓ
39.	ⓐ	ⓑ	ⓒ	ⓓ
40.	ⓐ	ⓑ	ⓒ	ⓓ
41.	ⓐ	ⓑ	ⓒ	ⓓ
42.	ⓐ	ⓑ	ⓒ	ⓓ
43.	ⓐ	ⓑ	ⓒ	ⓓ
44.	ⓐ	ⓑ	ⓒ	ⓓ
45.	ⓐ	ⓑ	ⓒ	ⓓ
46.	ⓐ	ⓑ	ⓒ	ⓓ
47.	ⓐ	ⓑ	ⓒ	ⓓ
48.	ⓐ	ⓑ	ⓒ	ⓓ
49.	ⓐ	ⓑ	ⓒ	ⓓ
50.	ⓐ	ⓑ	ⓒ	ⓓ

► Section 5: Biology

1.	a	b	c	d	18.	a	b	c	d	35.	a	b	c	d
2.	a	b	c	d	19.	a	b	c	d	36.	a	b	c	d
3.	a	b	c	d	20.	a	b	c	d	37.	a	b	c	d
4.	a	b	c	d	21.	a	b	c	d	38.	a	b	c	d
5.	a	b	c	d	22.	a	b	c	d	39.	a	b	c	d
6.	a	b	c	d	23.	a	b	c	d	40.	a	b	c	d
7.	a	b	c	d	24.	a	b	c	d	41.	a	b	c	d
8.	a	b	c	d	25.	a	b	c	d	42.	a	b	c	d
9.	a	b	c	d	26.	a	b	c	d	43.	a	b	c	d
10.	a	b	c	d	27.	a	b	c	d	44.	a	b	c	d
11.	a	b	c	d	28.	a	b	c	d	45.	a	b	c	d
12.	a	b	c	d	29.	a	b	c	d	46.	a	b	c	d
13.	a	b	c	d	30.	a	b	c	d	47.	a	b	c	d
14.	a	b	c	d	31.	a	b	c	d	48.	a	b	c	d
15.	a	b	c	d	32.	a	b	c	d	49.	a	b	c	d
16.	a	b	c	d	33.	a	b	c	d	50.	a	b	c	d
17.	a	b	c	d	34.	a	b	c	d					

► Section 6: Chemistry

1.	a	b	c	d	18.	a	b	c	d	35.	a	b	c	d
2.	a	b	c	d	19.	a	b	c	d	36.	a	b	c	d
3.	a	b	c	d	20.	a	b	c	d	37.	a	b	c	d
4.	a	b	c	d	21.	a	b	c	d	38.	a	b	c	d
5.	a	b	c	d	22.	a	b	c	d	39.	a	b	c	d
6.	a	b	c	d	23.	a	b	c	d	40.	a	b	c	d
7.	a	b	c	d	24.	a	b	c	d	41.	a	b	c	d
8.	a	b	c	d	25.	a	b	c	d	42.	a	b	c	d
9.	a	b	c	d	26.	a	b	c	d	43.	a	b	c	d
10.	a	b	c	d	27.	a	b	c	d	44.	a	b	c	d
11.	a	b	c	d	28.	a	b	c	d	45.	a	b	c	d
12.	a	b	c	d	29.	a	b	c	d	46.	a	b	c	d
13.	a	b	c	d	30.	a	b	c	d	47.	a	b	c	d
14.	a	b	c	d	31.	a	b	c	d	48.	a	b	c	d
15.	a	b	c	d	32.	a	b	c	d	49.	a	b	c	d
16.	a	b	c	d	33.	a	b	c	d	50.	a	b	c	d
17.	a	b	c	d	34.	a	b	c	d					

► Section 1: Verbal Ability

Find the correctly spelled word in the following questions. You have 15 minutes to answer the 50 questions in this section.

1. **a.** commitment
b. committent
c. comittment
d. comitment

2. **a.** rediculous
b. rediculus
c. ridiculous
d. ridiculus

3. **a.** anynonimous
b. anonimous
c. anounymous
d. anonymous

4. **a.** extraordinary
b. extraordinery
c. extrordinary
d. ecstraordinary

5. **a.** asurrance
b. assurance
c. assurence
d. assureance

6. **a.** frequently
b. frequintly
c. frequentlly
d. frequentley

7. **a.** enphasis
b. emphisis
c. emphasis
d. emfasis

8. **a.** concede
b. conceed
c. consede
d. conseed

9. **a.** encouredging
b. encouraging
c. incurraging
d. incouraging

10. **a.** phenomina
b. phenominna
c. phenomena
d. phinomina

11. **a.** compatibel
b. compatable
c. compatible
d. commpatible

12. **a.** skeptical
b. skeptikal
c. skepticle
d. skepticil

13. **a.** comencement
b. commencement
c. commencment
d. comencment

14. **a.** superviser
b. supervizer
c. supervizor
d. supervisor

15. **a.** neumonia
b. pneumonia
c. pnumonia
d. newmonia

16. **a.** annoid
b. anoyed
c. annoyed
d. annoyd

17. **a.** apperatus
b. aparatus
c. apparatus
d. aparratus

18. **a.** Coedeine
b. Codine
c. Codeine
d. Codiene

19. **a.** acompany
b. acommpany
c. accompeny
d. accompany

20. **a.** incessent
b. insessant
c. incesant
d. incessant

21. **a.** delemma
b. dilemma
c. dilema
d. dilemna

22. **a.** eficient
b. eficeint
c. efficient
d. efficeint

23. **a.** ameliorate
b. amiliorate
c. amieliorate
d. amielierate

24. **a.** viewpoint
b. veiwpoint
c. viewpointe
d. veiupoint

25. **a.** agravated
b. agravaeted
c. aggravated
d. aggravatid

Find the misspelled word in the following questions.

26. **a.** women
b. people
c. babys
d. no mistakes

27. **a.** radios
b. leaves
c. alumni
d. no mistakes

28. **a.** anouncement
b. advisement
c. description
d. no mistakes

29. **a.** omission
b. aisle
c. litrature
d. no mistakes

30. **a.** informal
b. servent
c. comfortable
d. no mistakes

31. **a.** vegetable
b. heifer
c. variation
d. no mistakes

32. **a.** associacion
b. unnecessary
c. illegal
d. no mistakes

33. **a.** parachute
b. rehearsel
c. together
d. no mistakes

34. **a.** intrigued
b. hypnotized
c. fasinated
d. no mistakes

35. **a.** distructive
b. decisive
c. distinguished
d. no mistakes

36. **a.** evaporate
b. vanish
c. disolve
d. no mistakes

37. **a.** illuminate
b. enlighten
c. clarify
d. no mistakes

38. **a.** abolish
b. forfit
c. negate
d. no mistakes

39. **a.** zoology
b. meterology
c. anthropology
d. no mistakes

40. **a.** ajournment
b. tournament
c. confinement
d. no mistakes

41. **a.** vague
b. trepidation
c. vengence
d. no mistakes

42. **a.** tuition
b. mediocre
c. tramendous
d. no mistakes

43. **a.** integrity
b. ingenuity
c. immortality
d. no mistakes

44. **a.** conjunction
b. preposition
c. capitolization
d. no mistakes

45. **a.** skien
b. knobby
c. blemished
d. no mistakes

46. **a.** brackets
b. parenthisis
c. ellipsis
d. no mistakes

47. **a.** visionary
b. virtuoso
c. wierd
d. no mistakes

48. **a.** language
b. philosophy
c. sonet
d. no mistakes

49. **a.** depo
b. aisle
c. knight
d. no mistakes

50. **a.** perscribe
b. deviate
c. plausible
d. no mistakes

▶ Section 2: Reading Comprehension

Read each passage and answer the accompanying questions based solely on the information found in the passage. You have 45 minutes to complete this section.

Millions of people in the United States are affected by eating disorders. More than 90% of those afflicted are adolescent or young adult women. While all eating disorders share some common manifestations, anorexia nervosa, bulimia nervosa, and binge eating each have distinctive symptoms and risks.

People who intentionally starve themselves (even while experiencing severe hunger pains) suffer from *anorexia nervosa*. The disorder, which usually begins around the time of puberty, involves extreme weight loss to at least 15% below the individual's normal body weight. Many people with the disorder look emaciated but are convinced they are overweight. In patients with anorexia nervosa, starvation can damage vital organs such as the heart and brain. To protect itself, the body shifts into slow gear: Menstrual periods stop, blood pressure rates drop, and thyroid function slows. Excessive thirst and frequent urination may occur. Dehydration contributes to constipation, and reduced body fat leads to lowered body temperature and the inability to withstand cold. Mild anemia, swollen joints, reduced muscle mass, and light-headedness also commonly occur in those having anorexia nervosa.

Anorexia nervosa sufferers can exhibit sudden angry outbursts or become socially withdrawn. One in ten cases of anorexia nervosa leads to death from starvation, cardiac arrest, other medical complications, or suicide. Clinical depression and anxiety place many individuals with eating disorders at risk for suicidal behavior.

People with *bulimia nervosa* consume large amounts of food and then rid their bodies of the excess calories by vomiting, abusing laxatives or diuretics, taking enemas, or exercising obsessively. Some use a combination of all these forms of purging. Individuals with bulimia who use drugs to stimulate vomiting, bowel movements, or urination may be in considerable danger, as this practice increases the risk of heart failure. Dieting heavily between episodes of binging and purging is common.

Because many individuals with bulimia binge and purge in secret and maintain normal or above normal body weight, they can often successfully hide their problem for years. But bulimia nervosa patients—even those of normal weight—can severely damage their bodies by frequent binge eating and purging. In rare instances, binge eating causes the stomach to rupture; purging may result in heart failure due to loss of vital minerals such as potassium. Vomiting can cause the esophagus to become inflamed and glands near the cheeks to become swollen. As in anorexia nervosa, bulimia may lead to irregular menstrual periods. Psychological effects include compulsive stealing as well as possible indications of obsessive-compulsive disorder, an illness characterized by repetitive thoughts and behaviors. Obsessive-compulsive disorder can also accompany anorexia nervosa. As with anorexia nervosa, bulimia typically begins during adolescence. Eventually, half of those with anorexia nervosa will develop bulimia. The condition occurs most often in women but is also found in men.

Binge-eating disorder is found in about 2% of the general population. As many as one-third of this group are men. It also affects older women, though with less frequency. Recent research shows that binge-eating disorder occurs in about 30% of people participating in medically supervised weight control programs. This disorder differs from bulimia because its sufferers do not purge. Individuals with binge-eating disorder feel that they lose control of themselves when eating. They eat large quantities of food and do not stop until they are uncomfortably full. Most sufferers are overweight or obese and have a history of weight fluctuations. As a result, they are prone to the serious medical problems associated with obesity, such as high cholesterol, high blood pressure, and diabetes. Obese individuals also have a higher risk for gallbladder disease, heart disease, and some types of cancer. Usually, they have more difficulty losing weight and keeping it off than do people with other serious weight problems. Like anorexics and bulimics who exhibit psychological problems, individuals with binge-eating disorder have high rates of simultaneously occurring psychiatric illnesses—especially depression.

1. Fatalities occur in what percent of people with anorexia nervosa?
a. 2%
b. 10%
c. 15%
d. 30%

2. Which of the following consequences do all the eating disorders mentioned in the passage have in common?
a. heart ailments
b. stomach rupture
c. swollen joints
d. diabetes

3. People with binge-eating disorder are prone to all of the following EXCEPT
a. loss of control.
b. depression.
c. low blood pressure.
d. high cholesterol.

4. Which of the following is NOT a true statement about people with eating disorders?
a. People with anorexia nervosa commonly have a blood-related deficiency.
b. People with anorexia nervosa perceive themselves as overweight.
c. The female population is the primary group affected by eating disorders.
d. Fifty percent of people with bulimia have had anorexia nervosa.

5. People who have an eating disorder but nevertheless appear to be of normal weight are most likely to have
a. obsessive-compulsive disorder.
b. bulimia nervosa.
c. binge-eating disorder.
d. anorexia nervosa.

6. Glandular functions of anorexia patients slow down as a result of
 a. lowering body temperatures.
 b. excessive thirst and urination.
 c. protective measures taken by the body.
 d. the loss of essential minerals.

7. The inability to eliminate body waste is related to
 a. dehydration.
 b. an inflamed esophagus.
 c. the abuse of laxatives.
 d. weight control programs.

8. Which of the following is true of bulimia patients?
 a. They may demonstrate unpredictable social behavior.
 b. They often engage in compulsive exercise.
 c. They are less susceptible to dehydration than are anorexia patients.
 d. They frequently experience stomach ruptures.

9. Which of the following represent up to two-thirds of the binge-eating disorder population?
 a. older males
 b. older females
 c. younger males
 d. younger females

The U.S. population is going gray. A rising demographic tide of aging baby boomers—those born between 1946 and 1964—and increased longevity have made adults age 65 and older the fastest growing segment of today's population. In thirty years, this segment of the population will be nearly twice as large as it is today. By then, an estimated 70 million people will be over age 65. The number of "oldest old"—those age 85 and older—is 34 times greater than in 1900 and likely to expand fivefold by 2050.

This unprecedented "elder boom" will have a profound effect on American society, particularly the field of healthcare. Is the U.S. health system equipped to deal with the demands of an aging population? Although we have adequate physicians and nurses, many of them are not trained to handle the multiple needs of older patients. Today, we have about 9,000 *geriatricians* (physicians who are experts in aging-related issues). Some studies estimate a need for 36,000 geriatricians by 2030.

Many doctors today treat a patient of 75 the same way they would treat a 40-year-old patient. However, although seniors are healthier than ever, physical challenges often increase with age. By age 75, adults often have two to three medical conditions. Diagnosing multiple health problems and knowing how they interact is crucial for effectively treating older patients. Healthcare professionals—often pressed for time in hectic daily practices—must be diligent about asking questions and collecting "evidence" from their elderly patients. Finding out about a patient's over-the-counter medications or living conditions could reveal an underlying problem.

Lack of training in geriatric issues can result in healthcare providers overlooking illnesses or conditions that may lead to illness. Inadequate nutrition is a common, but often unrecognized, problem among frail seniors. An elderly patient who has difficulty preparing meals at home may become vulnerable to malnutrition or another medical condition. Healthcare providers with training in aging issues may be able to address this problem without the costly solution of admitting a patient to a nursing home.

Depression, a treatable condition that affects nearly five million seniors, also goes undetected by some healthcare providers. Some healthcare professionals view depression as "just part of getting old." Untreated, this illness can have serious, even fatal consequences. According to the National Institute of Mental Health, older Americans account for a disproportionate share of suicide deaths, making up 18% of suicide deaths in 2000. Healthcare providers could play a vital role in preventing this outcome—several studies have shown that up to 75% of seniors who die by suicide visited a primary care physician within a month of their death.

Healthcare providers face additional challenges to providing high-quality care to the aging population. Because the numbers of ethnic minority elders are growing faster than the aging population as a whole, providers must train to care for a more racially and ethnically diverse population of elderly. Respect and understanding of diverse cultural beliefs is necessary to provide the most effective healthcare to all patients. Providers must also be able to communicate complicated medical conditions or treatments to older patients who may have a visual, hearing, or cognitive impairment.

As older adults make up an increasing proportion of the healthcare caseload, the demand for aging specialists must expand as well. Healthcare providers who work with the elderly must understand and address not only the physical but mental, emotional, and social changes of the aging process. They need to be able to distinguish between "normal" characteristics associated with aging and illness. Most crucially, they should look beyond symptoms and consider ways that will help a senior maintain and improve his or her quality of life.

10. The author uses the phrase *going gray* in order to
  a. maintain that everyone's hair loses its color eventually.
  b. suggest the social phenomenon of an aging population.
  c. depict older Americans in a positive light.
  d. demonstrate the normal changes of aging.

11. In the third paragraph, the author implies that doctors who treat elderly patients as they would *a 40-year-old patient*
  a. provide equitable, high-quality care.
  b. avoid detrimental stereotypes about older patients.
  c. encourage middle-age adults to think about the long-term effects of their habits.
  d. do not offer the most effective care to their older patients.

12. In the fourth paragraph, the word *address* most nearly means
  a. manage.
  b. identify.
  c. neutralize.
  d. analyze.

13. In the fifth paragraph, the author cites the example of untreated depression in elderly people in order to
  a. prove that mental illness can affect people of all ages.
  b. undermine the perception that mental illness only affects young people.
  c. support the claim that healthcare providers need age-related training.
  d. show how mental illness is a natural consequence of growing old.

14. According to the passage, which of the following is NOT a possible benefit of geriatric training for healthcare providers?
  a. improved ability to explain a medical treatment to a person with a cognitive problem
  b. knowledge of how heart disease and diabetes may act upon each other in an elderly patient
  c. improved ability to attribute disease symptoms to the natural changes of aging
  d. more consideration for ways to improve the quality of life for seniors

Scientists have been studying radon and its effects since the turn of the century. This inert gas has been proven to cause lung cancer and is suspected of being responsible for a range of other serious illnesses.

Radon gas is created as the result of the decaying of uranium and radium. At the culmination of this lengthy process, the disintegrating matter becomes radon, which then decays further, releasing additional radiation and transforming into what are known as radon daughters. Unlike radon, the daughters are not inert because they are highly sensitive to their surroundings and are chemically active. Thus, when the daughters enter buildings, attach to clothing, mingle with dust particles, or are inhaled, health risks increase dramatically. Radon exists across the United States, with somewhat higher amounts located in areas where granite is common.

Radon gas released directly into the atmosphere poses slight health risks. Conversely, when it is trapped and has the opportunity to accumulate, such as beneath houses and other structures, risks increase significantly. This colorless, tasteless, and odorless element can seep into buildings through walls, soil, water supplies, and natural gas pipelines. It can also be part of the properties of materials such as brick, wallboard, and concrete. When radon is prevalent in a building, it circulates in that building's air exchange and is inhaled by humans.

The majority of the radon daughters exhibit electrostatic qualities as they attach to items such as clothing, furniture, and dust, a magnetic process known as *plating out*. The remainder of the daughters do not attach to anything. As an individual breathes the potentially damaging air, the attached and unattached daughters enter the body. As the daughters travel through the body, particles become attached to the respiratory tract, the bronchial region, the nose, and the throat. Some particles are expelled during exhalation, but most remain within the individual.

The unattached daughters are the most dangerous as their untethered route often carries them directly to the lungs. They deposit significantly more radioactivity than the attached daughters—indeed, up to 40 times as much. Research indicates that those individuals who breathe primarily through their noses receive fewer doses than those who breathe primarily through their mouths.

Alpha radiation begins penetrating the lungs and other organs after radon daughters settle there. Penetration and the subsequent depositing of radiation are the result of a continuation of the decaying process. An appreciable dose of alpha particles can lead to cell destruction. Higher doses can be fatal. One comparative study analyzed similar doses from radon, X rays, and atom bombs, and concluded that the chances of developing lung cancer from radon were equal to those from the other two radiation sources. In the United States, most incidences involve lower-level doses, which destroy a relatively low number of cells. The body will regenerate lost cells, so serious health problems become less likely.

Serious problems materialize when cells are exposed repeatedly. The cycle of exposure-damage-regeneration-exposure can weaken cells and ultimately change their makeup. Cell alteration can lead to lung cancer, genetic changes, and a host of other medical problems.

15. Gases from an outdoor radon leak
- **a.** present serious health ramifications.
- **b.** are easy to detect.
- **c.** create a negligible health threat.
- **d.** transform into radon daughters.

16. It can be inferred from the passage that an inert gas such as radon is
- **a.** unusually likely to decay.
- **b.** dormant in terms of chemical reactions.
- **c.** more dangerous than radon daughters.
- **d.** created as the result of a distinct series of events.

17. One reason unattached daughters are more dangerous than attached daughters is that they
- **a.** demonstrate electrostatic qualities.
- **b.** are less likely to be expelled.
- **c.** regenerate after entering the lungs.
- **d.** have a free path toward internal organs.

18. *Plating out* is a term for a process of
- **a.** cohering.
- **b.** disseminating.
- **c.** deteriorating.
- **d.** permeating.

19. Health hazards from radon rise greatly when
- **a.** gases accumulate inside buildings.
- **b.** daughters leave the body via exhalation.
- **c.** individuals inhale mostly through their noses.
- **d.** regeneration takes place.

20. Radon is formed as a consequence of
- **a.** the alteration of cells.
- **b.** the breakdown of elements.
- **c.** exposure to the atmosphere.
- **d.** an electrostatic process.

21. In the United States, most cases of radon exposure involve doses that
- **a.** affect residents near granite formations.
- **b.** lead to genetic problems.
- **c.** cause recurring exposure.
- **d.** eliminate small amounts of cells.

The *dystonias* are movement disorders in which sustained muscle contractions cause twisting and repetitive movements or abnormal postures. The movements, which are involuntary and sometimes painful, may affect a single muscle; a group of muscles such as those in the arms, legs, or neck; or the entire body. Diminished intelligence and emotional imbalance are not usually features of the dystonias.

Generalized dystonia affects most or all of the body. *Focal dystonia* is localized to a specific body part. *Multifocal dystonia* involves two or more unrelated body parts. *Segmental dystonia* affects two or more adjacent parts of the body. *Hemidystonia* involves the arm and leg on the same side of the body.

Early symptoms may include a deterioration in handwriting after writing several lines, foot cramps, and a tendency of one foot to pull up or drag after running or walking some distance. The neck may turn or pull involuntarily, especially when the person is tired. Other possible symptoms are tremor and voice or speech difficulties. The initial symptoms can be very mild and may be noticeable only after prolonged exertion, stress, or fatigue. Over a period of time, the symptoms may become more noticeable and widespread and may be unrelenting; however, sometimes, there is little or no progression.

Torsion dystonia, previously called *dystonia musculum deformans* or DMD, is a rare, generalized dystonia that may be inherited, usually begins in childhood, and becomes progressively worse. It can leave individuals seriously disabled and confined to a wheelchair.

Spasmodic torticollis, or *torticollis*, is the most common of the focal dystonias. In torticollis, the muscles in the neck that control the position of the head are affected, causing the head to twist and turn to one side. In addition, the head may be pulled forward or backward. Torticollis can occur at any age, although most individuals first experience symptoms in middle age. It often begins slowly and usually reaches a plateau. About 10% to 20% of those with torticollis experience a spontaneous remission; however, the remission may not be lasting.

Blepharospasm, the second most common focal dystonia, is the involuntary, forcible closure of the eyelids. The first symptoms may be uncontrollable blinking. Only one eye may be affected initially, but eventually both eyes are usually involved. The spasms may leave the eyelids completely closed, causing functional blindness even though the eyes and vision are normal.

Cranial dystonia is a term used to describe dystonia that affects the muscles of the head, face, and neck. *Oromandibular dystonia* affects the muscles of the jaw, lips, and tongue. The jaw may be pulled either open or shut, and speech and swallowing can be difficult. *Spasmodic dysphonia* involves the muscles of the throat that control speech. Also called *spastic dysphonia* or *laryngeal dystonia*, it causes strained and difficult speaking or breathy and effortful speech. *Meige's syndrome* is the combination of blepharospasm and oromandibular dystonia and sometimes spasmodic dysphonia.

Dopa-responsive dystonia (DRD) is a condition successfully treated with drugs. Typically, DRD begins in childhood or adolescence with progressive difficulty in walking and, in some cases, spasticity. In *Segawa's dystonia*, the symptoms fluctuate during the day from relative mobility in the morning to increasingly worse disability in the afternoon and evening as well as after exercise. Some scientists feel DRD is not only rare but also rarely diagnosed since it mimics many of the symptoms of cerebral palsy.

22. The type of dystonia that may disappear immediately is
   a. dopa-responsive dystonia.
   b. spasmodic torticollis.
   c. torsion dystonia.
   d. cranial dystonia.

23. One symptom not typically experienced by dystonia patients is
   a. enunciation difficulties.
   b. hampered mobility.
   c. optical deficiencies.
   d. emotional instability.

24. Genetics may be implicated in
   a. torsion dystonia.
   b. torticollis.
   c. oromandibular dystonia.
   d. DRD.

25. Meige's syndrome directly affects both
   a. speech and mobility.
   b. mobility and vision.
   c. vision and speech.
   d. hearing and vision.

26. The symptoms of torticollis are most similar to those of
   a. cranial dystonia.
   b. DRD.
   c. blepharospasm.
   d. oromandibular dystonia.

27. A person with DRD usually
   a. has difficulty verbalizing.
   b. experiences writer's cramp.
   c. improves following exercise.
   d. responds well to medication.

28. All dystonia patients experience
- **a.** uncontrolled movement.
- **b.** progressive deterioration.
- **c.** symptoms at an early age.
- **d.** incessant discomfort.

29. Cranial dystonia is an example of a
- **a.** hemidystonia.
- **b.** multifocal dystonia.
- **c.** segmental dystonia.
- **d.** generalized dystonia.

30. The least common forms of dystonia mentioned in the passage are
- **a.** spasmodic and torsion dystonia.
- **b.** dopa-responsive and cranial dystonia.
- **c.** oromandibular and spasmodic dystonia.
- **d.** torsion and dopa-responsive dystonia.

Lyme disease is sometimes called the "great imitator"because its many symptoms mimic those of other illnesses. When treated, this disease usually presents few or no lingering effects. Left untreated, it can be extremely debilitating and sometimes fatal.

Lyme disease is caused by a bacterium carried and transmitted by the *Ixodes dammini* family of ticks. In 1982, the damaging microorganism was identified as *Borrelia burgdorferi*. Ticks are parasites that require blood for sustenance. They feed three times during a two-year life cycle (the larva, nymph, and adult stages), and feedings can last up to several days. As many as 3,000 eggs hatch into larvae, the first stage of the life cycle. The larvae then attach to host organisms, such as mice. Human infection by a tick at this stage is a rare occurrence.

Following the first blood meal, larvae molt into nymphs. These transformed organisms are about the size of a bread crumb. During this and subsequent stages of the life cycle, the tick chooses larger hosts on which to feed, including humans. Because of their tiny size, nymphs present the greatest danger to humans. Some studies indicate that as many as 80% of human hosts are infected by nymphs. As the life cycle progresses, nymphs engorged with blood become adults. During this stage, adults will mate, assuring continuance of the life cycle. Ticks generally rely on humid conditions and temperatures above 40° Fahrenheit.

Human infection occurs when the tick attaches itself to the body, feeding on blood while transmitting the bacteria. Since this process can take up to 48 hours, it is possible for an individual to remove the tick before infection occurs. When infection does occur, one of the early visible signs is a rash called *erythema migrans*, although in some cases, there is no rash at all. The mark left by the tick, often taking a bull's-eye shape, can range from the size of a quarter to one foot across. Some rashes disappear temporarily and then return. This inconsistent symptom adds to the perplexing nature of the disease.

Symptoms can materialize within a few days to a few weeks following bacterial transmission and include flu-like aches and pains, fever, and weakness. As the illness progresses, problems such as respiratory distress, irregular heartbeat, liver infection, bladder discomfort, and double vision can occur. Infected individuals may experience all, none, or a combination of symptoms.

Early diagnosis and antibiotic treatment of the earliest acute stage of Lyme disease generally leads to rapid recovery. An inaccurate diagnosis or lack of early treatment can lead to health problems such as heart muscle damage, severe joint pain, and meningitis. Lyme disease that reaches a chronic stage can lead to severe arthritis, paralysis, brain infection, and nervous system disorders; however, symptoms of chronic Lyme disease, despite lasting six months or longer, are generally treatable with antibiotics, and long-term illness is rare. Researchers are working on a vaccine, but its completion remains uncertain.

31. When tick larvae molt, they
a. infect hosts.
b. hatch from eggs.
c. mate with nymphs.
d. become nymphs.

32. Lyme disease that reaches the chronic stage tends to exhibit symptoms for
a. 48 hours or less.
b. a few days.
c. six months or more.
d. at least two years.

33. It can be inferred from the passage that *Ixodes dammini* ticks are LEAST likely to infect people in temperate zones during the
a. spring.
b. summer.
c. fall.
d. winter.

34. Diagnosis of Lyme disease is made difficult by the
a. similarities between it and other ailments.
b. changing shape of the erythema migrans.
c. unpredictable life cycle of the tick.
d. lack of prolonged effects produced.

35. Transmission of *Borrelia burgdorferi* to humans during the larva stage
a. accounts for the majority of infections.
b. is a relatively infrequent phenomenon.
c. generally occurs at temperatures below 40° F.
d. lasts up to several days.

36. One early symptom of Lyme disease is
a. arthritis.
b. meningitis.
c. fever.
d. difficulty breathing.

There are two types of diabetes, insulin-dependent and non-insulin-dependent. Between 90% and 95% of the estimated 13 to 14 million people in the United States with diabetes have non-insulin-dependent, or Type II, diabetes. Because this form of diabetes usually begins in adults over the age of 40 and is most common after the age of 55, it used to be called *adult-onset* diabetes. Its symptoms often develop gradually and are hard to identify at first; therefore, nearly half of all people with diabetes do not know they have it. For instance, someone who has developed Type II diabetes may feel tired or ill without knowing why. This can be particularly dangerous because untreated diabetes can cause damage to the heart, blood vessels, eyes, kidneys, and nerves. While the causes, short-term effects, and treatments of the two types of diabetes differ, both types can cause the same long-term health problems.

Most importantly, both types affect the body's ability to use digested food for energy. Diabetes does not interfere with digestion, but it does prevent the body from using an important product of digestion, *glucose* (commonly known as sugar), for energy. After a meal, the normal digestive system breaks some food down into glucose. The blood carries the glucose or sugar throughout the body, causing blood glucose levels to rise. In response to this rise, the hormone *insulin* is released into the bloodstream and signals the body tissues to metabolize or burn the glucose for fuel, which causes blood glucose levels to return to normal. The glucose that the body does not use right away is stored in the liver, muscle, or fat.

In both types of diabetes, however, this normal process malfunctions. A gland called the *pancreas*, found just behind the stomach, makes insulin. In people with insulin-dependent diabetes, the pancreas does not produce insulin at all. This condition usually begins in childhood and is known as Type I (formerly called *juvenile-onset*) diabetes. These patients must have daily insulin injections to survive. People with non-insulin-dependent diabetes usually produce some insulin in their pancreas, but the body's tissues do not respond very well to the insulin signal and therefore do not metabolize the glucose properly, a condition known as *insulin resistance*.

Insulin resistance is an important factor in non-insulin-dependent diabetes, and scientists are searching for the causes of insulin resistance. They have identified two possibilities. The first is that there could be a defect in the insulin receptors on cells. Like an appliance that needs to be plugged into an electrical outlet, insulin has to bind to a receptor in order to function. Several things can go wrong with receptors. For example, there may not be enough receptors for insulin to bind to, or a defect in the receptors may prevent insulin from binding. The second possible cause of insulin resistance is that, although insulin may bind to the receptors, the cells do not read the signal to metabolize the glucose. Scientists continue to study these cells to see why this might happen.

A National Institutes of Health panel of experts recommends that the best treatment for non-insulin-dependent diabetes is a diet that helps one maintain a normal weight and pays particular attention to a proper balance of the different food groups. Many experts, including those in the American Diabetes Association, recommend that 50% to 60% of daily calories come from carbohydrates, 12% to 20% from protein, and no more than 30% from fat. Foods that are rich in carbohydrates, like breads, cereals, fruits, and vegetables, break down into glucose during digestion, causing blood glucose to rise. Additionally, studies have shown that cooked foods raise blood glucose higher than raw, unpeeled foods. A doctor or nutritionist should always be consulted for more information and for help in planning a diet to offset the effects of this form of diabetes.

37. Which of the following may be the most dangerous aspect of Type II diabetes?
a. Insulin shots are needed daily for treatment of Type II diabetes.
b. In Type II diabetes, the pancreas does not produce insulin.
c. Type II diabetes interferes with digestion.
d. Persons with Type II diabetes may not know they have it and will therefore not seek treatment.

38. Which of the following are the same for Type I and Type II diabetes?
a. treatments
b. long-term health risks
c. short-term effects
d. causes

39. One place in which excess glucose is stored is the
a. stomach.
b. insulin receptors.
c. pancreas.
d. liver.

40. A diet dominated by which of the following is recommended for non-insulin-dependent diabetics?
a. protein
b. fat
c. carbohydrates
d. raw foods

41. Which of the following is the main function of insulin?
a. It signals tissues to metabolize sugar.
b. It breaks down food into glucose.
c. It carries glucose throughout the body.
d. It binds to receptors.

42. Which of the following statements best summarizes the main theme of the passage?
- **a.** Type I and Type II diabetes are best treated by maintaining a high protein diet.
- **b.** Type II diabetes is a distinct condition that can be managed by maintaining a healthy diet.
- **c.** Type I diabetes is an insidious condition most harmful when the patient is not taking daily insulin injections.
- **d.** Adults who suspect they may have Type II diabetes should immediately adopt a high carbohydrate diet.

43. Which of the following is mentioned in the passage as a possible problem with insulin receptors in insulin-resistant individuals?
- **a.** Overeating causes the receptors not to function properly.
- **b.** There may be an overabundance of receptors present.
- **c.** A defect causes the receptors to bind with glucose.
- **d.** A defect hinders the receptors from binding with insulin.

44. In normal individuals, which of the following processes occur immediately after the digestive system converts some food into glucose?
- **a.** The glucose is metabolized by body tissues.
- **b.** Insulin is released into the bloodstream.
- **c.** Blood sugar levels rise.
- **d.** The pancreas manufactures increased amounts of insulin.

45. Based on the information in the passage, which of the following best describes people with Type I diabetes?
- **a.** They do not need to be treated with injections of insulin.
- **b.** They comprise the majority of people with diabetes.
- **c.** Their pancreases do not produce insulin.
- **d.** They are usually diagnosed as adults.

▶ Section 3: Quantitative Ability

There are 50 questions in this section. You have 45 minutes to complete this section.

1. $4\frac{2}{5} + 3\frac{1}{2} + \frac{3}{8}$ is equal to
- **a.** $7\frac{3}{20}$.
- **b.** $7\frac{2}{5}$.
- **c.** $8\frac{11}{40}$.
- **d.** $8\frac{7}{8}$.

2. What is another way to write 2.75×100^2?
- **a.** 275
- **b.** 2,750
- **c.** 27,500
- **d.** 275,000

3. A licensed practical nurse has to lift four patients during his 8-hour shift. The patients weigh 152 pounds, 168 pounds, 182 pounds, and 201 pounds. Approximately how many pounds will the nurse have to lift during his shift?
- **a.** 690 pounds
- **b.** 700 pounds
- **c.** 710 pounds
- **d.** 750 pounds

4. If $x = 6$, $y = -2$, and $z = 3$, what is the value of the following expression?

$$\frac{xz - xy}{z^2}$$

- **a.** 5
- **b.** $3\frac{1}{3}$
- **c.** $\frac{2}{3}$
- **d.** $-\frac{2}{3}$

5. What is the area of a triangle with a height of 10 inches and a base of 2 inches?
- **a.** 10 square inches
- **b.** 12 square inches
- **c.** 20 square inches
- **d.** 22 square inches

6. It takes a medical transcriptionist 0.75 seconds to transcribe one word. At this rate, how many words can be transcribed in 60 seconds?
- **a.** 4.5
- **b.** 8
- **c.** 45
- **d.** 80

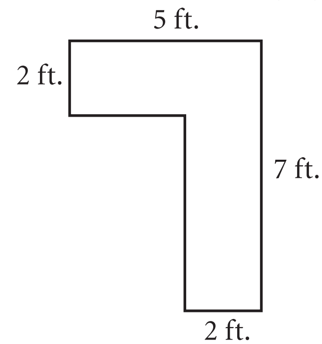
7. If $\frac{x}{2} + \frac{x}{6} = 4$, what is x?
- **a.** $\frac{1}{24}$
- **b.** $\frac{1}{6}$
- **c.** 3
- **d.** 6

8. $10^5 \div 10^2$ is equal to
- **a.** 10.
- **b.** 10^3.
- **c.** 10^7.
- **d.** 10^{10}.

9. $3.16 \div 0.079$ is equal to
- **a.** 0.025.
- **b.** 2.5.
- **c.** 4.0.
- **d.** 40.0.

10. $2\frac{5}{8} \div \frac{1}{3}$ is equal to
- **a.** $8\frac{1}{3}$.
- **b.** $7\frac{7}{8}$.
- **c.** $5\frac{11}{24}$.
- **d.** $\frac{7}{8}$.

11. What is the area of the following figure?

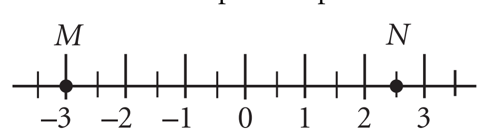


- **a.** 19 square feet
- **b.** 20 square feet
- **c.** 24 square feet
- **d.** 38 square feet

12. What is $7\frac{1}{5}$% of 465, rounded to the nearest tenth?
- **a.** 32.5
- **b.** 33
- **c.** 33.5
- **d.** 34

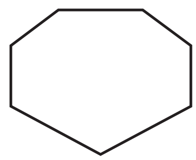
13. $3\frac{7}{10} - 2\frac{3}{8}$ is equal to
- **a.** $1\frac{13}{40}$.
- **b.** $1\frac{7}{20}$.
- **c.** $1\frac{11}{18}$.
- **d.** $2\frac{1}{80}$.

14. On the following number line, point L is to be located halfway between points M and N. What number will correspond to point L?



- **a.** $-\frac{1}{4}$
- **b.** $-\frac{1}{2}$
- **c.** $-1\frac{1}{4}$
- **d.** 0

15. What kind of polygon is the following figure?



a. pentagon
b. octagon
c. hexagon
d. heptagon

16. Which of the following is equivalent to $2y^2$?
a. $2y(y)$
b. $2(y + y)$
c. $y^2 + 2$
d. $y + y + y + y$

17. 367.08×0.15 is equal to
a. 22.0248.
b. 55.051.
c. 55.062.
d. 540.62.

18. $(–10) + (–4) + (\frac{1}{2}) – (–\frac{1}{4})$ is equal to
a. $–5\frac{3}{4}$.
b. $–6\frac{1}{4}$.
c. $–13\frac{1}{4}$.
d. $–13\frac{3}{4}$.

19. Which of these is equivalent to 35° C ?
$(F = \frac{9}{5}C + 32)$
a. 105° F
b. 95° F
c. 63° F
d. 19° F

20. What is the volume of a pyramid that has a rectangular base 5 feet by 3 feet and a height of 8 feet? $(V = \frac{1}{3}lwh)$
a. 16 cubic feet
b. 30 cubic feet
c. 40 cubic feet
d. 120 cubic feet

21. What is another way to write 7.25×10^3?
a. 72,500
b. 7,250
c. 725
d. 72.5

22. If $8n + 25 = 65$, then n is
a. 5.
b. 10.
c. 40.
d. 90.

23. What is the reciprocal of $3\frac{7}{8}$?
a. $\frac{8}{31}$
b. $\frac{31}{8}$
c. $\frac{8}{2}$
d. $-\frac{31}{8}$

24. Which of these angle measures form a right triangle?
a. 40°, 50°, 90°
b. 45°, 50°, 85°
c. 40°, 40°, 100°
d. 20°, 30°, 130°

25. Of 1,125 nurses who work in the hospital, 135 speak fluent Spanish. What percentage of the nursing staff speaks fluent Spanish?
a. 7.3%
b. 8.3%
c. 12%
d. 14%

26. A hospital emergency room receives an admission on August 3 at 10:42 P.M. and another admission at 1:19 A.M. on August 4. How much time has elapsed between admissions?
a. 1 hour 37 minutes
b. 2 hours 23 minutes
c. 2 hours 37 minutes
d. 3 hours 23 minutes

27. Second-year hospital resident Ann Green earns $26,000 a year. If she receives a 4.5% salary increase, how much will she earn?
a. $26,450
b. $27,170
c. $27,260
d. $29,200

28. Which of the following hospital rooms has the greatest perimeter?
a. a rectangular room 12 feet × 8 feet
b. a rectangular room 14 feet × 7 feet
c. a square room 10 feet × 10 feet
d. a square room 11 feet × 11 feet

29. A person can be scalded by hot water at a temperature of about 122° F. At about what temperature Centigrade could a person be scalded?
$C = \frac{5}{9}(F - 32)$
a. 35.5° C
b. 50° C
c. 55° C
d. 216° C

30. New nursing staff have to buy shoes to wear on duty at the full price of $84.50, but nurses who have worked in the hospital at least a year can get a 15% discount at a local shoe store, and nurses who have worked at least three years get an additional 10% off the discounted price. How much does a nurse who has worked at least three years have to pay for shoes?
a. $63.78
b. $64.65
c. $71.83
d. $72.05

31. There are 176 men and 24 women serving in a U.S. Army hospital. What percentage of the hospital's staff is women?
a. 12%
b. 14%
c. 16%
d. 24%

32. Body mass index (BMI) is equal to weight in kg divided by (height in m)^2. A man who weighs 64.8 kg has a BMI of 20. How tall is he?
a. 0.9 m
b. 1.8 m
c. 2.16 m
d. 3.24 m

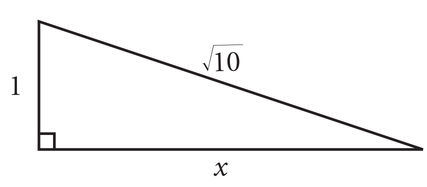
33. A patient's hospice stay costs one-fourth as much as his visit to the emergency room. His home nursing costs twice as much as his hospice stay. If his total health care bill was $140,000, how much did his home nursing cost?
a. $10,000
b. $20,000
c. $40,000
d. $80,000

34. An insurance policy pays 80% of the first $20,000 of a certain patient's medical expenses, 60% of the next $40,000, and 40% of the $40,000 after that. If the patient's total medical bill is $92,000, how much will the policy pay?
a. $36,800
b. $49,600
c. $52,800
d. $73,600

35. A doctor can treat four Alzheimer's patients per hour; however, stroke patients need three times as much of the doctor's time. If the doctor treats patients six hours per day and has already treated ten Alzheimer's patients and three stroke patients today, how many more stroke patients will she have time to treat today?
a. one
b. two
c. three
d. five

36. If an ambulance travels at the speed of 62 mph for 15 minutes, how far will it travel?
a. 9.3 miles
b. 15.5 miles
c. 16 miles
d. 24.8 miles

37. What is the value of x in the figure below?



a. 2
b. 3
c. 5
d. 9

38. $\frac{3\frac{1}{9}}{1\frac{1}{6}}$ is equal to
a. $\frac{4}{9}$.
b. $\frac{2}{3}$.
c. $1\frac{1}{3}$.
d. $2\frac{2}{3}$.

39. Ron is half as old as Sam, who is three times as old as Ted. The sum of their ages is 55. How old is Ron?
a. 5
b. 10
c. 15
d. 30

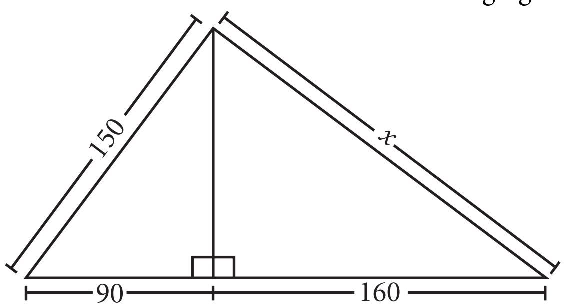
40. At a certain school, one-half of the students are female and one-twelfth of the students are from outside the state. What proportion of the students would you expect to be females from outside the state?
a. $\frac{1}{24}$
b. $\frac{1}{12}$
c. $\frac{1}{6}$
d. $\frac{1}{3}$

41. A floor plan is drawn to scale so that $\frac{1}{4}$ inch represents 2 feet. If a hall on the plan is 4 inches long, how long will the actual hall be when it is built?
a. 2 feet
b. 8 feet
c. 16 feet
d. 32 feet

42. 160% is equal to
a. $\frac{4}{25}$.
b. $\frac{3}{5}$.
c. $\frac{6}{5}$.
d. $\frac{8}{5}$.

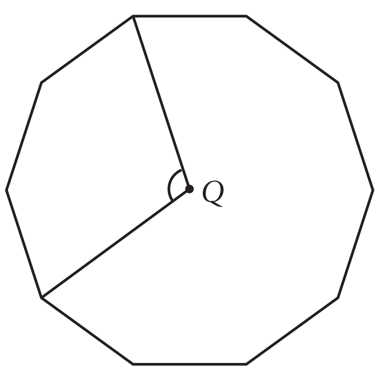
43. What is the surface area of a cylinder that is 0.8 meters wide and 2 meters tall?
a. 0.48π
b. 0.96π
c. 1.92π
d. 3.84π

44. What is the value of x in the following figure?



a. 200
b. 210
c. 240
d. 270

45. If the figure below is a regular decagon with a center at Q, what is the measure of the indicated angle?



a. 36 degrees
b. 45 degrees
c. 90 degrees
d. 108 degrees

46. Based on the information below, estimate the weight of a person who is 5'5" tall.

HEIGHT	WEIGHT
5'	110 lbs.
6'	170 lbs.

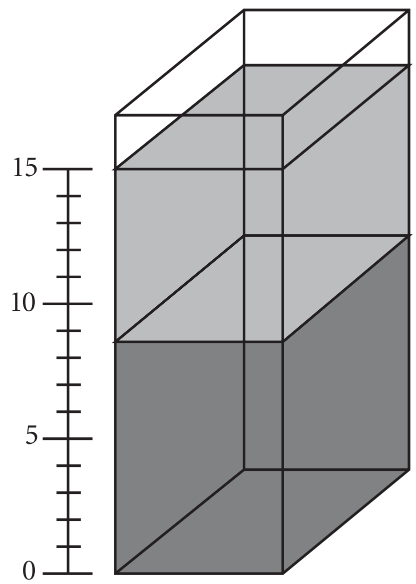
a. 125 lbs.
b. 130 lbs.
c. 135 lbs.
d. 140 lbs.

47. If no treatment has been given within three hours after injury to a certain organ, the organ's function starts decreasing by 20% each hour. If no treatment has been given within six hours after injury, about how much function will remain?
a. 50%
b. 60%
c. 70%
d. 80%

48. A study shows that 600,000 women die each year in pregnancy and childbirth, one-fifth more than scientists previously estimated. How many such deaths did the scientists previously estimate?
a. 120,000
b. 300,000
c. 480,000
d. 500,000

49. To lower a fever of 105 degrees, ice packs are applied for 1 minute and then removed for 5 minutes before being applied again. Each application lowers the fever by half a degree. How long will it take to lower the fever to 99 degrees?
a. 1 hour
b. 1 hour and 12 minutes
c. 1 hour and 15 minutes
d. 1 hour and 30 minutes

50. Fifteen milliliters of a solution separates into two liquids as shown in the figure below. The lighter liquid makes up what percentage of the total solution?



a. 33%
b. 40%
c. 60%
d. 66%

► Section 4: General Science

There are 50 questions in this section. You have 45 minutes to complete this section.

1. Considering the four fundamental forces of physics, this one governs beta decay of radioactive atoms.
a. strong nuclear force
b. electromagnetism
c. gravity
d. weak nuclear force

2. In sending an unmanned probe to Mars, this force would figure most prominently in the equations of the engineers and physicists planning the voyage.
a. weak nuclear force
b. strong nuclear force
c. electromagnetism
d. gravity

3. What table would you set not with plates and forks but with rows of types of atoms?
a. periodic table
b. molecular table
c. valence table
d. bonding table

4. The parts of an atom that create the chemical bonds with other atoms is
a. valence shells.
b. nuclei.
c. quark triplets.
d. isotopes.

5. In this kind of atomic bond between atoms, electrons are shared in pairs.
a. ionic
b. hydrogen
c. van der Waals
d. covalent

6. Consider the chemical reaction for photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 +$ ________ O_2. How many molecules of oxygen (O_2) are made on the right hand side (what number goes in the blank space)?
a. 6
b. 1
c. 12
d. 4

7. In photosynthesis, the charge on the carbon in the reactant carbon dioxide is +4, the charge on the carbon in the resulting carbohydrate product is –4. In this reaction, the carbon is said to have been
a. stripped.
b. increased.
c. neutralized.
d. reduced.

8. Applying an amount of energy less than the heat of fusion to a liquid at the melting point of a particular substance does what?
a. settles the liquid
b. warms the liquid
c. starts to solidify the liquid
d. evaporates the liquid

9. The state of matter at the center of the Sun is
a. gas.
b. liquid.
c. plasma.
d. solid.

10. Which is an example of an inorganic molecular state of matter?
a. blood hemoglobin
b. quartz
c. DNA
d. wood

11. Which is an example of a primary carbohydrate?
a. olive oil
b. butter
c. wheat germ
d. apple

12. Which unit of energy is equivalent to a Newton-meter?
a. joule
b. watt
c. volt
d. calorie

13. Turning a paddle wheel in water demonstrates what?
a. mechanical equivalent of work
b. force equivalent of heat
c. force equivalent of work
d. mechanical equivalent of heat

14. A scientist who was involved with the discovery of the first law of thermodynamics was
a. Joule.
b. Einstein.
c. Newton.
d. Galileo.

15. The most degraded form of energy is
a. electricity.
b. garbage.
c. water in a waterfall.
d. heat.

16. All forms of energy can be converted at maximum efficiency into
a. mechanical motion.
b. electricity.
c. potential energy.
d. heat.

17. When entropy decreases, what else must be true?
a. Entropy must increase on some larger scale.
b. The decrease must be at the level of the universe.
c. A mistake was made in the calculation.
d. Entropy is adjusted to a flow of heat.

18. Faster molecular motion of the molecules in a gas creates
a. higher heat of vaporization.
b. higher temperature.
c. the same equivalence in energy.
d. lower covalent bonds.

19. When a crane at a building site lifts a beam to its top height, what type of energy is created?
a. kinetic energy
b. potential energy
c. chemical energy
d. electrical energy

20. Your body operates by
a. gravitational potential energy.
b. electrical energy.
c. chemical potential energy.
d. nuclear energy.

21. A hydroelectric power plant creates energy from
a. kinetic energy.
b. chemical energy.
c. nuclear energy.
d. heat energy.

22. Approximately when did life begin?
a. 3.7 million years ago
b. 37 million years ago
c. 370 million years ago
d. 3,700 billion years ago

23. Which is not one of three main, largest groupings of life, as discovered by forming a tree of genetic relationships, derived from the ribosomal RNA (the rRNA) of all types of organisms, from giant sequoia trees to the tiniest microbe?
a. eukaryotes
b. protista
c. bacteria
d. archaea

24. In the ribosomes, which all cells have, what important cell process occurs?
a. DNA is duplicated.
b. Proteins are assembled.
c. Cell membranes are synthesized.
d. Cell nuclei are degraded.

25. Groups of DNA bases that code for types of amino acids occur as
a. quintuplets.
b. doublets.
c. triplets.
d. quadruplets.

26. In the universal tree of life, derived from comparing the rRNA possessed by all living forms, what does the *r* stand for?
a. rhizocyclic
b. retrospiral
c. recentible
d. ribosomal

27. Liposomes formed from lipids might be naturally occurring structures that formed the precursors for what later structure of cells?
a. immune systems
b. enzymes
c. nuclei
d. membranes

28. Which is most closely related to Tyrannosaurus Rex, in terms of closeness in the evolutionary sense?
a. today's rattlesnakes
b. today's pigeons
c. today's lobsters
d. today's frogs

29. If a cell has an organelle called a chloroplast, which type of cell is it?
a. bikaryotic
b. prokaryotic
c. eukaryotic
d. postkaryotic

30. The cells of a human body are
a. bikaryotic cells.
b. prokaryotic cells.
c. unkaryotic cells.
d. eukaryotic cells.

31. What organelle is sometimes called the "power plant"of the nucleated cell?
a. nucleus
b. chloroplast
c. cytoskeleton
d. mitochondrion

32. What were two evolutionary innovations that led to trees?
a. flowers-cellulose
b. cellulose-xylem
c. xylem-blastula
d. blastula-flowers

33. What type of organism has threads called *hyphae*?
a. plants
b. fungi
c. animals
d. bacteria

34. What type of organism has as embryonic stage called a *blastula*?
a. plants
b. fungi
c. animals
d. bacteria

35. What best describes what was happening around 265 MYA? (This date itself is probably not anything you have ever memorized, but you should know enough about evolution to be able to answer.)
a. radiation of reptiles
b. origin of life
c. extinction of the dinosaurs
d. emergence of Australopithecines

36. In plants, which type of vascular tissue takes food made in the leaves all the way down to the roots?
a. xylem
b. trachea
c. capillaries
d. phloem

37. We know that the Cretaceous-Tertiary mass extinction, which killed off the dinosaurs and many other species, including many species of ocean algae, was caused from an impact of a giant object from space, because of
a. a worldwide clay layer that contains lots of the element iridium.
b. charcoal evidence of worldwide forest fires.
c. chemical signatures of massive amounts of sulfuric acid aerosols in the atmosphere.
d. mutations in the surviving organisms caused by UV radiation after the ozone layer was destroyed.

38. The large, buried crater that was formed by the giant impact from space at the K-T boundary is found in what region of Mexico?
a. Sonoran desert
b. Yucatan peninsula
c. Alcupulco coast
d. Costa Rican border

39. Which is the characteristic that probably hurt the dinosaurs most, in terms of ability to make it through the K = T mass extinction (in other words, what probably most contributed to their downfall)?
a. their lack of brains
b. their size
c. their cold-bloodedness
d. their scales

40. What was the mass extinction that came just prior to the evolution of the dinosaurs?
a. Cretaceous-Tertiary
b. Permian-Triassic
c. Triassic-Jurassic
d. Carboniferous-Permian

41. The "make love" ape is the
a. gorilla.
b. chimpanzee.
c. bonobo.
d. orangutan.

42. If you were a scientist investigating the origin of human social bonding, you would be in the field of
a. evolutionary psychology.
b. reversible geology.
c. physical anthropology.
d. revolutionary biology.

43. Of the organisms listed, which is the most recent, in terms of evolution?
a. Australopithecus
b. Cyanobacteria
c. Fungi
d. Lichen

44. Considering human ancestry, which is furthest from humans, in terms of how long ago the lineage that led to us diverged from the lineage that led to this ape?
a. bonobo
b. chimp
c. gorilla
d. orangutan

45. In cultural organization, Christianity is to Catholicism and Protestantism the way that in biological organization
a. species is to kingdom.
b. genus is to species.
c. genus is to order.
d. kingdom is to superkingdom.

46. Alfred Wegener developed the theory of
a. ice ages.
b. dinosaur extinction.
c. polar wander.
d. continental drift.

47. What is a subduction zone?
a. places where currents fall toward Earth's core
b. places where magma oozes downward from a volcano
c. places where ocean crust plunges toward the mantle
d. places where currents in the ocean head toward the bottom

48. The important units in the modern theory that sums up much of all geological processes are
a. plates.
b. continents.
c. ridges.
d. volcanoes.

49. The geological era in which the dinosaurs lived was the
- **a.** Cenozoic.
- **b.** Mesozoic.
- **c.** Hadean.
- **d.** Paleozoic.

50. Until fairly recently, mammoths roamed the Earth during a series of ice ages. This time is called the
- **a.** Pleistocene.
- **b.** Anthropocene.
- **c.** Miocene.
- **d.** Oligocene.

▶ Section 5: Biology

There are 50 questions in this section. You have 45 minutes to complete this section.

1. Which of the following plant structures (organelles) contain DNA?

I. nucleus
II. mitochondria
III. chloroplasts

- **a.** I only
- **b.** I and II only
- **c.** I and III only
- **d.** I, II, and III

2. In most flowering plants, water moves upwards from the roots via which of the following structures?
- **a.** sieve tubes
- **b.** phloem
- **c.** stomata
- **d.** xylem

3. What is the process in which the genetic information contained in the DNA is transferred to messenger RNA?
- **a.** transduction
- **b.** transcription
- **c.** translation
- **d.** mitosis

4. A plant with both male and female flowers is best described as
- **a.** monogynous.
- **b.** dioecious.
- **c.** monoecious.
- **d.** dimorphic.

5. In mammals, which of the following are cell fragments that play a key role in blood clotting?
- **a.** platelets
- **b.** neutrophils
- **c.** red blood cells
- **d.** monocytes

6. Swelling that is due to excess fluid accumulating in interstitial spaces is known as
- **a.** effusion.
- **b.** erythema.
- **c.** edema.
- **d.** progenesis.

7. Pyruvate is converted to carbon dioxide and ethanol during which of the following processes?
- **a.** photosynthesis
- **b.** glycolysis
- **c.** alcoholic fermentation
- **d.** oxidation

8. Self-fertilization may also be referred to as
- **a.** syngamy.
- **b.** autogamy.
- **c.** allogamy.
- **d.** incompatibility.

9. The embryological process by which a fertilized ovum divides is known as
a. the G_2 phase.
b. the M phase.
c. cleavage.
d. cytokinesis.

10. Which of the following diseases is caused by bacteria?
a. tuberculosis
b. influenza
c. leukemia
d. measles

11. According to Linnaeus's classification system, which of the following groups is the most specific (i.e., has the smallest number of organisms)?
a. phylum
b. genus
c. class
d. order

12. More than 80% of all the known species of animals belong to the phylum
a. Mollusca.
b. Arthropoda.
c. Echinodermata.
d. Chordata.

13. Which of the following is the main function of the gallbladder?
a. to produce enzymes
b. to digest fats
c. to produce bile
d. to store bile

14. Peristalsis can best be defined as
a. the release of gastric juices into the stomach during digestion.
b. a series of muscular contractions that move food along the digestive tract.
c. the active transportation of polypeptides across the membranes of the small intestine.
d. the absorption of water from undigested materials in the colon.

15. The last and longest portion of the small intestine is called the
a. ascending colon.
c. jejunum.
b. duodenum.
d. ileum.

16. About how much blood does the average person have in his or her body?
a. 2.5 to 3 liters
b. 4.5 to 5 liters
c. 6 to 7 liters
d. 8 to 9.5 liters

17. Blood from the lungs travels to the left atrium of the heart through the
a. aorta.
b. superior vena cava.
c. pulmonary artery.
d. pulmonary veins.

18. Rh factors can harm a developing embryo if
a. the child is Rh negative and the mother is Rh positive.
b. the child is Rh positive and the mother is Rh negative.
c. both the mother and child are Rh negative.
d. the child is Rh negative and is the mother's firstborn.

19. Transfusion of incorrect blood types results in
- **a.** excess production.
- **b.** chemical reduction of hemoglobin.
- **c.** agglutination of erythrocytes.
- **d.** lymphocytosis.

20. Which of the following does NOT occur during inspiration?
- **a.** The diaphragm contracts and flattens.
- **b.** The ribs move up and out.
- **c.** The size of the chest cavity increases.
- **d.** Air pressure in the thorax increases.

21. The hypothalamus stimulates the pituitary gland to secrete vasopressin when
- **a.** the amount of water in the blood is too low.
- **b.** a woman's estrogen level increases.
- **c.** the thyroid is not functioning properly.
- **d.** insulin production is too high.

22. One of the hormones produced in the islets of Langerhans is
- **a.** epinephrine.
- **b.** cortisol.
- **c.** renin.
- **d.** insulin.

23. Which of the following is characteristic of smooth, or nonstriated, muscles?
- **a.** They are voluntary muscles, controlled at will.
- **b.** When viewed under a microscope, they have a striped appearance.
- **c.** They make up the walls of the hollow organs of the body.
- **d.** They are not stimulated by nerves.

24. Contraction of the biceps muscle causes the
- **a.** elbow joint to bend.
- **b.** arm to straighten.
- **c.** triceps muscle to contract simultaneously.
- **d.** shoulder to relax.

25. Which of the following is true of a resting neuron?
- **a.** There is an equal concentration of both sodium and potassium within the cell.
- **b.** The cell membrane becomes more permeable, and a flow of sodium and potassium ions causes a depolarization.
- **c.** The concentration of sodium outside the cell is higher than it is inside; the concentration of potassium inside the cell is lower than it is outside.
- **d.** The concentration of sodium outside the cell is higher than it is inside; the concentration of potassium inside the cell is higher than it is outside.

26. What is the main function of the cerebellum?
- **a.** to control respiration and heartbeat
- **b.** to coordinate skeletal movements
- **c.** to determine personality
- **d.** to act as a relay center between the cerebrum and the medulla

27. The myelin sheath covers
- **a.** the lungs.
- **b.** the retina of the eye.
- **c.** tendons.
- **d.** the axons of neurons.

28. Which of the following is an example of an exocrine gland?
- **a.** pineal
- **b.** pituitary
- **c.** salivary
- **d.** adrenal

29. How are sponges and coelenterates different?
- **a.** Coelenterates have nerve cells; sponges do not.
- **b.** Coelenterates have bony skeletons; sponges do not.
- **c.** Sponges are marine animals; coelenterates are not.
- **d.** Sponges reproduce sexually; coelenterates do not.

30. More than 90% of dietary fat is in the form of
- **a.** triglycerides.
- **b.** phospholipids.
- **c.** cholesterol.
- **d.** lipase.

31. The ventricles are actively filled during which phase of the cardiac cycle?
- **a.** atrial systole
- **b.** atrial diastole
- **c.** ventricular systole
- **d.** valvular stenosis

32. In humans, which of the following is the only layer of skin that contains actively dividing cells?
- **a.** subcutaneous cuticle
- **b.** basement membrane
- **c.** stratum corneum
- **d.** stratum basale

33. Which of the following is the site of protein synthesis within a eukaryotic cell?
- **a.** the ribosomes
- **b.** the nucleus
- **c.** the mitochondria
- **d.** the Golgi apparatus

34. The Streptococcus bacteria cause all of the following diseases EXCEPT
- **a.** pneumonia.
- **b.** scarlet fever.
- **c.** endocarditis.
- **d.** typhoid fever.

35. Nutrients, wastes, and gases are exchanged between maternal and fetal blood via the
- **a.** placenta.
- **b.** amnion.
- **c.** yolk sac.
- **d.** fallopian tube.

36. The gene for blue eyes is recessive. If your mother has blue eyes and your brown-eyed father has one gene for blue eyes and one for brown eyes, what are your chances of having blue eyes?
- **a.** 100%
- **b.** 75%
- **c.** 50%
- **d.** 25%

37. On some invertebrates, which of the following are the bristle-like, hollow, or chitinous outgrowths of the epidermis?
- **a.** the setae
- **b.** the cilia
- **c.** the hair
- **d.** the whiskers

38. Where are the reproductive organs of a tapeworm located?
- **a.** the head
- **b.** the proglottids
- **c.** the scolex
- **d.** the attachment hooks

39. What are the tiny air sacs where exchange of respiratory gases occurs in mammals and reptiles?
a. the bronchioles
b. the bronchi
c. the sinuses
d. the alveoli

40. Bioluminescence, which occurs in deep-sea fish, bacteria, and fireflies, occurs during the oxidation of which of the following substances?
a. chlorophyll
b. hemoglobin
c. luciferin
d. melanin

41. Which of the following is the bony material perforated by tiny canals containing nerve cells in human teeth?
a. gingiva
b. pulp
c. enamel
d. dentin

42. Which of the following is an example of an exocrine gland?
a. the sweat gland
b. the pituitary gland
c. the thyroid gland
d. the ovary

43. Which of the following is an attribute of prokaryotes?
a. They have a defined nucleus.
b. Their DNA is formed into chromosomes.
c. They have membrane-enclosed mitochondria.
d. They are unicellular.

44. Which of the following is considered an accessory organ in the digestive system?
a. the anus
b. the liver
c. the esophagus
d. the pharynx

45. Which of the following would be considered an acquired characteristic?
a. the large muscles of a weight lifter
b. the appendix of a human being
c. the nocturnal vision of an owl
d. the large ears of a rabbit

46. What is the fluid found in animals with open circulatory systems?
a. blood
b. adrenaline
c. hemolymph
d. protoplasm

47. The human pelvic girdle consists of the ischium, pubis, and
a. scapulae.
b. clavicles.
c. sternum.
d. ilium.

48. In which stage of mitotic cell division do the chromatids move to opposite ends of the spindle?
a. telophase
b. anaphase
c. prophase
d. metaphase

49. Which of the following separates the buccal and nasal cavities in mammals?
a. the hard palate
b. the maxillary sinuses
c. the perpendicular plate of the ethmoid
d. the tongue

50. Which of the following is NOT caused by a herpes virus?
a. infectious mononucleosis
b. cold sores
c. tetanus
d. chicken pox

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB	VIIIB	VIIIB	IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 H 1.00794																1 H 1.00794	2 He 4.002602
3 Li 6.941	4 Be 9.012182											5 B 10.811	6 C 12.0107	7 N 14.00674	8 O 15.9994	9 F 18.9984032	10 Ne 20.1797
11 Na 22.989770	12 Mg 24.3050											13 Al 26.981538	14 Si 28.0855	15 P 30.973761	16 S 32.066	17 Cl 35.4527	18 Ar 39.948
19 K 39.0983	20 Ca 40.078	21 Sc 44.955910	22 Ti 47.867	23 V 50.9415	24 Cr 51.9961	25 Mn 54.938049	26 Fe 55.845	27 Co 58.933200	28 Ni 58.6934	29 Cu 63.546	30 Zn 65.39	31 Ga 69.723	32 Ge 72.61	33 As 74.92160	34 Se 78.96	35 Br 79.904	36 Kr 83.80
37 Rb 85.4678	38 Sr 87.62	39 Y 88.90585	40 Zr 91.224	41 Nb 92.90638	42 Mo 95.94	43 Tc (98)	44 Ru 101.07	45 Rh 102.90550	46 Pd 106.42	47 Ag 107.8682	48 Cd 112.411	49 In 114.818	50 Sn 118.710	51 Sb 121.760	52 Te 127.60	53 I 126.90447	54 Xe 131.29
55 Cs 132.90545	56 Ba 137.327	57 La* 138.9055	72 Hf 178.49	73 Ta 180.9479	74 W 183.84	75 Re 186.207	76 Os 190.23	77 Ir 192.217	78 Pt 195.078	79 Au 196.96655	80 Hg 200.59	81 Tl 204.3833	82 Pb 207.2	83 Bi 208.98038	84 Po (209)	85 At (210)	86 Rn (222)
87 Fr (223)	88 Ra (226)	89 Ac** (227)	104 Rf (261)	105 Db (262)	106 Sg (263)	107 Bh (262)	108 Hs (265)	109 Mt (266)	110 Ds (269)	111 Uuu (272)	112 Uub (277)		114 Uug (289) (287)		116 Uuh (289)		118 Uuo (293)

* Lanthanide series	58 Ce 140.116	59 Pr 140.90765	60 Nd 144.24	61 Pm (145)	62 Sm 150.36	63 Eu 151.964	64 Gd 157.25	65 Tb 158.92534	66 Dy 162.50	67 Ho 164.93032	68 Er 167.26	69 Tm 168.93421	70 Yb 173.04	71 Lu 174.967
** Actinide series	90 Th 232.0381	91 Pa 231.03588	92 U 238.0289	93 Np (237)	94 Pu (244)	95 Am (243)	96 Cm (247)	97 Bk (247)	98 Cf (251)	99 Es (252)	100 Fm (257)	101 Md (258)	102 No (259)	103 Lr (262)

▶ Section 6: Chemistry

There are 50 questions in this section. You have 45 minutes to complete this section. Use the periodic table on this page when necessary to help you answer the questions below.

1. Which of the following has the greatest mass?
a. one water molecule
b. one mole of electrons
c. one mole of protons
d. five molecules of benzene

2. Which of the following is immiscible with water?
a. HCl
b. CCl_4
c. methanol
d. KOH

3. How many oxygen atoms are contained in a one-formula unit of tin (IV) oxide?
a. 1
b. 2
c. 3
d. 4

4. Which of the following describes the function of insulin in the body?
a. It decreases glucose uptake by cells.
b. It stimulates the release of glucagon.
c. It increases serum levels of glucose.
d. It increases glucose conversion to glycogen.

5. Which of the following is NOT a function of epinephrine?
a. It increases blood glucose levels.
b. It increases heart rate.
c. It dilates blood vessels to the brain and muscles.
d. It decreases blood levels of Ca^{+2}.

6. Which of the following functional groups is found in all aldehydes?
a. NH_2
b. COOH
c. C=O
d. OH

7. Which of the following molecules could be considered a polymer?
a. PCl_5
b. CH_3OH
c. NaCl
d. $CH_3CH_2CH_2CH_2CH_2CH_3$

8. Which of the following choices best describes the structure of the class of molecules that is the major constituent of cell membranes?
a. a carboxylic acid bonded to an amino group
b. one molecule of glycerol bonded to three fatty acids
c. one molecule of glycerol bonded to two fatty acids and one phosphate group
d. one molecule of glycerol bonded to one fatty acid and two hydroxyl groups

9. Osmotic pressure is defined as
a. the change in pressure of a liquid undergoing osmosis.
b. pressure that must be applied to prevent net diffusion of pure solvent through a semipermeable membrane into solution.
c. the combined pressure of gases in the external atmosphere of a system undergoing osmosis.
d. pressure that is proportional to osmotic potential.

10. Which of the following is classified as an aldehyde?
a. CH_4
b. CH_2Cl_2
c. $CH_3C(O)CH_3$
d. $CH_3CH_2C(O)H$

11. Which of the following molecules is the least stable?
a. cyclobutane
b. cyclopentane
c. cyclohexane
d. cycloheptane

12. What is the formula for bismuth (III) hydroxide?
a. Bi_3OH
b. $Bi(OH)_3$
c. $Bi(OH)_2$
d. BiOH

13. What are the products of the reaction between sodium metal and water?
a. $NaH^+_{(aq)} + OH^-_{(aq)}$
b. $NaOH_{(aq)} + H_{2(g)}$
c. $Na_{(s)} + H_{2(g)} + O_{2(g)}$
d. $NaOH_{(aq)} + H_{2(g)} + O_{2\,(g)}$

14. Which best describes the following redox reaction: $Br^-_{(aq)} + MnO_4^-{}_{(aq)} \rightarrow Br_{2(l)} + Mn^{+2}_{(aq)}$?
a. Br and Mn are both reduced.
b. Br is oxidized and Mn is reduced.
c. Br is oxidized and O is reduced.
d. Br is reduced and Mn is oxidized.

15. Rank the following atoms in order of increasing atomic size: Cs, F, Li, N.
a. Li < Cs < N < F
b. F < N < Li < Cs
c. F < Li < Cs < N
d. Cs < F < N < Li

16. Which of the following is NOT characteristic of a good buffer solution?
a. It can absorb OH^-.
b. It can absorb H^+.
c. It does not react with itself.
d. It contains a strong acid and a strong base.

17. What is the molecular formula of a compound with empirical formula CH_2O and molar mass 90 g?
a. CH_2O
b. $C_3H_3O_3$
c. $C_3H_6O_3$
d. $C_6H_{14}O$

18. Which of the following has the largest radius?
a. K
b. Rb
c. Ca
d. Sr

19. In which of the following states of matter are molecules most likely to move freely?
a. solid
b. liquid
c. gas
d. All have similar freedom of movement.

20. Which of the following species is being oxidized in this redox reaction?
$Zn_{(s)} + Cu^{2+}{}_{(aq)} \rightarrow Zn^{2+}{}_{(aq)} + Cu_{(s)}$
a. $Zn_{(s)}$
b. $Cu^{2+}{}_{(aq)}$
c. Zn2+ (aq)
d. $Cu_{(s)}$

21. Which of the following is the strongest acid?
a. $H_2PO_4^-$
b. KOH
c. NH_4^+
d. H_3PO_4

22. In which of the following solutions is Ag_2CO_3 most soluble?
a. 0.2 M Na_2CO_3
b. 0.3 M KCl
c. 0.1 M Na_2CO_3
d. 0.01 M $AgNO_3$

23. The isotope ${}^{234}_{92}U$ decays by releasing an alpha particle. What is the resulting isotope?
a. ${}^{234}_{93}Np$
b. ${}^{233}_{91}Pa$
c. ${}^{234}_{91}Pa$
d. ${}^{230}_{90}Th$

24. When titrating 50 ml of 0.2 M HCl, what quantity of 0.5 M NaOH is needed to bring the solution to the equivalence point?
a. 80 ml
b. 40 ml
c. 20 ml
d. 10 ml

25. Which of the following are the general products of a combustion reaction?
a. $C_{(s)}$, O_2, and H_2
b. $C_{(s)}$, H_2O, and O_2
c. CO_2 and H_2
d. CO_2 and H_2O

26. The normal boiling point of water is 100° C. Suppose 256 grams of a compound with the formula $C_{10}H_8$ is dissolved in 5.15 kg of water. K_b of water is 0.52° C kg/mol. What is the change in the boiling point?
a. 0.2°
b. 0.05°
c. 0.4°
d. 2.0°

27. Which of the following has the greatest number of atoms?
a. 1.0 mol N
b. 1.0 g N
c. 1.0 mol NO_2
d. 0.5 mol NH_3

28. Which of the following equations describes the reaction between $Al_{(s)}$ and H_2SO_4?

a. $2Al_{(s)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_4)_3 + 3H_{2(g)}$
b. $Al_{(s)} + H_2SO_{4(aq)} \rightarrow Al(SO_4) + H_{2(g)}$
c. $2Al_{(s)} + 3H_2SO_{4(aq)} \rightarrow Al_2(SO_3)_3 + 3H_2O_{(l)}$
d. No reaction occurs.

29. Which of the following has an increase in entropy?

a. $CO_{2(g)} \rightarrow CO_{2(s)}$
b. $Ag^+_{(aq)} + Cl^-_{(aq)} \rightarrow AgCl_{(s)}$
c. $2CO_{(g)} + O_{2(g)} \rightarrow 2CO_{2(g)}$
d. $2Fe_2O_{3(s)} \rightarrow 4Fe_{(s)} + 3O_{2(g)}$

30. Which of the following is the probable charge for an ion formed from Ca?

a. +1
b. +2
c. –1
d. –2

31. Which of the following is the electron configuration of a neutral atom of Ca?

a. [Ar] $3s^2$
b. [Ar] $3d^2$
c. [Ar] $4p^2$
d. [Ar] $4s^2$

32. Which of the following bonds is the most polar?

a. Cl_2
b. NaCl
c. F_2
d. HF

33. Which of the following is the correct name for Li_2SO_3?

a. lithium sulfite
b. lithium sulfide
c. lithium sulfate
d. lithium disulfate

34. What is the oxidation number of sodium in the following reaction? $Pb(NO_3)_{2(aq)} + 2NaI_{(aq)} \rightarrow PbI_{2(s)} + 2NaNO_{3(aq)}$

a. +1
b. +2
c. –1
d. –2

35. Carbon dating involves the decay of a carbon-14 isotope with a beta particle. Which of the following equations describes this decay?

a. ${}^{14}_{6}C \rightarrow {}^{13}_{5}B + {}^{1}_{1}H$
b. ${}^{14}_{6}C \rightarrow {}^{14}_{7}N + {}^{0}_{-1}\beta$
c. ${}^{14}_{6}C \rightarrow {}^{13}_{5}B + {}^{1}_{0}n$
d. ${}^{14}_{7}N + {}^{1}_{0}n \rightarrow {}^{14}_{6}C + {}^{1}_{1}H$

36. A dating technique involves electron capture by potassium-40 isotope according to the following equation: ${}^{40}_{19}K + {}^{0}_{-1}e \rightarrow {}^{40}_{18}Ar$. If the half-life is 1.2×10^9 years, how long does it take for only 10 g to remain of the original 40 g of potassium-40 in a rock sample?

a. 1.2×10^9 years
b. 0.6×10^9 years
c. 2.4×10^9 years
d. 1.8×10^9 years

37. Which of the following is an alkaline earth metal?

a. Na
b. Mg
c. Sc
d. Ti

38. Which of the following is the symbol for the isotope with 18 protons and 22 neutrons?

a. ${}^{40}_{18}Ar$
b. ${}^{22}_{18}Ar$
c. ${}^{40}_{22}Ti$
d. ${}^{90}_{40}Zr$

$$:\ddot{O}:\quad :C:\quad :\ddot{O}:$$

39. Using the Lewis dot structure above, estimate the total bond energy of the compound CO_2 given the following bond strengths:
C−O 358 kJ/mol
C=O 799 kJ/mol
C≡O 1,072 kJ/mol
a. 358
b. 579
c. 799
d. 1,598

40. What is the effect of the addition of a catalyst to a reaction in equilibrium?
a. The reaction favors the formation of the products.
b. The reaction favors the formation of the reactants.
c. There is no change in composition of the reaction.
d. The rate of the reaction slows.

41. Which of the following pairs are allotropes?
a. O_2 and O_3
b. Fe^{2+} and Fe^{3+}
c. OH^- and H_3O^+
d. H_2O_2 and H_2O

42. Which of the following will have the highest boiling point?
a. H_2S
b. H_2Se
c. H_2O
d. H_2Te

43. Which of the following is the name of the oxyacid $HClO_4$?
a. perchloric acid
b. chloric acid
c. chlorous acid
d. hypochlorous acid

44. Which of the following is an example of a decomposition reaction?
a. $C_3H_{8(g)} + 5O_{2(g)} \rightarrow 3CO_{2(g)} + 4H_2O_{(l)}$
b. $N_{2(g)} + 3H_{2(g)} \rightarrow 2NH_{3(g)}$
c. $CaCO_{3(s)} \rightarrow CaO_{(s)} + CO_{2(g)}$
d. $CaO_{(s)} + H_2O_{(l)} \rightarrow Ca(OH)_{2(s)}$

45. Which of the following does NOT have the electron configuration [Ne] $3s^2\ 3p^6$?
a. Cl
b. S^{2-}
c. K^+
d. Ca^{2+}

46. Which of the following is the composition of the bonds in the molecule N_2?
a. one σ bond
b. one σ bond and one π bond
c. one σ bond and two π bonds
d. two σ bonds and two π bonds

47. If temperature and pressure are held constant for a sample of gas, and the number of moles is doubled, in what manner will the volume change?
a. It will double.
b. It will quadruple.
c. It will be halved.
d. There will be no change.

48. What will happen if a semipermeable membrane is placed between two different concentrations of a NaCl solution?
- **a.** The solute will move toward the higher concentration.
- **b.** The solute will move toward the lower concentration.
- **c.** The solvent will move toward the higher concentration.
- **d.** The solvent will move toward the lower concentration.

49. Which of the following is an example of an alkane?
- **a.** C_2H_6
- **b.** C_2H_4
- **c.** CH_3OH
- **d.** $C_6H_{12}O_6$

50. Proteins are polymers of which of the following organic compounds?
- **a.** amino acids
- **b.** alkynes
- **c.** alcohols
- **d.** fatty acids

▶ Answers

Section 1: Verbal Ability

1. a. commitment
2. c. ridiculous
3. d. anonymous
4. a. extraordinary
5. b. assurance
6. a. frequently
7. c. emphasis
8. a. concede
9. b. encouraging
10. c. phenomena
11. c. compatible
12. a. skeptical
13. b. commencement
14. d. supervisor
15. b. pneumonia
16. c. annoyed
17. c. apparatus
18. c. Codeine
19. d. accompany
20. d. incessant
21. b. dilemma
22. c. efficient
23. a. ameliorate
24. a. viewpoint
25. c. aggravated
26. c. babies
27. d. no mistakes
28. a. announcement
29. c. literature
30. b. servant
31. d. no mistakes
32. a. association
33. b. rehearsal
34. c. fascinated
35. a. destructive
36. c. dissolve
37. d. no mistakes
38. b. forfeit
39. b. meteorology
40. a. adjournment
41. c. vengeance
42. c. tremendous
43. d. no mistakes
44. c. capitalization
45. a. skein
46. b. parenthesis
47. c. weird
48. c. sonnet
49. a. depot
50. a. prescribe

Section 2: Reading Comprehension

1. b. See the third paragraph: *One in ten* (10% of) cases of anorexia end in death.
2. a. See the second and third paragraphs for reference to heart problems with anorexia, the fourth and fifth paragraphs for discussion of heart problems with bulimia, and the last paragraph, where heart disease is mentioned as a risk in obese people who suffer from binge-eating disorder.
3. c. Near the end of the last paragraph, the passage indicates that binge-eating disorder patients experience *high* blood pressure.
4. d. It is the other way around—50% of people with anorexia develop bulimia, as stated near the end of the fifth paragraph.
5. b. The first sentence of the fifth paragraph tells us that bulimia sufferers are often able to keep their problem a secret, partly because they maintain a normal or above-normal weight.
6. c. In the second paragraph, the thyroid gland function is mentioned as slowing down—one effort on the part of the body to protect itself.
7. a. According to the second paragraph, dehydration contributes to constipation.
8. b. As stated in the opening sentence of the fourth paragraph, bulimia patients may exercise obsessively.

9. d. See the second sentence of the sixth paragraph. If as many as one-third of the binge-eating disorder population are men, it stands to reason that up to two-thirds are younger women, given that about 90% of all eating disorder sufferers are adolescent and young adult women.

10. b. The author uses the phrase *going gray* as a metaphor for growing older. It describes the phenomenon of a large segment of a population growing older.

11. d. The passage emphasizes the need for age-specific care.

12. a. In this context, *address* most nearly means *manage*, or treat. The sentence implies that some kind of action is taken after the problem has first been identified, analyzed, and dissected.

13. c. Although choices **a** and **b** may be correct statements, they do not reflect the author's purpose in citing the example of untreated depression in the elderly. Choice **d** is incorrect.

14. c. According to the passage, geriatric training improves a healthcare provider's ability to *distinguish between "normal" characteristics associated with aging and illness*.

15. c. See the first sentence of the third paragraph. It is when the gas is trapped, as in a building, that serious ramifications can develop.

16. b. That inert gases are chemically inactive can be inferred from the second paragraph, which says that radon is unlike its *chemically active* daughters.

17. d. The fifth paragraph says that the unattached daughters pose danger to the lungs because they can travel directly to those organs.

18. a. The fourth paragraph says that *plating out* is the process by which radon daughters attach to matter.

19. a. The beginning of the third paragraph points out the relative danger posed by trapped radon as opposed to radon that is released into the atmosphere.

20. b. The beginning of the second paragraph says that radon is formed as uranium and radium decay.

21. d. See the sixth paragraph, the next-to-last sentence.

22. b. The last sentence of the fifth paragraph states that 10% to 20% of torticollis patients experience spontaneous remission.

23. d. Emotional imbalance is not usually a feature of the dystonias, as stated in the last sentence of the first paragraph.

24. a. According to the fourth paragraph, torsion dystonia may be inherited.

25. c. Meige's syndrome combines symptoms of blepharospasm (affecting the eyes) and oromandibular dystonia (affecting the lips and tongue).

26. a. Both torticollis and cranial dystonia affect the neck and head, as indicated in the fifth and seventh paragraphs.

27. d. The first sentence of the last paragraph states that DRD patients can be successfully treated with drugs.

28. a. The second sentence states that dystonia-related movements are involuntary.

29. c. Cranial dystonia affects muscles in the head, face, and neck. Since it affects two or more adjacent body parts, cranial dystonia is a segmental dystonia.

30. d. In the fourth paragraph, torsion dystonia is referred to as a *rare* ailment. Dopa-responsive dystonia is also labeled rare in the last sentence of the passage.

31. d. See the first two sentences of the third paragraph.

32. c. See the last paragraph of the passage.

33. d. The end of the third paragraph says that ticks prefer humid, relatively warm weather.

34. a. See the first sentence of the passage.

35. b. The end of the second paragraph says that larval infection is a *rare occurrence*.

36. c. After the rash, which may or may not appear, the next symptoms are the flu-like symptoms listed in the fifth paragraph.

37. d. The first paragraph mentions that the symptoms of Type-II diabetes may occur gradually and thus be attributed to other causes. Left untreated, diabetes can cause damage to several major organs in the body.

38. b. According to the end of the first paragraph, only the long-term health problems are the same for these two different disorders.

39. d. The second paragraph mentions that when the body has more glucose than needed, it stores the overflow in muscle tissue, fat, or the liver.

40. c. According to the last paragraph, non-insulin dependent diabetics should stick to a diet consisting of 50% to 60% carbohydrates. The paragraph also notes that raw foods do not cause as high a blood sugar level as cooked foods.

41. a. The second and fourth paragraphs mention that the main role of insulin is to signal the burning of glucose/sugar for energy. Most hormones function as stimuli for other processes.

42. b. Type II, or non-insulin-dependent, diabetes is the main subject of the passage, which distinguishes Type II from Type I and goes on to stress the importance of diet.

43. d. The fourth paragraph of the passage says that possible problems with insulin receptors include a paucity of receptors or a defect causing improper binding of the insulin to the receptors.

44. c. The second paragraph states that normally, after the digestive system breaks down food into smaller molecules, including glucose, the blood sugar level rises. Insulin is then released from the pancreas, thus signaling tissues to metabolize the glucose.

45. c. Type I diabetes is the insulin-dependent form of this condition. The minority of diabetics are afflicted with this form. They are diagnosed as children and must take daily injections of insulin to make up for what their pancreases do not produce.

Section 3: Quantitative Ability

1. c. $4\frac{2}{5} + 3\frac{1}{2} + \frac{3}{8}$ can be rewritten: $4 + 3 + \frac{2}{5} + \frac{1}{2} + \frac{3}{8}$. To add the fractions, find the least common multiple of 5, 2, and 8, which is 40. Next, rewrite the problem: $7 + \frac{16}{40} + \frac{20}{40} + \frac{15}{40} = 7\frac{51}{40} = 8\frac{11}{40}$.

2. c. $100^2 = 100 \times 100 = 10{,}000$; $10{,}000 \times 2.75 = 27{,}500$.

3. b. Add all four weights for a total of 703; 703 rounded to the nearest tenth is 700.

4. b. Substitute the values into the given expression: $\frac{6(3) - 6(-2)}{9}$ then becomes $\frac{18 - (-12)}{9} = \frac{30}{9}$, or $3\frac{1}{3}$.

5. a. The formula to use here is $A = \frac{1}{2}bh$ or $A = \frac{1}{2}(10)(2) = 10$ square inches.

6. d. This problem is solved by dividing 60 by 0.75 to get 80.

7. d. First, find the least common denominator, which is 6. The equation then becomes $\frac{3x}{6} + \frac{x}{6} = 4$, or $\frac{4x}{6} = 4$. Multiply both sides by 6 to get $4x = 24$. Divide through by 4 to get $x = 6$.

8. b. To divide exponential expressions containing the same base, subtract the exponents.

9. d. This is a simple division problem as long as you keep the decimal values straight.

10. b. First, convert the mixed number in the numerator to a fraction: $\frac{21}{8}$. Then, invert the denominator and multiply: $(\frac{21}{8})(\frac{3}{1}) = \frac{63}{8}$, or $7\frac{7}{8}$.

11. b. To solve this problem, find the area of two rectangles and then add the results. Use an imaginary line to block off the first rectangle at the top of the figure. This rectangle measures 5 feet by 2 feet. Using the formula $A = lw$, this comes to 10 square feet. The second rectangle is also 5 feet by 2 feet. Add the two together for a total of 20 square feet.

12. **c.** Change the percent to a decimal and then multiply: $0.072 \times 465 = 33.48$, which, rounded to the nearest tenth, is 33.5.

13. **a.** First, find the least common denominator, 40, and rewrite the problem as $3\frac{28}{40} - 2\frac{15}{40}$. Subtract the whole numbers, then the fractions, and then add the results to get $1\frac{13}{40}$.

14. **a.** The halfway point on the number line is between 0 and $-\frac{1}{2}$, which is $-\frac{1}{4}$.

15. **d.** A heptagon has seven sides.

16. **a.** To square y, multiply y times y.

17. **c.** This is a simple multiplication problem as long as you keep the decimal values straight.

18. **c.** Do the operations in order from left to right: $-10 + (-4) = -14$. Next, $-14 + \frac{1}{2} = -13\frac{1}{2}$. Then, $-13\frac{1}{2} - (-\frac{1}{4}) = -13\frac{1}{2} + \frac{1}{4} = -13\frac{1}{4}$.

19. **b.** Use 35 for C. $F = (\frac{9}{5} \times 35) + 32$. Therefore, $F = 63 + 32 = 95$.

20. **c.** $(\frac{1}{3})(5)(3)(8) = 40$.

21. **b.** $(7.25)(10)(10)(10) = 7{,}250$.

22. **a.** Subtract 25 from both sides to get $8n = 40$, and divide through by 8 to get $n = 5$.

23. **a.** Convert the mixed number $3\frac{7}{8}$ to the improper fraction $\frac{31}{8}$ and then invert.

24. **a.** This is the only choice that includes a 90-degree angle.

25. **c.** Divide 135 (the number of Spanish-speaking nurses at the hospital) by 1,125 (the total numbers of nurses at the hospital) to arrive at 0.12 or 12%.

26. **c.** From 10:42 to 12:42, 2 hours have elapsed. From 12:42 to 1:00, another 18 minutes have elapsed ($60 - 42 = 18$). Next, between 1:00 and 1:19, there is another 19 minutes, for a total of 2 hours and 37 minutes.

27. **b.** First, convert 4.5% to a decimal: 0.045. Multiply that by $26,000 to find out how much the salary increases. Finally, add the result ($1,170) to the original salary of $26,000 to find out the new salary, $27,170.

28. **d.** First, you have to determine the perimeters of all four rooms. This is done by using the formula for a square ($P = 4s$), or for a rectangle ($P = 2l + 2w$), as follows: $(2 \times 12) + (2 \times 8) = 40$ for choice **a**; $(2 \times 14) + (2 \times 7) = 42$ for choice **b**; $4 \times 10 = 40$ for choice **c**; $4 \times 11 = 44$ for the correct choice, **d**.

29. **b.** Convert Fahrenheit to Centigrade using the formula given: $C = \frac{5}{9}(122 - 32)$; that is, $C = \frac{5}{9} \times 90$; so $C = 50$.

30. **b.** You cannot just take 25% off the original price, because the 10% discount after three years of service is taken off the price that has already been reduced by 15%. Figure the problem in two steps: After the 15% discount, the price is $71.83. Ninety percent of that—subtracting 10%—is $64.65.

31. **a.** Add the number of men and number of women to get the total number of staff: 200. The number of women, 24, is 12% of 200.

32. **b.** Substituting known quantities into the formula yields $20 = \frac{64.8}{x^2}$. Next, multiply both sides by x^2 to get $20x^2 = 64.8$, and then divide through by 20 to get $x^2 = 3.24$. Now take the square root of both sides to get $x = 1.8$.

33. **c.** Let E = emergency room cost; H = hospice cost; N = home nursing cost; $H = \frac{1}{4}E$, and $N = 2H = 2(\frac{1}{4}E) = \frac{1}{2}E$. The total bill is $E + H + N = E + (\frac{1}{4})E + (\frac{2}{4})E = 140{,}000$. So $(\frac{7}{4})E = 140{,}000$. Multiplying both sides by $\frac{4}{7}$ yields $E = 80{,}000$. Therefore, $H = (\frac{1}{4})E = 20{,}000$ and $N = 2H = 40{,}000$.

34. **c.** You must break the 92,000 into the amounts mentioned in the policy: $92{,}000 = 20{,}000 + 40{,}000 + 32{,}000$. The amount the policy will pay is $(0.8)(20{,}000) + (0.6)(40{,}000) + (0.4)(32{,}000) = 16{,}000 + 24{,}000 + 12{,}800 = 52{,}800$.

35. a. Each Alzheimer's patient takes $\frac{1}{4}$ hour. Each stroke patient thus takes $\frac{3}{4}$ hour. The doctor has already spent $10(\frac{1}{4}) + 3(\frac{3}{4}) = \frac{10}{4} + \frac{9}{4} = \frac{19}{4} = 4\frac{3}{4}$ hours with patients today. Her 6-hour schedule minus $4\frac{3}{4}$ hours leaves $1\frac{1}{4}$ hours left to see patients. Since each stroke patient takes $\frac{3}{4}$ hour, the doctor has time to treat only one more stroke patient in the $1\frac{1}{4}$ hours remaining.

36. b. Solving this problem requires converting 15 minutes to 0.025 hour, which is the time, then using the formula distance = rate × time: 62 mph. × 0.25 hour = 15.5 miles.

37. b. Use the Pythagorean theorem: $1^2 + x^2 = (\sqrt{10})^2$; $1 + x^2 = 10$, so $x^2 = 9$. Thus, $x = 3$.

38. d. First, convert the mixed numbers to improper fractions: $\frac{3\frac{1}{9}}{1\frac{1}{6}} = \frac{\frac{28}{9}}{\frac{7}{6}}$. Next, invert the denominator and multiply, canceling where possible: $\frac{28}{9} \times \frac{6}{7} = \frac{8}{3} = 2\frac{2}{3}$.

39. c. Let T = Ted's age; S = Sam's age = $3T$; R = Ron's age = $\frac{S}{2} = \frac{3T}{2}$. The sum of the ages is $\frac{3T}{2} + 3T + T = \frac{3T}{2} + \frac{6T}{2} + \frac{2T}{2} = \frac{11T}{2}$, which is equal to 55. Now multiply both sides of the resulting equation, $55 = \frac{11T}{2}$, by 2 to get $110 = 11T$. Divide through by 11 to get $10 = T$. That is Ted's age, so Sam is $3T = 3(10) = 30$ years old, and Ron is $\frac{S}{2} = \frac{30}{2} = 15$ years old.

40. a. If half the students are female, then you would expect half of the out-of-state students to be female. One-half of $\frac{1}{12} = (\frac{1}{2})(\frac{1}{12}) = \frac{1}{24}$.

41. d. Four inches is equal to 16 quarter inches. Since each quarter inch is 2 feet, multiply 16 by 2 to get 32 feet.

42. d. 160% is equal to $\frac{160}{100}$. Reduce this fraction by dividing both top and bottom by 20 to get $\frac{8}{5}$.

43. c. The surface area of a cylinder is equal to the area of the two circles on the top and bottom plus the area of a rectangle that is as tall as the cylinder and as wide as the circumference of the circles. The area of the two circles $= 2\pi r^2 = 2\pi(0.4)2 = 2\pi(0.16) = 0.32\pi$. The area of the rectangle is its height multiplied by the circumference of the circle $= 2(2\pi r) = 2(2\pi)(0.4) = 1.6\pi$. Now add: $0.32\pi + 1.6\pi = 1.92\pi$.

44. a. First, find the length of the side that is common to both of the right triangles in the figure. Call that side y. Apply the Pythagorean theorem to the triangle on the left: $90^2 + y^2 = 150^2$, so that $y^2 = 150^2 - 90^2 = 22{,}500 - 8{,}100 = 14{,}400$. If $y^2 = 14{,}400$, then $y = 120$. Now you know the lengths of the two legs of the triangle on the right, so apply the Pythagorean theorem again: $120^2 + 160^2 = x^2$, which means that $14{,}400 + 25{,}600 = x^2$. Thus, $40{,}000 = x^2$, and x is therefore 200. (If you realize that both triangles are 3-4-5 triangles, your work will be easier.)

45. d. If the figure is a regular decagon, it can be divided into ten equal sections by lines passing through the center. Two such lines form the indicated angle, which includes three of the ten sections; $\frac{3}{10}$ of 360 degrees = 108 degrees.

46. c. A foot in height makes a difference of 60 lbs., or 5 lbs. per inch of height over 5'. A person who is 5'5" is (5)(5 lbs.) = 25 lbs. heavier than the person who is 5', so add 25 lbs. to 110 lbs. to get 135 lbs.

47. a. At the end of three hours, the organ still has 100% function. After four hours, it has 80% of that 100%, or 0.8 . After five hours, it has 80% of the 80% it had at the end of four hours: (0.8)(0.8) = 64%. After six hours, it has 80% of the 64% it had after five hours: (0.8)(0.64) = 0.512, or about 50%.

48. d. Let E = the estimate. One-fifth more than the estimate means $\frac{6}{5}$ or 120% of E, so $600{,}000 = 1.2(E)$. Divide both sides by 1.2 to get $E = 500{,}000$.

49. **b.** The difference between 105 degrees and 99 degrees is 6 degrees. Application of the ice pack plus a resting period of 5 minutes before reapplication means that the temperature is lowered by half a degree every 6 minutes, or 1 degree every 12 minutes. Six degrees times 12 minutes per degree is 72 minutes, or 1 hour and 12 minutes.

50. **b.** The lighter liquid is $\frac{6}{15}$, or $\frac{2}{5}$, of the total solution; $\frac{2}{5}$ = 0.4, or 40%.

Section 4: General Science

1. **d.** The weak nuclear force determines beta decay, which occurs when a neutron converts to a proton, with the ejection of an electron.

2. **d.** Gravity must be accounted for in great detail, to guide the probe across the vastness of the solar system, in the presence of the gravitational field of the massive Sun.

3. **a.** The periodic table has rows of the elements, arranged by their properties, derived mainly from the patterns of electrons inside their atoms.

4. **a.** The valence shell either gains or loses electrons to create the atomic bonds with other atoms. Valence means *strength* (think *value*).

5. **d.** The covalent bond is a shared pair of electrons, which "spend time"in both atoms, though often in one more than the other.

6. **a.** The number 6 brings the total number of oxygen atoms on the right-hand side to 18, the same as the total on the left-hand side, thereby balancing the reaction.

7. **d.** Reduction of an element in a chemical reaction occurs when its charge is numerically lowered (in this case, from +4 to –4).

8. **b.** The liquid is warmed. The heat of fusion is the amount of energy is takes to melt a solid, to turn it into liquid at the same temperature. Because our example is already liquid, applying any heat at all only warms it up. This may or may not also evaporate the liquid, we don't know without more information.

9. **c.** Matter at the center of the Sun is in a plasma, because the electrons are stripped away from the nuclei of the atoms.

10. **b.** Only quartz contains no carbon, a necessary condition for an organic molecule. Therefore, quartz is an inorganic molecule.

11. **d.** The apple with its sugar has a large amount of carbohydrate.

12. **a.** The joule is 1 N-m. The calorie is also a unit of energy but is not equal to a N-m. The watt is a unit of energy flow rate, or power, not energy itself.

13. **d.** The conversion of mechanical motion into heat in the first law of thermodynamics comes from the mechanical equivalent of heat.

14. **a.** Joule conducted early experiments of turning one form of energy into another.

15. **d.** Heat is the most degraded form of energy. Garbage can be burned to make high-quality electricity, and water can turn a turbine, also making high-quality electricity.

16. **d.** Though all forms of energy can be converted into all other forms, the efficiency varies and is sometimes very low. Heat, the most degraded form of energy, according to the law of entropy, can be made from the other forms with a conversion rate that is theoretically 100%.

17. **a.** Entropy can decrease only if the decrease is strictly local and is more than balanced by an increase on some larger scale.

18. **b.** Temperature is molecular motion on the atomic scale.

19. **b.** Potential energy is created at the top, when the crane stops. Kinetic energy would occur were the beam dropped.

20. **c.** Chemical potential energy is released from the food we eat, when combined with oxygen in the air.

21. **a.** The power plant harnesses the kinetic energy in the falling water.

22. **d.** 3,700 million years ago (equal to 3.7 billion years ago) is right between the two kinds of evidence for the origin of life, from fossils and from carbon isotopes.

23. **b.** Protista are single-celled eukaryotes. Eukaryotes, bacteria, and archaea are the three main groupings in the universal tree of life.

24. **b.** Proteins are assembled at ribosomes, from amino acids brought to the ribosomes by transfer molecules, according to the genetic code.

25. **c.** Triplets of bases—for example AAT or CGT or GAC—code for amino acids. This was discovered by, among others, English biologist Francis Crick, who many years earlier, first discovered the double helix structure of DNA.

26. **d.** The *r* in rRNA stands for *ribosomal*. The ribosomes are used to construct the universal tree of life because all organisms possess ribosomes.

27. **d.** Liposomes are hollow spheres of lipid molecules, which are similar to (though simpler than) membranes of cells. Liposomes might have played a role in the origin of life and the evolution of cells.

28. **b.** Perhaps, strangely, it is today's pigeons that descended from ancestral birds, which descended directly from bipedal dinosaurs.

29. **c.** Eukaryotic cells have organelles, prokaryotic cells do not. The other answers are nonsense.

30. **d.** The human body, like the bodies of plants and fungi, is made of eukaryotic cells, cells with nuclei.

31. **d.** The mitochondrion converts food inside the eukaryotic cell (here called by the alternative name *nucleated* cell) into high-energy molecules, and thus supplies power to run the cell.

32. **b.** The cellulose molecule and the xylem tube system inside plants enabled tallness to evolve, and thus paved the way for trees. The blastula is a feature of the animal embryo, and flowers only came millions of years after the evolution of trees.

33. **b.** Fungi possess the underground threads called hyphae, that spread out to decompose and thus feed upon organic litter in the soil.

34. **c.** Animals have the blastula stage of embryonic development, which is a tiny hollow sphere of cells.

35. **a.** It's the radiation of reptiles. The other answers are either much earlier (the origin of life) or substantially later.

36. **d.** Phloem is the special tube-like tissue in plants that transports food downward. Xylem conducts water and minerals up from the soil. The other choices are found in animals.

37. **a.** The evidence of a world-wide clay layer that contains lots of the element iridium was found first in Italy, and then in many parts of the world. Iridium at those concentrations must have come from an impactor from space.

38. **b.** It is found on the Yucatan peninsula. The crater is no longer visible at the surface because it is covered with millions of years of sediment. But geologists found it.

39. **b.** It was their size. Being so large made them vulnerable to perturbations in their environment, because they required lots of food and their populations would have been relatively smaller than the tiny, rat-sized mammals, which made it through the mass extinction.

40. **b.** An older mass extinction than the one that did in the dinosaurs came at the end of the Permian stage of geological time, at the Permian-Triassic boundary, about 250 million years ago.

41. **c.** The bonobo in central Africa is a species related to the chimp. But unlike the aggressive chimp, the bonobo uses lots and lots of sex to smooth social relations and bond the band.

42. **a.** The field that studies the evolution of human behavior and the evolution of the human mind as it originated back in time is called evolutionary psychology.

43. a. Australopithecus, a human ancestor (a hominid), is the most recent by far.

44. d. The orangutan is most distantly related to us, of those in the list.

45. b. "Genus is to species" is like "Christianity to Catholicism and Protestantism" because both genus and Christianity are the larger grouping that contain the smaller types.

46. d. Wegener called his idea "continental drift," because it looked like South America and Africa were once together.

47. c. Places where ocean crust plunges toward the mantle are called subduction zones, because the crust is subducted down into the deeper layers of rock.

48. a. The plates are the large scale units of Earth's surface, at whose boundaries much of the geological action occurs.

49. b. Dinosaurs lived in the Mesozoic, which is subdivided into three periods of Triassic, Jurassic, and Cretaceous.

50. a. The time of recent ice ages was the Pleistocene, near the end of which (defined by the last melting of the ice sheets), humans reached a high level of culture, as shown by cave art. They also hunted mammoths.

Section 5: Biology

1. d. All these organelles contain DNA. Mitochondria and chloroplasts contain their own DNA independent of the nuclear DNA.

2. d. Xylem tissue conducts water and minerals from the roots to the rest of the plant, while phloem tissue carries sugars from the leaves to other parts of the plant. Sieve tubes are phloem components. Stomata are minute openings in leaves that allow air to enter.

3. b. Genetic information is relayed to mRNA during *transcription*. Afterward, the information in the mRNA undergoes translation into codons, thus continuing the process of protein synthesis.

4. c. An individual monoecious plant has *both* male and female reproductive organs. A dioecious plant has *either* male or female flowers.

5. a. Platelets are cell fragments (with no nucleus) that release serotonin and other chemicals, thus instigating the blood-clotting process.

6. c. Edema, also known as *dropsy*, is the interstitial collection of watery fluid.

7. c. Alcoholic fermentation occurs during anaerobic respiration, producing ethanol and carbon dioxide.

8. b. Remember that the prefix *auto* means *self*. Autogamy is a common method of fertilization used in plants. Syngamy is the union of male and female gametes also known as fertilization, and allogamy is cross-fertilization.

9. c. A single fertilized egg cell divides and becomes multicellular during cleavage. The other answers are all stages that a cell passes through during the four-staged cell cycle: G_2 phase, M phase (mitosis and cytokinesis), G_1 phase, and S phase.

10. a. Tuberculosis is caused by the bacterium *Mycobacterium tuberculosis*, which destroys parts of the lung tissue. The bacteria are spread through inhalation and exhalation.

11. b. In the complete classification of an organism, the groups from most inclusive to most exclusive are: kingdom, phylum, class, order, family, genus, and species.

12. b. The largest phylum is Arthropoda, the arthropods, which include insects. Insects make up approximately 80% of all known animal species.

13. d. Bile is produced in the liver and stored in the gall bladder.

14. b. Food is moved down the esophagus and along the rest of the alimentary canal by a series of alternating muscular contractions and relaxations called peristalsis.

15. **d.** The first part of the small intestine is the duodenum; the second part is the jejunum; the third, last, and longest part is the ileum.

16. **b.** Every person's body contains an average of 4.5 to 5 liters of blood.

17. **d.** Oxygen-rich blood collects into venules and finally into a pulmonary vein from each lung. Veins return blood to the heart, while arteries carry blood away from the heart.

18. **b.** During the tissue trauma that occurs during the birth of an Rh-negative mother's first Rh-positive child, some of the child's red blood cells may enter the mother's circulatory system. In response, the mother produces antibodies, which may pass across the placenta into the bloodstream of subsequent fetuses.

19. **c.** If incorrect blood types are transfused (for example, if type B blood is injected into a person with type A blood), red cells will clump together. This process is called agglutination.

20. **d.** The opposite occurs: Air pressure in the thorax decreases according to Boyle's law, which states that as the volume of a gas increases, the pressure decreases at a constant rate.

21. **a.** Water balance in the blood is controlled by the hormone vasopressin, which is secreted by the pituitary gland.

22. **d.** The islets of Langerhans are the small, round specialized tissue of the pancreas that produce insulin.

23. **c.** Smooth muscles are called involuntary muscles. They make up the walls of the hollow organs of the body, such as those of the alimentary canal.

24. **a.** Muscles work in pairs. Contraction of the biceps muscle bends the elbow; contraction of the triceps muscle straightens the arm.

25. **d.** Because a resting neuron's cell membrane is relatively impermeable to both sodium and potassium, and because active transport systems work to move sodium to the extracellular fluid and potassium to the intracellular fluid, the concentration of sodium ions is about 14 times higher outside the cell than inside, and the concentration of potassium ions is 20 to 30 times higher inside the cell than outside.

26. **b.** The cerebellum coordinates impulses sent out from the cerebrum. Its main function is to coordinate skeletal movements.

27. **d.** The myelin sheath is the outer layer that encloses the axon of many neurons.

28. **c.** The salivary glands have ducts and are called exocrine glands. The others are endocrine glands, which are ductless and pour their secretions directly into the blood.

29. **a.** A sponge does not have a nervous system; other animals have some kind of nervous system. Choice **b** is incorrect because neither sponges nor coelenterates have a bony skeleton. Choice **c** is incorrect because both are marine animals. Choice **d** is incorrect because coelenterates can reproduce sexually.

30. **a.** Triglycerides are the major constituent in dietary fat. To a lesser extent, phospholipids and cholesterol are also present in dietary fat. Lipase is an enzyme in vertebrates that catalyzes the breakdown of fats into fatty acids and glycerol.

31. **b.** The diastole phase of a heartbeat occurs between two contractions of the heart during which the heart muscles relax and the ventricles fill up with blood.

32. **d.** The Malpighian layer—synonymous with *stratum basale*—is the only layer of the skin in which mitosis occurs.

33. **a.** Ribosomes, located on the endoplasmic reticulum (ER) and the cytoplasm, are where protein synthesis occurs.

34. **d.** Typhoid fever is caused by *Salmonella typhi*. Pneumonia is caused by *Streptococcus pneumoniae*, scarlet fever by *S. pyogenes*, and endocarditis by *S. viridans*.

35. a. The placenta is the organ in viviparous animals which connects the embryo to its mother's uterus.

36. c. Draw a Punnett square diagram. Blue eye color (**b**) is a recessive trait and brown (**B**) is dominant. Your mother must be homozygous recessive to have blue eyes (**bb**) and your father is heterozygous (**Bb**). Therefore, your chances of having blue eyes is 50%.

37. a. Setae (singular *seta*) are the bristle-like projections on some invertebrates. Hair only occurs on mammals, and whiskers are a type of hair.

38. b. Tapeworms consist of a head and repeating segments. The head, called a scolex, has hooks and suckers for attachment to a host. The segments, or proglottids, contain the male and female reproductive organs.

39. d. The alveoli, where carbon dioxide and oxygen are exchanged, are located at the ends of tubes called bronchioles.

40. c. Light is produced without heat in bioluminscent animals when luciferin is oxidized.

41. d. Dentin is the thick, bony layer underneath the calcium phosphate deposit that makes up the enamel of teeth.

42. a. Exocrine glands, such as sweat glands and digestive glands, discharge secretions onto a surface via a duct. Endocrine glands release hormones directly into the interstitial fluid, from which they diffuse into the bloodstream.

43. d. Prokaryotes include only unicellular organisms: bacteria and cyanobacteria (blue-green algae). All other characteristics listed are seen only in eukaryotic cells.

44. b. Digestive organs called accessory organs contribute to the digestive process, but food does not pass through them. Choice **b**, the liver, is an example. The other choices are part of the alimentary canal or gastrointestinal tract, which is the tube through which food passes as it is digested.

45. a. Acquired characteristics are features that develop within the lifetime of an individual organism, as do large muscles in a weight lifter. The large ears of rabbits and nocturnal vision of owls have developed over generations to help these animals survive. The human appendix is a vestigial organ.

46. c. In arthropods, hemolymph carries nutrients and oxygen to cells.

47. d. The ilium is the third component of the human pelvic girdle. The human pectoral girdle consists of the scapulae, backbone, and clavicles attached to the sternum.

48. b. The chromatids split apart and move to opposite poles during anaphase. Mitotic division occurs in the following order: prophase, metaphase, anaphase, and telophase.

49. a. The roof of the mouth, or hard palate, separates the nasal cavity (the space inside the internal nose) and the buccal cavity (the mouth).

50. c. Tetanus is caused by the bacterium *Clostridium tetani*. Epstein-Barr virus, which causes infectious mononucleosis; the herpes simplex virus, which causes cold sores; and the varicella-zoster virus, which causes chicken pox; are all types of herpes virus.

Section 6: Chemistry

1. c. A proton weighs considerably more than an electron, so one mole of protons weighs more than one mole of electrons. A water molecule weighs approximately the same as 18 protons, and 5 molecules of benzene weighs approximately the same as 390 protons, both considerably less than the 6.02×10^{23} protons in a mole.

2. b. Water is a polar molecule, so other polar molecules will be soluble in it but nonpolar molecules will not. Like dissolves like. CCl_4 is the only choice that is nonpolar.

3. b. The (IV) notation means that tin has an oxidation number of +4. Therefore, there must be two atoms of oxygen, each with an oxidation number of –2, to give the formula unit a net charge of 0.

4. d. Insulin increases the conversion of glucose to glycogen. Choices **a** and **c** are the opposites of two related functions of insulin: Insulin increases glucose uptake by cells, thereby decreasing its serum levels. Insulin has no direct control over the release of glucagon.

5. d. Decreasing the blood levels of Ca^{+2}, a necessary function for life, is done by the C cells of the thyroid. Epinephrine causes all three other effects.

6. c. Aldehydes consist of a central carbon atom bonded to a lone hydrogen atom and a carbon chain, and double bonded to an oxygen. Thus, choice **c** is correct.

7. d. Polymers, molecules which make up many of the important compounds in the human body, are defined as large molecules consisting of many identical or similar subunits strung together. Choice **d**, although not important in the body, is the choice that best fits the definition.

8. c. Phospholipids, the major components of cell membranes, are made up of one molecule of glycerol bonded to two fatty acids and one phosphate group. Choice **a** describes a peptide bond, and choice **b** describes a fat.

9. b. Choice **b** is the definition of osmotic pressure. Osmotic potential, mentioned in choice **d**, is inversely proportional to osmotic pressure and is the Gibbs free energy value for the osmosis reaction.

10. d. An aldehyde is a molecule containing a carbonyl group, C=O, a hydrogen atom, and an alkyl group. The only choice that fits this definition is choice **d**.

11. a. Cyclobutane is the least stable of these molecules because it has both angle strain and torsional strain. Sp^3 hybridized carbon atoms, like the ones in cyclobutane, require bond angles of 109.5° to achieve maximum overlap and stability. However, cyclobutane's carbon atoms have bond angles of 88°, causing great angle strain and reducing stability. Cyclobutane also has reduced stability because of its torsional strain, which is caused by all four of its carbons being in the same plane.

12. b. Bismuth (III) has an oxidation number of +3, and the hydroxide ion has an oxidation number of –1. Therefore, three hydroxide ions must bond to each bismuth atom to form an uncharged compound.

13. b. When an alkali metal such as sodium reacts with water, an explosive reaction takes place, and the result is a metal hydroxide and hydrogen gas.

14. b. When an atom loses electrons, it is said to be oxidized; and when an atom gains electrons, it is said to be reduced. In this reaction, Br goes from negatively charged to neutral, thus losing an electron and being oxidized. Mn goes from a charge of +7 to a charge of +2, gaining electrons in the process and becoming reduced.

15. b. Atoms decrease in radius across rows of the periodic table to the right. For any row, the outermost orbital of electrons is the same for all elements in the row, and each added electron fills that orbital. However, each atom gains a proton, as well, which increases the attraction between the nucleus and electrons, reducing the atomic radius. Atoms increase in radius going down a column because each successive atom adds an orbital of electrons, increasing in size. Since Li, N, and F are in the same row, and Li is the leftmost atom, it is the largest of the three. However, Cs is below Li and is therefore the largest.

16. d. The buffer solution should definitely not contain a strong acid or a strong base, much less both of them. A buffer solution is intended to keep pH at a fairly constant level, and addition of a small quantity of strong acid or base can greatly alter pH.

17. c. The mass of the empirical compound CH_2O = (1C × 12 g) + (2H × 1 g) + (1O × 16 g) = 30 g. Since the molar mass of the compound is 90 g, the multiplier is $\frac{90}{30} = 3$, yielding a molecular formula of $C_3H_6O_3$.

18. b. As a general rule, radius increases as you go down and to the left in the periodic table. Rb is the farthest down and to the right.

19. c. Gases move freely compared with solids and liquids.

20. a. In redox reactions, atoms that lose electrons are being oxidized. The half reaction $Zn_{(s)} \rightarrow Zn^{2+}_{(aq)} + 2e^-$ shows that $Zn_{(s)}$ is losing two electrons in this reaction.

21. d. Both KOH and NH_4^+ are basic, leaving only H_3PO_4 and $H_2PO_4^-$. Because acidic compounds are generally H^+ donors, and $H_2PO_4^-$ has already lost one H^+, H_3PO_4 is the more acidic.

22. b. Because there are already either Ag^{2+} or CO_3^{2-} ions in the solutions in choices **a**, **c**, and **d**, $AgCO_3$ will be apt to form some solid. However, neither of these ions exist in the solution of KCl, allowing $AgCO_3$ to dissolve.

23. d. An alpha particle is of the form ${}^{4}_{2}He$, giving the atomic equation ${}^{234}_{92}U \rightarrow {}^{4}_{2}He + {}^{230}_{90}Th$.

24. c. Because HCl and NaOH are a strong acid and a strong base, respectively, the same number of moles of each will bring the solution to the equivalence point; 0.050 l × 0.2 M HCl = 0.001 mol HCl; $\frac{0.0001 \text{ Mol}}{0.5 \text{ M NaOH}} = 20$ ml.

25. d. Combustion reactions produce CO_2 and H_2O.

26. a. Use the equation $\Delta T = \frac{K_b(\text{moles solute})}{\text{mass of solution}}$. This gives $\frac{0.52(\frac{256}{128})}{5.15}$; $\frac{0.52}{5.15}$ is approximately $\frac{1}{10}$, and $\frac{256}{128} = 2$, so the answer is 0.2.

27. c. Because the molar mass of N is greater than 1, there are more atoms in 1 mole of N than in 1 gram. There are obviously more atoms in 1 mole of NO_2 than in 1 mole of N, since NO_2 has 3 atoms compared with 1 atom in N. While there are 4 atoms in each molecule of NH_3, there are half as many molecules in the NH_3 as in the NO_2 (0.5 mol compared to 1 mol).

28. a. Because H_2SO_4 is a strong acid, it will react with Al. Choice **a** is the only option that is balanced.

29. d. Choices **a** and **b** are going to a solid form, a decrease in entropy. Choice **c** goes from two separate molecules to form one compound, also decreasing in entropy. Choice **d** decomposes into two molecules from one, an increase in entropy.

30. b. Use the periodic table to answer this question. Elements in group IIA tend to go to a +2 ion.

31. d. Ca has two valence shells, which occur in the 4s shell.

32. d. Choices **a** and **c** are not polar bonds. Fluorine will always form more polar bonds than chlorine in covalent compounds.

33. a. The SO_3^{2-} anion is named sulfite; Li is lithium.

34. a. The oxidation numbers of NO_3^- and I^- are generally both –1; to make the net charge zero, the oxidation number for Na must be +1.

35. b. Choice **b** is the only one involving a beta particle.

36. c. It will take one half-life to go from 40 g to 20 g; it will take another half-life to go from 20 g to 10 g. This gives a total of 2.4×10^9 years.

37. b. The alkaline earth metals are in the second group; Mg is the only choice from this group.

38. a. The number of protons is the atomic number, or the lower number; the upper number is the sum of the protons and neutrons.

39. d. The Lewis dot structure shows that there are *two* double bonds in the molecule. Therefore, the total bond strength is 799 × 2 = 1,598.

40. c. The only effect of the addition of a catalyst is to increase the rate of reaction. There is no change in the composition.

41. a. Allotropes are two different formats of an element. Ozone and O_2 are two different formats for the element oxygen.

42. c. Hydrogen bonds greatly increase the boiling point of a compound. Hydrogen bonds occur between molecules that have hydrogen as well as F, O, or N.

43. a. Oxyacids of halogens are named by the number of oxygens attached. HClO is hypochlorous acid, $HClO_2$ is chlorous acid, $HClO_3$ is chloric acid, and $HClO_4$ is perchloric acid.

44. c. A decomposition reaction involves a single molecule breaking down into two separate molecules.

45. a. The electron configuration for Cl is [Ne] $3s^2 3p^5$.

46. c. First, the Lewis structure must be drawn. This shows that N_2 has a triple bond. Triple bonds consist of one σ bond and two π bonds.

47. a. This problem follows Avogadro's law, which states that volume is proportional to the number of moles if temperature and pressure are constant.

48. c. This is an example of osmosis. If the concentration is unequal on either side, the solvent will move toward the higher concentration.

49. a. The formula for alkanes is C_nH_{2n+2}; therefore, C_2H_6 is an alkane.

50. a. Proteins are macromolecules consisting of amino acids.

▶ Scoring

After you take the actual HOEE, a complicated formula will be used to convert your raw score on each section of the test into a percentile. The raw score is simply the number you get right on each section; wrong answers don't count against you. A percentile is a way of comparing your score with that of other test takers; this number indicates what percent of other test takers scored lower than you did on this section.

First, count the number of questions you got right in each section, and record them in the blanks below:

Section 1: _______ of 50 questions right
Section 2: _______ of 45 questions right
Section 3: _______ of 50 questions right
Section 4: _______ of 50 questions right
Section 5: _______ of 50 questions right
Section 6: _______ of 50 questions right

Next, convert your raw score into a *percentage* for each section of the exam. (Remember that this percentage is not the same as a *percentile*.) By now, your quantitative ability should be good enough to tell you how to arrive at a percentage, but if you've forgotten, refer back to the Scoring instructions in Chapter 3.

Now you can compare your scores on this test with those on the first practice exam. Chances are, your scores went up. If they didn't, it's probably because you took the first practice exam without having to worry about time, whereas in this exam, you had some fairly tight time limits to meet.

So if your scores went *down* between the first practice exam and this one, the problem is not so much the limits of your knowledge as your ability to work quickly without sacrificing accuracy. In that case, reread Chapter 2, "LearningExpress Test Prep System," for tips on how to improve your time management during the exam. Then, practice your time management skills on the sample exam in the next chapter. Before you begin each section, figure out the average amount of time allotted for each question by dividing the number of minutes allowed by the number of questions. Then, as you work through the section, keep yourself moving according to the schedule you've worked out. Remember to rack up the easy points by answering the easiest questions first, leaving the harder questions for last.

On the other hand, if your scores went up, you're probably wondering if they went up enough and, if not, what you should do about it. First of all, remember than no one is expected to score 100% on a section, so don't be too hard on yourself. Here's what you should do, based on your percentage scores on this practice exam:

- **For sections on which you scored less than 50%**, you need some concentrated work in those areas. (If you scored under 50% on all five sections, you might have to postpone taking the exam while you work on your skills.) If biology and chemistry were your problem areas, more work with your textbooks and other materials might be enough, especially if you weren't especially conscientious about reviewing before you took this practice exam. For other areas, and for biology and chemistry if you did review your textbooks, an extra college course is your best bet. If you don't have time or money for a complete course, find a tutor who will work with you individually. Most colleges have free or low-cost peer tutorial programs, or you may be able to get help from a professional teacher for a reasonable hourly fee.
- **For sections on which you scored 50–70%,** more review and practice is in order. Find a tutor, or form a study group with other students who are preparing for the HOEE. Go to the library or bookstore for other books that review the relevant areas; if those books also contain practice test questions, all the better. When you've done a fair amount of review, go back to the appropriate chapters of this book to review the practice questions and strategies.
- **For sections on which you scored 70–80%,** you're on your way to a score that will look good to the admissions department of your chosen program, but a little more work wouldn't hurt. Start by reviewing the appropriate chapters in this book. If you feel at all shaky about the material, use other resources: additional books, a friend who's good at the appropriate subject, a study group, or a peer tutor.
- **For sections on which you scored more than 80%,** you're in pretty good shape. But you should keep studying and practicing up to the day before the test, so you'll know that you're as prepared as possible to score as well as you can. Keep reviewing Chapters 4–9 of this book right up until test day, and use additional resources whenever you can.

One of the biggest keys to your success on the HOEE is your self-confidence. The more comfortable you are with your ability to perform, the more likely you are to do well on the exam. You know what to expect, you know your strengths and weaknesses, and you can work to turn those weaknesses into strengths before the actual exam. Your preparedness should give you the confidence that you'll need to do well on exam day.

CHAPTER

11 Practice Exam III

CHAPTER SUMMARY

How ready are you? This is the last of the three practice exams presented in this book. Use this test for extra practice and to determine the areas in which you should concentrate your attention in the time leading up to exam day.

THIS PRACTICE TEST will give you additional preparation and help you focus your study in the final days before the exam. As with the two earlier practice exams, this multiple-choice test is designed to reflect the topics and format of the entrance exams used by health training programs. The six test sections include Verbal Ability, Quantitative Ability, General Science, Biology, Chemistry, and Reading Comprehension. Although this practice test is general enough to prepare you for any health occupations entrance exam, be sure to investigate the specifics of the test you will be taking. The more you know, the better prepared you will be.

Before you take this third exam, find a quiet place where you can work undisturbed for four hours. Set a timer, stopwatch, or alarm clock to time yourself according to the directions in each section. Work as quickly as you can to meet the time limits, but do not sacrifice accuracy. Stop working when you run out of time even if you have not answered all of the questions. Allow yourself a five-minute break between each section and a fifteen-minute break after Section 3.

Using a number 2 pencil, mark your answers on the answer sheet on the following pages. The answer key is located on page 381—refer to this only once you have completed the test. A section about how to score your exam follows the answer key.

► Section 1: Verbal Ability

1.	a	b	c	d
2.	a	b	c	d
3.	a	b	c	d
4.	a	b	c	d
5.	a	b	c	d
6.	a	b	c	d
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43.	a	b	c	d
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47.	a	b	c	d
48.	a	b	c	d
49.	a	b	c	d
50.	a	b	c	d

► Section 2: Reading Comprehension

1.	a	b	c	d
2.	a	b	c	d
3.	a	b	c	d
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36.	a	b	c	d
37.	a	b	c	d
38.	a	b	c	d
39.	a	b	c	d
40.	a	b	c	d
41.	a	b	c	d
42.	a	b	c	d
43.	a	b	c	d
44.	a	b	c	d
45.	a	b	c	d

► Section 3: Quantitative Ability

1.	a	b	c	d	**18.**	a	b	c	d	**35.**	a	b	c	d
2.	a	b	c	d	**19.**	a	b	c	d	**36.**	a	b	c	d
3.	a	b	c	d	**20.**	a	b	c	d	**37.**	a	b	c	d
4.	a	b	c	d	**21.**	a	b	c	d	**38.**	a	b	c	d
5.	a	b	c	d	**22.**	a	b	c	d	**39.**	a	b	c	d
6.	a	b	c	d	**23.**	a	b	c	d	**40.**	a	b	c	d
7.	a	b	c	d	**24.**	a	b	c	d	**41.**	a	b	c	d
8.	a	b	c	d	**25.**	a	b	c	d	**42.**	a	b	c	d
9.	a	b	c	d	**26.**	a	b	c	d	**43.**	a	b	c	d
10.	a	b	c	d	**27.**	a	b	c	d	**44.**	a	b	c	d
11.	a	b	c	d	**28.**	a	b	c	d	**45.**	a	b	c	d
12.	a	b	c	d	**29.**	a	b	c	d	**46.**	a	b	c	d
13.	a	b	c	d	**30.**	a	b	c	d	**47.**	a	b	c	d
14.	a	b	c	d	**31.**	a	b	c	d	**48.**	a	b	c	d
15.	a	b	c	d	**32.**	a	b	c	d	**49.**	a	b	c	d
16.	a	b	c	d	**33.**	a	b	c	d	**50.**	a	b	c	d
17.	a	b	c	d	**34.**	a	b	c	d					

► Section 4: General Science

1.	a	b	c	d	**18.**	a	b	c	d	**35.**	a	b	c	d
2.	a	b	c	d	**19.**	a	b	c	d	**36.**	a	b	c	d
3.	a	b	c	d	**20.**	a	b	c	d	**37.**	a	b	c	d
4.	a	b	c	d	**21.**	a	b	c	d	**38.**	a	b	c	d
5.	a	b	c	d	**22.**	a	b	c	d	**39.**	a	b	c	d
6.	a	b	c	d	**23.**	a	b	c	d	**40.**	a	b	c	d
7.	a	b	c	d	**24.**	a	b	c	d	**41.**	a	b	c	d
8.	a	b	c	d	**25.**	a	b	c	d	**42.**	a	b	c	d
9.	a	b	c	d	**26.**	a	b	c	d	**43.**	a	b	c	d
10.	a	b	c	d	**27.**	a	b	c	d	**44.**	a	b	c	d
11.	a	b	c	d	**28.**	a	b	c	d	**45.**	a	b	c	d
12.	a	b	c	d	**29.**	a	b	c	d	**46.**	a	b	c	d
13.	a	b	c	d	**30.**	a	b	c	d	**47.**	a	b	c	d
14.	a	b	c	d	**31.**	a	b	c	d	**48.**	a	b	c	d
15.	a	b	c	d	**32.**	a	b	c	d	**49.**	a	b	c	d
16.	a	b	c	d	**33.**	a	b	c	d	**50.**	a	b	c	d
17.	a	b	c	d	**34.**	a	b	c	d					

► Section 5: Biology

1.	a	b	c	d	18.	a	b	c	d	35.	a	b	c	d
2.	a	b	c	d	19.	a	b	c	d	36.	a	b	c	d
3.	a	b	c	d	20.	a	b	c	d	37.	a	b	c	d
4.	a	b	c	d	21.	a	b	c	d	38.	a	b	c	d
5.	a	b	c	d	22.	a	b	c	d	39.	a	b	c	d
6.	a	b	c	d	23.	a	b	c	d	40.	a	b	c	d
7.	a	b	c	d	24.	a	b	c	d	41.	a	b	c	d
8.	a	b	c	d	25.	a	b	c	d	42.	a	b	c	d
9.	a	b	c	d	26.	a	b	c	d	43.	a	b	c	d
10.	a	b	c	d	27.	a	b	c	d	44.	a	b	c	d
11.	a	b	c	d	28.	a	b	c	d	45.	a	b	c	d
12.	a	b	c	d	29.	a	b	c	d	46.	a	b	c	d
13.	a	b	c	d	30.	a	b	c	d	47.	a	b	c	d
14.	a	b	c	d	31.	a	b	c	d	48.	a	b	c	d
15.	a	b	c	d	32.	a	b	c	d	49.	a	b	c	d
16.	a	b	c	d	33.	a	b	c	d	50.	a	b	c	d
17.	a	b	c	d	34.	a	b	c	d					

► Section 6: Chemistry

1.	a	b	c	d	18.	a	b	c	d	35.	a	b	c	d
2.	a	b	c	d	19.	a	b	c	d	36.	a	b	c	d
3.	a	b	c	d	20.	a	b	c	d	37.	a	b	c	d
4.	a	b	c	d	21.	a	b	c	d	38.	a	b	c	d
5.	a	b	c	d	22.	a	b	c	d	39.	a	b	c	d
6.	a	b	c	d	23.	a	b	c	d	40.	a	b	c	d
7.	a	b	c	d	24.	a	b	c	d	41.	a	b	c	d
8.	a	b	c	d	25.	a	b	c	d	42.	a	b	c	d
9.	a	b	c	d	26.	a	b	c	d	43.	a	b	c	d
10.	a	b	c	d	27.	a	b	c	d	44.	a	b	c	d
11.	a	b	c	d	28.	a	b	c	d	45.	a	b	c	d
12.	a	b	c	d	29.	a	b	c	d	46.	a	b	c	d
13.	a	b	c	d	30.	a	b	c	d	47.	a	b	c	d
14.	a	b	c	d	31.	a	b	c	d	48.	a	b	c	d
15.	a	b	c	d	32.	a	b	c	d	49.	a	b	c	d
16.	a	b	c	d	33.	a	b	c	d	50.	a	b	c	d
17.	a	b	c	d	34.	a	b	c	d					

► Section 1: Verbal Ability

Find the correctly spelled word in the following questions. You have 15 minutes to complete 50 questions.

1. **a.** abscessed
b. absessed
c. abscesed
d. abcessed

2. **a.** paralel
b. paralell
c. parallal
d. parallel

3. **a.** fundimentally
b. fundamentally
c. fundamentaly
d. fundamentelly

4. **a.** tonsillitis
b. tonsilitis
c. tonscilitis
d. tonscillitis

5. **a.** exeled
b. exceled
c. exseled
d. excelled

6. **a.** guardain
b. gaurdian
c. gardain
d. guardian

7. **a.** accustomed
b. acustomed
c. acusstomed
d. accustommed

8. **a.** pastureized
b. pasteurized
c. pastuerized
d. pastuerised

9. **a.** delirious
b. delerious
c. delireous
d. delireous

10. **a.** pleed
b. plede
c. plead
d. plaed

11. **a.** inundated
b. innundated
c. inondatted
d. inundatid

12. **a.** lazyness
b. lazeness
c. laziness
d. lazyiness

13. **a.** incunspicuous
b. inconspicuous
c. inconspicus
d. inconspicious

14. **a.** prosecuted
b. prossecuted
c. prosecutted
d. prosecuited

15. **a.** counterfiet
b. counterfit
c. countirfit
d. counterfeit

16. **a.** symetricaly
b. symetrically
c. symmetricully
d. symmetrically

17. **a.** dalaying
b. delaing
c. deleying
d. delaying

18. **a.** vacuum
b. vaccuum
c. vacum
d. vacume

19. **a.** acomodate
b. acommodate
c. acommedate
d. accommodate

20. **a.** coleagues
b. collegues
c. colleagues
d. colleages

21. **a.** souveniers
b. suovenirs
c. suvenirs
d. souvenirs

22. **a.** marrigeable
b. marrageable
c. marriageable
d. mariageable

23. **a.** ilegible
b. illegible
c. ilegable
d. illegable

24. **a.** penicillen
b. penicillin
c. penicillen
d. penicilin

25. **a.** adolescense
b. adolessents
c. adolescence
d. adolscence

Find the misspelled word in the following questions.

26. **a.** association
b. niusance
c. solidarity
d. no mistakes

27. **a.** playwright
b. dramatic
c. actor
d. no mistakes

28. **a.** specialized
b. negotiate
c. peacable
d. no mistakes

29. **a.** abundant
b. bounteous
c. luxuraint
d. no mistakes

30. **a.** gullable
b. lyrical
c. inheritance
d. no mistakes

31. **a.** initial
b. graditude
c. influential
d. no mistakes

32. **a.** loosely
b. emancipate
c. traffickable
d. no mistakes

33. **a.** flys
b. business
c. acquisition
d. no mistakes

34. **a.** border
b. bullitin
c. acquisition
d. no mistakes

35. **a.** ambassador
b. dignitary
c. embasy
d. no mistakes

36. **a.** nevertheless
b. neutral
c. neurotic
d. no mistakes

37. **a.** problematic
b. questionniare
c. controversial
d. no mistakes

38. **a.** pungaent
b. aromatic
c. spicy
d. no mistakes

39. **a.** hybrid
b. hypnosis
c. hygeinic
d. no mistakes

40. **a.** judge
b. ilegal
c. magistrate
d. no mistakes

41. **a.** correspondent
b. corrosivness
c. coronation
d. no mistakes

42. **a.** acrobat
b. somersault
c. gymnist
d. no mistakes

43. **a.** woful
b. blinking
c. acquire
d. no mistakes

44. **a.** lair
b. wasteing
c. peasant
d. no mistakes

45. **a.** panicy
b. jittery
c. nervous
d. no mistakes

46. **a.** spiteful
b. hungrier
c. crazyness
d. no mistakes

47. **a.** yellowish
b. spoiled
c. returnable
d. no mistakes

48. **a.** chiase
b. lounge
c. seat
d. no mistakes

49. **a.** extremly
b. abundance
c. dancing
d. no mistakes

50. **a.** spiteful
b. freindly
c. laughing
d. no mistakes

► Section 2: Reading Comprehension

Read each passage and answer the accompanying questions based only on the information found in the passage. You have 45 minutes to complete this section.

One out of five Americans suffers from an allergic disease, which results from the immune system reacting to a normally innocuous substance such as pollen or dust. Most of these people have allergies that affect nasal passages and sinuses, including allergies to pollen ("hay fever") and allergic reactions in the airways of the lungs that contribute to asthma. Hay fever alone affects some 22 million Americans, who in total see their doctors 9.4 million times a year. Asthma afflicts 10 to 15 million Americans.

An allergic response begins with a process called *sensitization*. When a foreign substance such as pollen (an allergen) first enters the body of an allergic person, cells called *macrophages* engulf the invader, chop it into pieces, and display the pieces on their surfaces. T-helper cells recognize certain allergen fragments and bind to the macrophages. This process causes the T-helper cells to secrete signaling molecules, including interleukin-4 (IL-4). IL-4, in turn, spurs nearby B cells to mature into plasma cells. Plasma cells produce Y-shaped antibody proteins.

One class of antibodies of great importance in allergic diseases and asthma is immunoglobulin E (IgE). The two arms of IgE are tailor-made to specifically attach to the allergen. The stem of the IgE molecule attaches to two classes of immune cells: mast cells, which concentrate in tissues exposed to the outside world, especially the skin, and the linings of the nose, lungs, and gastrointestinal tract; and basophilic cells, which circulate in the blood.

When the same allergen next enters the person's body, it binds to the arms of the IgE molecules protruding from the surfaces of mast cells and basophils. The interaction of an allergen with two IgE molecules triggers enzymes associated with the cell membrane, such as tyrosine kinases. The enzymes start a series of biochemical reactions in the cell, which causes the cell to release chemicals, including histamine, from storage pouches called *granules* in the cell interior.

These chemicals allow fluid to leak from blood vessels, producing symptoms such as redness and swelling in nearby tissues. They also constrict smooth muscles and stimulate mucus production. In addition, the reactions cause such symptoms as a runny nose, sneezing, itching, hives, or abdominal cramps. In severe cases, anaphylactic shock may occur following the release of some chemicals, like histamine, which can constrict the lungs' airways. Also, mast cells secrete chemical messengers that recruit other cells from the bloodstream, including T lymphocytes and eosinophils, into the tissues.

In the tissues, some of the recently arrived cells release substances that can increase and prolong early symptoms and may injure and inflame local tissue. Such responses often occur several hours after the initial encounter with an allergen. Collectively, they are called the *late-phase reaction*. The cells present in late-phase reactions are quite similar to those cells found in the tissues of patients with chronic allergic rhinitis and asthma.

1. In the allergic reaction process, enzymes are produced as the result of
a. the forming of Y-shaped antibody proteins.
b. the onset of anaphylactic shock.
c. allergens coming in contact with antibodies.
d. T-helper cells interacting with macrophages.

2. Cells that surround pollen within the body are known as
a. T-helper cells.
b. macrophage cells.
c. B cells.
d. plasma cells.

3. The substances that diminish lung capacity
a. are present during sensitization.
b. can alleviate skin inflammation.
c. can trigger the development of plasma cells.
d. are located inside granules.

4. Which of the following is NOT mentioned in the passage?
a. the obvious symptoms of anaphylactic shock
b. the location where basophils exist
c. the type of molecule released by T-helper cells
d. the result of mast cells emitting messengers

5. One result of mast cells' chemical messenger activity is
a. relief of symptoms such as inflamed tissue.
b. an allergen connecting to immunoglobulin E.
c. the development of enzymes such as tyrosine kinases.
d. a lengthening of the time a patient experiences symptoms.

6. What occurs the second time an allergen enters the body?
a. Macrophages cut the allergen into pieces.
b. Mast cells become connected to the allergen.
c. T helper cells detect portions of the allergen.
d. The allergen eliminates tyrosine kinases.

7. An allergic disease occurs when the body's immune system reacts to a substance that is usually
a. harmless.
b. toxic.
c. irritating.
d. infecting.

By using tiny probes as neural prostheses, scientists may be able to restore nerve function in quadriplegics and make the blind see or the deaf hear. Thanks to advanced techniques, a single, small, implanted probe can stimulate individual neurons electrically or chemically and then record responses. Preliminary results suggest that the microprobe telemetry systems can be permanently implanted and replace damaged or missing nerves.

The tissue-compatible microprobes represent an advance over the typical aluminum wire electrodes used in studies of the cortex and other brain structures. Researchers accumulate much data using traditional electrodes, but there is a question of how much damage they cause to the nervous system. Microprobes, which are about as thin as a human hair, cause minimal damage and disruption of neurons when inserted into the brain.

In addition to recording nervous system impulses, the microprobes have minuscule channels that open the way for delivery of drugs, cellular growth factors, neurotransmitters, and other neuroactive compounds to a single neuron or to groups of neurons. The probes can have up to four channels, each with its own recording/stimulating electrode.

The probes can be left in place for a fairly long time. In one guinea pig, a probe continued to transmit data from the animal's hearing center for eleven months. The long-term implantability of the probes makes them promising candidates for neural prostheses. Researchers envision the probes being used to affect the motor center of the brain: for example, to stimulate a hand grasp in patients who have lost motor control. They might also be used to create a visual prosthesis, connecting an external miniature video camera to the visual center in the cortex, thereby circumventing damaged eyes and optic nerves.

In quadriplegics and paraplegics, probes might bridge injured areas of the spinal cord and restore nerve connection to the limbs. Additionally, people who lack or produce too little of essential biochemicals or who need drugs could receive minute doses delivered with pinpoint accuracy through permanently implanted probes.

One obstacle to using any electrode as a long-term implant has been the lack of satisfactory connections to the outside world. Wires are bulky, they break easily, and they must be tethered to prevent damage to surrounding tissue. Even with implantable telemetry systems, which have their own power supply and can transmit data via radio waves, leads still must connect the electrodes to the electronic package (a system similar to integrated circuits used on computer chips). To overcome the connection problem, researchers have developed ultraflexible silicon ribbon cables. The cables are significantly more flexible than a commonly used aluminum wire.

It is easiest to place probes in the brain cortex, compared to deeper structures. Because the probes are so small, implantation must be viewed under the microscope. They can be manually inserted using forceps or affixed to special mounting mechanisms.

8. One similar feature of microprobes and wire electrodes is the
- **a.** minimal disturbance of neurons.
- **b.** density of material.
- **c.** capacity for multiple leads.
- **d.** ability to generate information.

9. Which of the following best expresses the main idea of the passage?
- **a.** Microprobes require further technological advances before they can be used in humans.
- **b.** Wire electrodes are an antiquated means for delivering neuroactive compounds to the brain.
- **c.** Microprobes have great potential to help counteract neural damage.
- **d.** Technology now exists that may enable repair of the nervous system.

10. All of the following are mentioned in the passage as potential uses for prostheses EXCEPT
- **a.** transportation of medication.
- **b.** induction of physical movement.
- **c.** compensation for damaged nerves.
- **d.** removal of biochemicals from the cortex.

11. The initial function of microprobe channels is to
- **a.** create pathways.
- **b.** disrupt neurons.
- **c.** replace ribbon cables.
- **d.** study the brain.

12. In order to keep a body's structural material from being harmed, electrode wires must be
- **a.** as small as possible.
- **b.** fastened.
- **c.** implanted manually.
- **d.** viewed under a microscope.

13. Devising acceptable external telemetry links is essential to
a. the implanting of probes with special tools.
b. the administration of drugs with pinpoint accuracy.
c. improvement in the duration of implants.
d. creation of a usable power supply.

A government report addressing concerns about the many implications of genetic testing outlined policy guidelines and legislative recommendations intended to avoid involuntary and ineffective testing and to protect confidentiality.

The report identified urgent concerns, such as quality control measures (including federal oversight for testing laboratories) and better genetics training for medical practitioners. It recommended voluntary screening; urged couples in high-risk populations to consider carrier screening; and advised caution in using and interpreting presymptomatic or predictive tests as certain information could easily be misused or misinterpreted.

About three in every 100 children are born with a severe disorder presumed to be genetic or partially genetic in origin. Genes, often in concert with environmental factors, are being linked to the causes of many common adult diseases such as coronary artery disease, hypertension, various cancers, diabetes, and Alzheimer's disease. Tests to determine predisposition to a variety of conditions are under study, and some are beginning to be applied.

The report recommended that all screening, including screening of newborns, be voluntary. Citing results of two different voluntary newborn screening programs, the report said these programs can achieve compliance rates equal to or better than those of mandatory programs. State health departments could eventually mandate the offering of tests for diagnosing treatable conditions in newborns; however, careful pilot studies for conditions diagnosable at birth need to be done first.

Although the report asserted that it would prefer that all screening be voluntary, it did note that if a state requires newborn screening for a particular condition, the state should do so only if there is strong evidence that a newborn would benefit from effective treatment at the earliest possible age. Newborn screening is the most common type of genetic screening today. More than four million newborns are tested annually so that effective treatment can be started in a few hundred infants.

Prenatal testing can pose the most difficult issues. The ability to diagnose genetic disorders in the fetus far exceeds any ability to treat or cure them. Parents must be fully informed about risks and benefits of testing procedures, the nature and variability of the disorders they would disclose, and the options available if test results are positive. Obtaining informed consent—a process that would include educating participants, not just processing documents—would enhance voluntary participation. When offered testing, parents should receive comprehensive counseling, which should be nondirective. Relevant medical advice, however, is recommended for treatable or preventable conditions.

Genetics also can predict whether certain diseases might develop later in life. For single-gene diseases, population screening should only be considered for treatable or preventable conditions of relatively high frequency. Children should be tested only for disorders for which effective treatments or preventive measures could be applied early in life.

14. As it is used in the passage, the word *predisposition* most nearly means
- **a.** willingness.
- **b.** susceptibility.
- **c.** impartiality.
- **d.** composure.

15. The report stressed the need for caution in the use and interpretation of
- **a.** predictive tests.
- **b.** newborn screening.
- **c.** informed consent.
- **d.** pilot studies.

16. How many infants are treated for genetic disorders as a result of newborn screening?
- **a.** dozens
- **b.** hundreds
- **c.** thousands
- **d.** millions

17. One intention of the policy guidelines was to
- **a.** implement compulsory testing.
- **b.** minimize concerns about quality control.
- **c.** endorse the expansion of screening programs.
- **d.** preserve privacy in testing.

18. According to the report, states should implement mandatory infant screening only
- **a.** if the compliance rate for voluntary screening is low.
- **b.** for mothers who are at high risk for genetic disease.
- **c.** after meticulous research is undertaken.
- **d.** to avoid the abuse of sensitive information.

19. The most prevalent form of genetic testing is conducted on
- **a.** high-risk populations.
- **b.** adults.
- **c.** fetuses prior to birth.
- **d.** infants shortly after birth.

Scientists have developed an innovative procedure that reveals details of tissues and organs that are difficult to see by conventional magnetic resonance imaging (MRI). By using "hyperpolarized" gases, scientists have taken the first clear MRI pictures of human lungs and airways. Researchers hope the new technique will aid the diagnosis and treatment of lung disorders, and perhaps lead to improved visualization of blood flow.

The air spaces of the lungs have been notoriously difficult for clinicians to visualize. Chest X rays can detect tumors or inflamed regions in the lungs but provide poor soft-tissue contrast and no clear view of air passages. Computed tomography, a cross sectional X ray scan, can provide high resolution images of the walls of the lungs and its airways but gives no measure of function. Conventional MRI, because it images water protons, provides poor images of the lungs, which are filled with air, not water.

The new MRI technique detects not water but inert gases whose nuclei have been strongly aligned, or hyperpolarized, by laser light. Initially this technique seemed to have no practical application, but exhaustive research has proven its potential. Scientists plan to further refine this technology with animal and human studies, in part because they have yet to produce a viable 3-D image of human lungs.

By 1995 researchers had produced the first 3-D MRI pictures of a living animal's lungs. In the first human test, a member of the research team inhaled hyperpolarized helium-3. His lungs were then imaged using a standard MRI scanner that had been adjusted to detect helium. The results were impressive, considering that the system had yet to be optimized and there was only a relatively small volume of gas with which to work.

When a standard MRI is taken, the patient enters a large magnet. Many of the body's hydrogen atoms (primarily the hydrogen atoms in water) align with the magnetic field like tiny bar magnets, and the nucleus at the center of each atom spins constantly about its north-south axis. Inside the MRI scanner, a radio pulse temporarily knocks the spinning nuclei out of position, and as their axes gradually realign within the magnetic field, they emit faint radio signals. Computers convert these faint signals into an image.

The new gas-based MRI is built around similar principles. But circularly polarized light, rather than a magnet, is used to align spinning nuclei, and the inert gases helium-3 or xenon-129 (rather than hydrogen) provide the nuclei that emit the image-producing signals. The laser light polarizes the gases through a technique known as *spin exchange*. Helium-3 and xenon-129 are ideal for gas-based MRI because they take hours to lose their polarization. Most other gases readily lose their alignment. The clarity of an MRI picture depends in part on the volume of aligned nuclei.

20. The MRI innovation is different from the standard MRI in that it
a. distinguishes gases rather than water.
b. uses magnets rather than light.
c. has a range of useful applications.
d. provides better images of blood circulation.

21. The inability to generate satisfactory images of air routes is a deficiency of
a. computed tomography.
b. the spin exchange process.
c. 3-D pictures.
d. X rays.

22. Standard MRI scanners detect radio signals emitted
a. before nuclei rotate on an axis.
b. before atoms align with magnets.
c. after nuclei are aligned by magnetism.
d. after signals are transformed into pictures.

23. The word that can best be interchanged with *hyperpolarization* in the passage is
a. visualization.
b. alignment.
c. emission.
d. tomography.

24. Use of which of the following is substituted for use of a magnet in one of the MRI techniques?
a. light
b. hydrogen
c. helium-3
d. X rays

25. An image lacking in clarity is likely to be the result of
a. a high number of aligned nuclei.
b. hydrogen being replaced with xenon.
c. an abbreviated period of alignment.
d. nuclei regaining their aligned position.

Once people wore garlic around their necks to ward off disease. Today, most Americans would scoff at the idea of wearing a necklace of garlic cloves to enhance their wellbeing. However, you might find a number of Americans willing to ingest capsules of pulverized garlic or other herbal supplements in the name of health.

Complementary and alternative medicine (CAM), which includes a range of practices outside of conventional medicine such as herbs, homeopathy, massage, yoga, and acupuncture, holds increasing appeal for Americans. In fact, according to one estimate, 42% of Americans have used alternative therapies. A Harvard Medical School survey found that young adults (those born between 1965 and 1979) are the most likely to use alternative treatments, whereas people born before 1945 are the least likely to use these therapies. Nonetheless, in all age groups, the use of unconventional healthcare practices has steadily increased since the 1950s, and the trend is likely to continue.

CAM has become a big business as Americans dip into their wallets to pay for alternative treatments. A 1997 American Medical Association study estimated that the public spent $21.2 billion for alternative medicine therapies in that year, more than half of which were "out-of-pocket" expenditures, meaning they were not covered by health insurance. Indeed, Americans made more out-of-pocket expenditures for alternative services than they did for out-of-pocket payments for hospital stays in 1997. In addition, the number of total visits to alternative medicine providers (about 629 million) exceeded the tally of visits to primary care physicians (386 million) in that year.

However, the public has not abandoned conventional medicine for alternative healthcare. Most Americans seek out alternative therapies as a complement to their conventional healthcare whereas only a small percentage of Americans rely primarily on alternative care. Why have so many patients turned to alternative therapies? Frustrated by the time constraints of managed care and alienated by conventional medicine's focus on technology, some feel that a holistic approach to healthcare better reflects their beliefs and values. Others seek therapies that will relieve symptoms associated with chronic disease, symptoms that mainstream medicine cannot treat.

Some alternative therapies have crossed the line into mainstream medicine as scientific investigation has confirmed their safety and efficacy. For example, today physicians may prescribe acupuncture for pain management or to control the nausea associated with chemotherapy. Most U.S. medical schools teach courses in alternative therapies and many health insurance companies offer some alternative medicine benefits. Yet, despite their gaining acceptance, the majority of alternative therapies have not been researched in controlled studies. New research efforts aim at testing alternative methods and providing the public with information about which ones are safe and effective and which ones are a waste of money, or possibly dangerous.

So what about those who swear by the health benefits of the "smelly rose," garlic?

Observational studies that track disease incidence in different populations suggest that garlic use in the diet may act as a cancer-fighting agent, particularly for prostate and stomach cancer. However, these findings have not been confirmed in clinical studies. And yes, reported side effects include garlic odor.

26. The author describes wearing garlic as an example of
- **a.** an arcane practice considered odd and superstitious today.
- **b.** the ludicrous nature of complementary and alternative medicine.
- **c.** a scientifically tested medical practice.
- **d.** a socially unacceptable style of jewelry.

27. As it is used in the second paragraph, the word *conventional* most nearly means
- **a.** appropriate.
- **b.** established.
- **c.** formal.
- **d.** moralistic.

28. The author most likely uses the Harvard survey results in the second paragraph to imply that

a. as people age, they always become more conservative.
b. people born before 1945 view alternative therapies with disdain.
c. the survey did not question baby boomers (those born between 1945–1965) on the topic.
d. many young adults are open-minded to alternative therapies.

29. The statistic in the third paragraph comparing total visits to alternative medicine practitioners with those to primary care physicians is used to illustrate the

a. popularity of alternative medicine.
b. public's distrust of conventional healthcare.
c. accessibility of alternative medicine.
d. affordability of alternative therapies.

30. In paragraph four, *complement* most nearly means

a. tribute.
b. commendation.
c. replacement.
d. addition.

31. The information in the fourth paragraph indicates that Americans believe that conventional healthcare

a. offers the best relief from the effects of chronic diseases.
b. should not use technology in treating illness.
c. combines caring for the body with caring for the spirit.
d. falls short of their expectations in some aspects.

In space flight, there are the obvious hazards of meteors, debris, and radiation; however, astronauts must also deal with two vexing physiological foes—muscle atrophy and bone loss. Space shuttle astronauts, because they spend only about a week in space, undergo minimal wasting of bone and muscle. But when longer stays in microgravity or zero gravity are contemplated, as in the space station or a two-year round-trip voyage to Mars, these problems are of particular concern because they could become acute.

Some studies show that muscle atrophy can be kept largely at bay with appropriate exercise, but bone loss caused by reduced gravity cannot. Scientists can measure certain flight-related hormonal changes and can obtain animal bone biopsies immediately after flights, but they do not completely understand how gravity affects the bones or what happens at the cellular level.

Even pounding the bones or wearing a supender-like pressure device does nothing to avert loss of calcium from bones. Researchers say that after a three-month or longer stay in space, much of the profound bone loss may be irreversible. Some argue that protracted missions should be curtailed. They are conducting a search for the molecular mechanisms behind bone loss, and they hope these studies will help develop a prevention strategy to control tissue loss associated not only with weightlessness but also with prolonged bed rest.

Doctors simulate bone-depleting microgravity conditions by putting volunteers to bed for long time periods. The bed support of the supine body decreases the load on it significantly, thus simulating reduced gravity. One study involves administering either *alendronate*, a drug that blocks the breakdown of bone, or a placebo, a look-alike substance without medical effects, to volunteers for two weeks prior to and then during a three-week bed rest.

Prior to bed rest, alendronate-treated volunteers excreted only about one-third as much calcium as did the persons receiving the placebo. Bed rest increased urinary calcium excretion in both groups, but in alendronate-treated persons the urinary calcium levels were even lower than those in the placebo group before bed rest. Blood levels of parathyroid hormone and vitamin D, which are involved in regulation of bone metabolism, were also significantly elevated in drug recipients.

Although these results suggest that alendronate inhibits bone loss and averts high urinary calcium concentrations that can cause kidney stones, they do not point to the precise molecular mechanisms at work. Thus, plans are to initiate a more prolonged bed rest project over the next several years.

32. Astronauts who exercise regularly can
- **a.** expect bone loss to be temporary.
- **b.** greatly reduce the amount of atrophy.
- **c.** use special implements that maintain calcium levels.
- **d.** minimize the percentage of bone loss.

33. Compared to volunteers who received a placebo, volunteers who received alendronate experienced
- **a.** lower levels of parathyroid hormone.
- **b.** lower levels of hormonal changes.
- **c.** higher levels of vitamin D.
- **d.** higher levels of calcium excretion.

34. Specialized equipment for astronauts in weightless conditions
- **a.** reduces the amount of calcium in their bones.
- **b.** makes lengthy space flights more feasible.
- **c.** enables scientists to better comprehend molecular mechanisms.
- **d.** has a negligible impact on bone loss.

35. The passage suggests that the bone-loss studies may yield information that could aid the treatment of
- **a.** kidney stones.
- **b.** muscular atrophy.
- **c.** thyroid disease.
- **d.** urinary infections.

36. Volunteers in the study mentioned in the passage received alendronate for a total of
- **a.** two weeks.
- **b.** three weeks.
- **c.** five weeks.
- **d.** six weeks.

About three million Americans have open-angle glaucoma, the most common form of glaucoma in the United States. For unknown reasons, small changes within the eye gradually interfere with the normal flow of fluids that feed tissues in the front of the eye. If these fluids do not drain properly, the resulting higher pressure inside the eye can damage the optic nerve and narrow the field of vision. This change happens so slowly that many people are not diagnosed with glaucoma until they have significant loss of vision.

Laser therapy is a safe and effective alternative to eyedrops as a first-line treatment for patients with newly diagnosed primary open-angle glaucoma. This finding comes from a follow-up study undertaken to learn if early laser treatment is safe and whether it offers any medical advantages over eyedrops for newly diagnosed open-angle glaucoma. A total of 271 patients were enrolled in the initial study. Each patient had laser treatment in one eye and medication in the other eye. Over two hundred patients were followed for an average of seven years after treatment.

Post-study analysis revealed that all measures used to evaluate the two treatments showed that the "laser-first" eyes and the "medication-first" eyes had a similar status on all measures used to evaluate the two treatments. Researchers assessed changes in the patient's visual field, visual acuity, intraocular pressure, and optic nerve. The results suggested that initial treatment with laser surgery is at least as effective as initial treatment with eyedrops. However, researchers cautioned that neither treatment method is a "magic bullet" for long-term control of glaucoma. They noted that two years after the start of treatment, 56% of "laser-first" eyes and 70% of "medication-first" eyes needed new or extra medications to control pressure inside the eye.

Researchers noted that both treatments caused side effects. However, the side effects of laser treatment were temporary or made no apparent difference in the long run, whereas the side effects of eyedrops were troublesome for some patients for as long as the drops were used. Eyedrops used for glaucoma treatment can cause discomfort in the eye, blurry vision, headaches, and fast or slow heartbeat.

In 34% of "laser-first" eyes, the laser treatment caused a temporary jump in intraocular pressure for the first few days after treatment. Also, some 30% of the "laser-first" eyes developed *peripheral anterior synechiae*—adhesions that form when the iris sticks to part of the cornea.

37. Over half the patients in the study discussed in the passage required supplemental treatment for
a. optic nerve damage.
b. intraocular pressure.
c. visual field weakness.
d. lack of visual acuity.

38. The primary purpose of the passage is to
a. advocate the use of glaucoma medication.
b. define the needs of glaucoma patients.
c. defend the safety of laser treatment for glaucoma.
d. weigh the effects of glaucoma treatments.

39. Greater pressure within the eye results from
a. a disruption of fluid concentration.
b. the rapid accumulation of fluids.
c. a gradual broadening of the field of vision.
d. initial treatment with eyedrops.

40. The study concluded that, compared with medication, laser therapy is
a. slightly more effective.
b. significantly more effective.
c. just as effective.
d. less effective.

41. The study was conducted on patients who were
a. in the initial stages of open-angle glaucoma.
b. experiencing a rare form of glaucoma.
c. given eyedrop medication in both eyes.
d. in the late stages of open-angle glaucoma.

Almost 50% of American teens are not vigorously active on a regular basis, contributing to a trend of sluggishness among Americans of all ages, according the U.S. Centers for Disease Control (CDC). Adolescent female students are particularly inactive—29% are inactive compared with 15% of male students. Unfortunately, the sedentary habits of young "couch potatoes" often continue into adulthood. According to the Surgeon General's 1996 Report on Physical Activity and Health, Americans become increasingly less active with each year of age. Inactivity can be a serious health risk factor, setting the stage for obesity and associated chronic illnesses like heart disease or diabetes. The benefits of exercise include building bone, muscle, and joints, controlling weight, and preventing the development of high blood pressure.

Some studies suggest that physical activity may have other benefits as well. One CDC study found that high school students who take part in team sports or are physically active outside of school are less likely to engage in risky behaviors, like using drugs or smoking. Physical activity does not need to be strenuous to be beneficial. The CDC recommends moderate, daily physical activity for people of all ages, such as brisk walking for 30 minutes or 15–20 minutes of more intense exercise. A survey conducted by the National Association for Sport and Physical Education questioned teens about their attitudes toward exercise and about what it would take to get them moving. Teens chose friends (56%) as their most likely motivators for becoming more active, followed by parents (18%) and professional athletes (11%).

42. The first paragraph of the passage serves all of the following purposes EXCEPT
- **a.** to provide statistical information to support the claim that teenagers do not exercise enough.
- **b.** to list long-term health risks associated with lack of exercise.
- **c.** to express skepticism that teenagers can change their exercise habits.
- **d.** to show a correlation between inactive teenagers and inactive adults.

43. In the first paragraph, *sedentary* most nearly means
- **a.** slothful.
- **b.** apathetic.
- **c.** stationary.
- **d.** stabilized.

44. Which of the following techniques is used in the last sentence of the passage?
- **a.** explanation of terms
- **b.** comparison of different arguments
- **c.** contrast of opposing views
- **d.** illustration by example

45. The primary purpose of the passage is to
- **a.** refute an argument.
- **b.** make a prediction.
- **c.** praise an outcome.
- **d.** promote a change.

▶ Section 3: Quantitative Ability

Choose the correct answer for each problem. You have 45 minutes to complete this section.

1. How many inches are there in $3\frac{1}{3}$ yards?
- **a.** 120
- **b.** 126
- **c.** 160
- **d.** 168

2. $\frac{3}{4} + \frac{5}{7}$ is equal to
- **a.** $\frac{8}{11}$.
- **b.** $1\frac{6}{7}$.
- **c.** $1\frac{1}{4}$.
- **d.** $1\frac{13}{28}$.

3. 0.97 is equal to
- **a.** 97%.
- **b.** 9.7%.
- **c.** 0.97%.
- **d.** 0.097%.

4. In a triangle, angle A is 70 degrees and angle B is 30 degrees. What is the measure of angle C?
- **a.** 90 degrees
- **b.** 70 degrees
- **c.** 80 degrees
- **d.** 100 degrees

5. 6^3 is equal to
- **a.** 36.
- **b.** 1,296.
- **c.** 18.
- **d.** 216.

6. Dr. Drake charges $36.00 for an office visit, which is $\frac{3}{4}$ of what Dr. Jean charges. How much does Dr. Jean charge?
- **a.** $48.00
- **b.** $27.00
- **c.** $38.00
- **d.** $57.00

7. The nursing assistants give baths to the patients every morning at 7:00. NA Garcia gives Ms. Rogers her bath in 20 minutes. NA West gives Mr. Taft his bath in 17 minutes, and NA Owens gives Ms. Johnson her bath in 14 minutes. What is the average time for the three baths?
- **a.** 20 minutes
- **b.** 17 minutes
- **c.** 14 minutes
- **d.** 12 minutes

8. What percentage of 50 is 12?
- **a.** 4%
- **b.** 14%
- **c.** 24%
- **d.** 34%

9. A hospital waiting room is 8 feet wide and 10 feet long. What is the area of the waiting room?
- **a.** 18 square feet
- **b.** 40 square feet
- **c.** 60 square feet
- **d.** 80 square feet

10. Mr. Beard's temperature is 98 degrees Fahrenheit. What is his temperature in degrees Celsius? $C = \frac{5}{9}(F - 32)$
- **a.** 35.8
- **b.** 36.7
- **c.** 37.6
- **d.** 31.1

11. $\frac{2}{5} \times \frac{3}{7}$ is equal to
- **a.** $\frac{6}{35}$.
- **b.** $\frac{14}{15}$.
- **c.** $\frac{5}{12}$.
- **d.** $\frac{29}{35}$.

12. $(12 + 14) \times 7$ is equal to
- **a.** 98.
- **b.** 266.
- **c.** 110.
- **d.** 100.

13. Which of the following is 14% of 232?
- **a.** 3.248
- **b.** 32.48
- **c.** 16.57
- **d.** 165.7

14. One side of a square bandage is 4 inches long. What is the perimeter of the bandage?
- **a.** 4 inches
- **b.** 8 inches
- **c.** 12 inches
- **d.** 16 inches

15. $12(9 \times 4)$ is equal to
- **a.** 432.
- **b.** 72.
- **c.** 108.
- **d.** 336.

16. 33 is 12% of which of the following numbers?
- **a.** 3,960
- **b.** 396
- **c.** 275
- **d.** 2,750

17. $945.6 \div 24$ is equal to
- **a.** 3,940.
- **b.** 394.
- **c.** 39.4.
- **d.** 3.946.

18. $72 + 98 - 17$ is equal to
- **a.** 143.
- **b.** 163.
- **c.** 170.
- **d.** 153.

19. The radius of a circle is 13. What is the approximate area of the circle?
- **a.** 81.64
- **b.** 1,666.27
- **c.** 530.66
- **d.** 169

20. $\frac{7}{8} - \frac{3}{5}$ is equal to
- **a.** $\frac{11}{40}$.
- **b.** $1\frac{1}{3}$.
- **c.** $\frac{1}{10}$.
- **d.** $1\frac{19}{40}$.

21. All the rooms on the orthopedic ward are rectangular with 8-foot ceilings. One room is 9 feet wide by 11 feet long. What is the combined area of the four walls, including doors and windows?
- **a.** 99 square feet
- **b.** 160 square feet
- **c.** 320 square feet
- **d.** 72 square feet

22. What is the value of 195.6 divided by 7.2, rounded to the nearest hundredth?
- **a.** 271.67
- **b.** 27.17
- **c.** 27.16
- **d.** 2.717

23. 17^2 is equal to
- **a.** 34.
- **b.** 68.
- **c.** 136.
- **d.** 289.

24. $\frac{5}{8} \div 3$ is equal to
- **a.** $\frac{5}{24}$.
- **b.** $\frac{3}{8}$.
- **c.** $1\frac{7}{8}$.
- **d.** $\frac{3}{24}$.

25. On the cardiac ward, there are 7 nursing assistants. NA Basil has 8 patients; NA Hobbes has 5 patients; NA McGuire has 9 patients; NA Hicks has 10 patients; NA Garcia has 10 patients; NA James has 14 patients, and NA Davis has 7 patients. What is the average number of patients per nursing assistant?
- **a.** 7
- **b.** 8
- **c.** 9
- **d.** 10

26. (25 + 17)(64 – 49) is equal to
  a. 57.
  b. 630.
  c. 570.
  d. 63.

27. What percentage of 18,000 is 234?
  a. 1,300%
  b. 130%
  c. 13%
  d. 1.3%

28. How many minutes are in $7\frac{1}{6}$ hours?
  a. 430 minutes
  b. 2,580 minutes
  c. 4,300 minutes
  d. 258 minutes

29. 72.687 + 145.29 is equal to
  a. 87.216.
  b. 217.977.
  c. 217.877.
  d. 882.16.

30. 12(84 – 5) – (3 × 54) is equal to
  a. 54,000.
  b. 841.
  c. 796.
  d. 786.

31. 400 × 76 is equal to
  a. 52,000.
  b. 30,100.
  c. 30,400.
  d. 20,400.

32. 6.35 × 5 is equal to
  a. 31.75.
  b. 30.75.
  c. 3.175.
  d. 317.5.

33. 2,273 × 4 is equal to
  a. 9,092.
  b. 8,982.
  c. 8,892.
  d. 8,882.

34. 52,830 ÷ 9 is equal to
  a. 5,870.
  b. 5,826.
  c. 5,871.
  d. 5,981.

35. 703 × 365 is equal to
  a. 67,595.
  b. 255,695.
  c. 256,595.
  d. 263,595.

36. $4\frac{1}{5} + 1\frac{2}{5} + 3\frac{3}{10}$ is equal to
  a. $9\frac{1}{10}$.
  b. $8\frac{9}{10}$.
  c. $8\frac{4}{5}$.
  d. $8\frac{6}{15}$.

37. 62,035 ÷ 5 is equal to
  a. 1,247.
  b. 12,470.
  c. 13,610.
  d. 12,407.

38. $76\frac{1}{2} + 11\frac{5}{6}$ is equal to
  a. $87\frac{1}{2}$.
  b. $88\frac{1}{3}$.
  c. $88\frac{5}{6}$.
  d. $89\frac{1}{6}$.

39. 5.9 – 4.166 is equal to
a. 1.844.
b. 1.843.
c. 1.744.
d. 1.734.

40. $30 \div 2\frac{1}{2}$ is equal to
a. $\frac{1}{15}$.
b. 12.
c. 15.
d. 75.

41. 172×0.56 is equal to
a. 9.632.
b. 96.32.
c. 963.2.
d. 0.9632.

42. $7{,}400 \div 74$ is equal to
a. 1.
b. 10.
c. 100.
d. 1,000.

43. $(-\frac{3}{10}) \div (-\frac{1}{5})$ is equal to
a. $1\frac{1}{2}$.
b. $-\frac{2}{3}$.
c. $-\frac{3}{50}$.
d. $\frac{3}{50}$.

44. 35% of what number is equal to 14?
a. 4
b. 40
c. 49
d. 400

45. A piece of gauze 3 feet 4 inches long was divided into 5 equal parts. How long was each part?
a. 1 foot 2 inches
b. 10 inches
c. 8 inches
d. 6 inches

46. What is 0.716 rounded to the nearest tenth?
a. 0.7
b. 0.8
c. 0.72
d. 1.0

47. Which of these has a 9 in the thousandths place?
a. 3.0095
b. 3.0905
c. 3.9005
d. 3.0059

48. Out of 100 shoppers polled, 80 said they buy fresh fruit every week. How many shoppers out of 30,000 could be expected to buy fresh fruit every week?
a. 2,400
b. 6,000
c. 22,000
d. 24,000

49. Which of the following means $5n + 7 = 17$?
a. 7 more than 5 times a number is 17.
b. 5 more than 7 times a number is 17.
c. 7 less than 5 times a number is 17.
d. 12 times a number is 17.

50. What is the value of y when $x = 3$ and $y = 5 + 4x$?
a. 6
b. 9
c. 12
d. 17

▶ Section 4: General Science

There are 50 questions in this section. You have 45 minutes to complete this section.

1. The innermost layer of Earth is
a. magnetically inert.
b. an iron core.
c. not known.
d. a plastic mantle.

2. When did the Earth form?
a. 4.6 billion years ago
b. 3.5 billion years ago
c. 4.6 hundred million years ago
d. 3.5 hundred million years ago

3. The lithosphere is
a. relatively light and deep.
b. relatively light and uppermost.
c. relatively heavy and deep.
d. relatively heavy and uppermost.

4. Mountains are parts of Earth's
a. mantle.
b. crust.
c. aesthenosphere.
d. troposphere.

5. The average depth of the ocean is about
a. 0.5 km.
b. 10 km.
c. 2 km.
d. 4 km.

6. The Earth's mantle
a. is between the crust and the core.
b. is under the core and the crust.
c. is heavier than the core.
d. contains both crust and core.

7. Most of the rock at Earth's surface (in other words, the rock that we see) is
a. sedimentary.
b. metamorphic.
c. igneous.
d. bedrock.

8. On the Mohs Scale of Hardness, diamond has a hardness of
a. 10.
b. 1.
c. 100.
d. 0.0001.

9. Slate is a dark, metamorphic rock whose sedimentary precursor was
a. limestone.
b. shale.
c. granite.
d. mica.

10. What kind of rock is granite?
a. sedimentary
b. metamorphic
c. igneous
d. mantle

11. Which is NOT a kind of sedimentary rock?
a. limestone
b. basalt
c. shale
d. sandstone

12. How long does it take the global atmosphere to circulate?
a. one day
b. one year
c. one decade
d. one century

13. What ultimately drives the circulation of the atmosphere and ocean?
a. biosphere
b. Sun
c. volcanism
d. lithosphere

14. The atmospheres of Venus and Mars, unlike Earth's, are mostly what gas?
a. carbon dioxide
b. oxygen
c. nitrogen
d. argon

15. The timescale for the entire ocean to mix is about
a. one year.
b. one decade.
c. one thousand years.
d. one hundred thousand years.

16. Which does life affect least?
a. biosphere
b. atmosphere
c. hydrosphere
d. lithosphere

17. Soil is thickest, generally, where
a. vegetation is densest.
b. climate is coldest.
c. vegetation is hardiest.
d. climate is wettest.

18. Today, we have classified about 270,000 species of vascular plants. Which of these groups have an even larger number of species already described?
a. insects
b. fungi
c. viruses
d. mollusks

19. A tropical entomologist wants to know how many species of insects still remain to be discovered, especially in the tropical rain forests. Suppose the entomologist comes up with a number that 100 species of insect are specialized to just the canopy of a particular species of tropical tree. Also assume that half the species of insects that are specialized to each tree species live in the canopy and half live underground in and around the roots of that species. How many total species of insects are specialized to that species of tree?
a. 50
b. 100
c. 200
d. 400

20. Which biome has the thickest soils that are hugely abundant in organic matter, because decomposition is so slow?
a. tropical rain forests
b. tundra
c. tropical dry forests
d. chaparral

21. In which biome are the solar collecting organs of the net primary producers particularly tough with the chemical called lignin?
a. tundra
b. tropical dry forest
c. deciduous forest
d. boreal forest

22. Which of the following is true in biological classification?
a. Family is equal to genus.
b. Genus has many families.
c. Genus is equal to species.
d. Genus has many species.

23. What is the theory called that MacArthur and Wilson pioneered in the 1960s that has proven useful in analyzing species numbers on relatively isolated areas of land types?
- **a.** continental drift
- **b.** island biogeography
- **c.** evolutionary ecology
- **d.** biodiversity

24. The major theoretical question with regard to the widespread prevalence of sexual reproduction in the animal kingdom is:
- **a.** How are genes put into sperm and egg?
- **b.** What good are males?
- **c.** Why are there no asexually reproducing mammals?
- **d.** What benefits come from larger males?

25. The special type of cell division that creates sex cells with half the number of chromosomes (and thus genes) from an individual male or female in a sexual species is called
- **a.** mitosis.
- **b.** symbiosis.
- **c.** parthenogenesis.
- **d.** meiosis.

26. The Northern spotted owl is protected because it requires the old growth forests of the Pacific northwest. It therefore is an example of a(n)
- **a.** umbrella species.
- **b.** invasive species.
- **c.** keystone species.
- **d.** extinct species.

27. What is an invasive species?
- **a.** a nonnative species that is introduced from elsewhere and spreads
- **b.** a native species that suddenly booms in population, threatening the other native species
- **c.** an endemic species that suddenly booms in population, threatening the native species
- **d.** an endemic species that is introduced from elsewhere and spreads

28. When you eat, you take in "embodied energy." What exactly has become embodied?
- **a.** carbon dioxide
- **b.** sunlight
- **c.** oxygen
- **d.** infrared

29. The functional role that bacteria play in the recycling of elements in the ocean is the equivalent to the role played on land by
- **a.** leaf litter.
- **b.** worms.
- **c.** root nodules.
- **d.** soil bacteria.

30. Which is not larger than a community?
- **a.** ecosystem
- **b.** population
- **c.** biome
- **d.** species

31. The limit to a population of a species in a community, determined by environmental conditions or species interactions, is called the
- **a.** ultimate yield.
- **b.** maximum sustainable yield.
- **c.** carrying capacity.
- **d.** deadlock number.

32. A form of marine protein that is increasing in supply is from
- **a.** aquaculture.
- **b.** upwelling zones.
- **c.** pelagic fishing.
- **d.** benthic fishing.

33. In addition to performing photosynthesis, plants, in one of their metabolic activities, perform respiration for an internal function. They do this when
- **a.** animals eat them.
- **b.** capturing sunlight.
- **c.** creating photosynthesized molecules.
- **d.** building other molecules subsequent to simple sugars.

34. Two gases that contain carbon and are released by bacteria are
- **a.** sulfuric acid and methane.
- **b.** carbon dioxide and methane.
- **c.** sulfuric acid and water.
- **d.** water and carbon dioxide.

35. Bacteria that live in nodules attached to the roots of certain plants perform the chemical transformation called
- **a.** denitrification.
- **b.** ammoniafication.
- **c.** nitrification.
- **d.** nitrogen fixation.

36. Which contains nitrogen?
- **a.** carbohydrate
- **b.** chlorophyll
- **c.** lipid
- **d.** protein

37. The main supply of phosphorus to the ocean (and thus to marine life in the ocean) is as phosphate ions, via
- **a.** wind.
- **b.** undersea volcanoes.
- **c.** rain.
- **d.** rivers.

38. From most to least, in terms of mass, the four most abundant elements in the human body are
- **a.** H, C, Fe, P.
- **b.** H, C, P, Fe.
- **c.** C, H, P, Fe.
- **d.** C, P, Fe, H.

39. Which is NOT a macronutrient?
- **a.** copper
- **b.** magnesium
- **c.** nitrogen
- **d.** sulfur

40. During the hunting and gathering stage of human history, prior to agriculture, the global population was about
- **a.** 10 thousand.
- **b.** 10 billion.
- **c.** 100 thousand.
- **d.** 10 million.

41. What is the global population growth rate?
- **a.** about the population of New York City per year
- **b.** about the population of Canada per year
- **c.** about $\frac{1}{3}$ of the United States population per year
- **d.** about $\frac{1}{10}$ of the world population per year

42. The fraction of the over-65 segment of the population is
a. growing in the United States and in Europe.
b. growing in the United States but shrinking in China.
c. shrinking in the United States but growing in China.
d. shrinking in the United States and shrinking globally.

43. The remaining land that can be converted to agriculture might not be as good as the land already employed for agriculture, because
a. erosion from irrigation has already taken a toll.
b. its soils are less rich.
c. it is closer to the poles.
d. it would be reclaimed from former urbanized land.

44. The urbanized area of the world is
a. about 1%.
b. shrinking as people move to dense cities.
c. about equal to the tundra biome.
d. about 10%.

45. Considering our atmosphere, carbon dioxide is
a. an abundant gas.
b. a greenhouse gas.
c. a gas more abundant than argon.
d. a gas with no traces of energy interactions.

46. The burning of a fossil fuel does not create
a. greenhouse gases.
b. stratospheric ozone.
c. carbon dioxide.
d. acid rain.

47. Methane in Earth's atmosphere, like CO_2, is a greenhouse gas. A greenhouse gas
a. absorbs shortwave radiation and is transparent to long-wave radiation.
b. absorbs shortwave radiation and reflects long-wave radiation.
c. absorbs longwave radiation and is transparent to short-wave radiation.
d. absorbs longwave radiation and reflects short-wave radiation.

48. The chemical formula for ozone is
a. O.
b. O_2.
c. O_3.
d. O_4.

49. Nitrates and sulfates in Earth's atmosphere create
a. polar melting.
b. acid rain.
c. a greenhouse effect.
d. equilibrium clouds.

50. The most deaths annually from poisoning come from
a. carbon monoxide poisoning.
b. carbon trioxide poisoning.
c. ozone poisoning.
d. hydroxide poisoning.

► Section 5: Biology

There are 50 questions in this section. You have 45 minutes to complete this section.

1. Which of the following vitamins prevents scurvy, aids in the production of collagen, and may boost the immune system?
a. vitamin K
b. vitamin C
c. vitamin A
d. vitamin D

2. What is another term for the meat preservatives that contain the NO_2^- ion?
a. nitrites
b. nitrates
c. sodium chloride
d. sodium hydrochloride

3. Which of the following actions is controlled by smooth muscles?
a. running
b. heart beat
c. peristalsis
d. movement of bones and joints

4. The resting potential of a neuron is
a. –70 m V.
b. +70 m V.
c. –50 m V.
d. 0 m V.

5. An important function of a plant's root system is to
a. produce glucose through photosysnthesis.
b. break down organic compounds.
c. release carbon dioxide.
d. absorb minerals and water from the soil.

6. Carbohydrates are much better foods for quick energy than fats because they
a. are digested more easily and absorbed more quickly.
b. supply essential amino acids, which provide energy.
c. are high in both protein and iron.
d. carry oxygen to the blood.

7. The function of a leukocyte, or white blood cell, is to
a. carry oxygen to the blood.
b. produce hemoglobin.
c. protect the body against infection.
d. help in the clotting of blood.

8. The process that yields four gametes, each containing half the chromosome number of the parent cell, is
a. morphogenesis.
b. mitosis.
c. metamorphosis.
d. meiosis.

9. What are the two kinds of chambers of the heart, and how are they different from one another?
a. A superior vena cava pumps blood to areas above the heart, and an inferior vena cava pumps blood to the lower body.
b. A superior vena cava pumps blood to the lower body, and an inferior vena cava pumps blood to areas above the heart.
c. An atrium pumps blood away from the heart, and a ventricle receives blood coming from the heart.
d. An atrium receives blood coming into the heart, and a ventricle pumps blood away from the heart.

10. An aneurysm is best described as a
a. weak spot that swells in a main artery.
b. coronary heart attack.
c. buildup of fatty deposits.
d. calcium deposit in the wall of an artery.

11. Which of the following groups of organisms produce flowers?
a. angiosperms
b. mosses
c. gymnosperms
d. fungi

12. Which of the following is NOT an effect of the hormone adrenaline?
a. enhancement of the effects of sympathetic nerves
b. decrease in blood sugar
c. increase in the heartbeat rate
d. inhibition of movement of smooth muscles in the stomach and intestines

13. A disease related to the thyroid gland is
a. diabetes mellitus.
b. Addison's disease.
c. rickets.
d. goiter.

14. To which specialist would a patient with a suspected tumor most likely be referred?
a. an oncologist
b. a urologist
c. a podiatrist
d. a cardiologist

15. All of the following bones are found in a human leg EXCEPT the
a. fibula.
b. ulna.
c. patella.
d. femur.

16. Which of the following parts of the brain controls breathing rates?
a. the medulla oblongata
b. the cerebellum
c. the thalamus
d. the temporal lobe

17. If a DNA helix has this strand, ACTGCCAT, what is the base sequence of its complementary strand?
a. CTGATTCG
b. TGACGGTA
c. ATGGCAGT
d. GCTTAGTC

18. Which of the following is an organelle?
a. the spleen
b. a neuron
c. a mitochondrion
d. fibrin

19. Which of the following best defines an antigen?
a. a chemical that prevents blood clotting
b. a chemical extracted from a living microbe
c. an antibody that attaches itself to a toxin and makes the toxin harmless
d. a substance that stimulates the production of antibodies

20. Cell membranes generally have which of the following structures?
a. phospholipid bilayer
b. amino acid monolayer
c. aminopeptide bilayer
d. phosphopeptide monolayer

21. Which of the following is a vertebrate?
a. a sponge
b. a starfish
c. an octopus
d. a snake

22. In genetics, what kind of diagram indicates all of the possible genotypes in the F_2 generation of a Mendelian cross?
a. Punnett square
b. flow chart
c. periodic table
d. test square

23. Which of the following is the function of a ligament?
a. to connect bones together
b. to connect muscles together
c. to attach muscle to bone
d. to serve as a cushion between vertebrae

24. Which of the following plants lacks a vascular system?
a. a moss
b. a fern
c. a fir tree
d. a peanut plant

25. An energy-rich molecule found in cells is
a. adrenaline.
b. adenosine triphosphate.
c. acetylcholine.
d. amino acids.

26. What is another name for adrenaline?
a. norepinephrine
b. epinephrine
c. acetylcholine
d. dopamine

27. Which of the following is an abiotic factor in the life of a zebra?
a. grasses
b. trees
c. water
d. lions

28. When a plant is placed near a sunny window, the plant's stem grows toward the light. This is an example of
a. positive tropism.
b. negative tropism.
c. germination.
d. transpiration.

29. A group of individuals that belong to the same species and inhabit a particular geographic area is called
a. a community.
b. an ecosystem.
c. a population.
d. a kingdom.

30. Which of the following is NOT a biome?
a. a tundra
b. a mountain
c. a desert
d. a savanna

31. When a tapeworm lives in the intestines of a cow, this is an example of
a. commensalism.
b. parasitism.
c. mutualism.
d. succession.

32. Which of the following structures prevents rupture of the tympanic membrane when a person changes altitude?
a. the cochlea
b. the ossicles
c. the Eustachian tube
d. the pinna

33. An osteocyte is a
a. muscle cell.
b. blood cell.
c. nerve cell.
d. bone cell.

34. What is a name for the process of acquiring nutrients when animals such as plankton strain small particles of food from the surrounding water?
a. filter feeding
b. scavenging
c. rumination
d. herbivory

35. In the scientific name for the emperor penguin, *Aptenodytes forsteri*, the word *Aptenodytes* indicates the
a. phylum.
b. genus.
c. species.
d. order.

36. Which of the following substances is NOT an enzyme?
a. lactase
b. lactose
c. sucrase
d. amylase

37. In vertebrates, which of the following is a section of the brainstem?
a. the frontal lobe
b. the cerebrum
c. the medulla oblongata
d. the cerebellum

38. A chemical signal emitted by one animal to stimulate a specific response in another animal of the same species is called
a. a hormone.
b. a pheromone.
c. an antigen.
d. a receptor.

39. In messenger RNA, a codon contains how many nucleotides?
a. one
b. two
c. three
d. four

40. Which of the following is another word for the digits in the hands and feet of vertebrates?
a. carpals
b. tarsals
c. phalanges
d. metacarpals

41. What is the primary purpose of anticoagulants?
a. to cause amnesia
b. to paralyze the muscles
c. to prevent the blood from clotting
d. to prevent the heart from stopping

42. What are the blood vessels that carry blood toward the heart?
a. arteries
b. veins
c. capillaries
d. arterioles

43. A human embryo will be female if the
a. mother's egg contributes an X chromosome.
b. mother's egg contributes a Y chromosome.
c. father's sperm contributes an X chromosome.
d. father's sperm contributes a Y chromosome.

44. What is the term for the skeleton of soft-bodied animals such as mollusks and annelid worms?
a. internal skeleton
b. hydrostatic skeleton
c. exoskeleton
d. external skeleton

45. In warm-blooded animals, shivering is an aspect of
a. thermoregulation.
b. freezing.
c. osmoregulation.
d. hibernation.

46. Which of the following is the region between two nerve cells across which electronic impulses are transmitted?
a. neuron
b. myelin sheath
c. synapse
d. axon

47. When egg cells are created and grow in an animal ovary, the process is called
a. oogenesis.
b. oocyte.
c. oogonia.
d. ova.

48. All of the following are examples of asexual reproduction EXCEPT
a. budding.
b. parthenogenesis.
c. vegetative propagation.
d. *in vivo* fertilization.

49. In humans, the ossicles, utricle, and cochlea are all part of which organ?
a. the stomach
b. the heart
c. the ear
d. the brain

50. Which of the following drugs is NOT a stimulant?
a. cocaine
b. nicotine
c. alcohol
d. amphetamines

► Section 6: Chemistry

There are 50 questions in this section. Use the periodic table on this page when necessary to help you answer the questions. You have 45 minutes to complete this section.

IA	IIA	IIIB	IVB	VB	VIB	VIIB	VIIIB			IB	IIB	IIIA	IVA	VA	VIA	VIIA	VIIIA
1 **H** 1.00794																1 **H** 1.00794	2 **He** 4.002602
3 **Li** 6.941	4 **Be** 9.012182											5 **B** 10.811	6 **C** 12.0107	7 **N** 14.00674	8 **O** 15.9994	9 **F** 18.9984032	10 **Ne** 20.1797
11 **Na** 22.989770	12 **Mg** 24.3050											13 **A1** 26.981538	14 **Si** 28.0855	15 **P** 30.973761	16 **S** 32.066	17 **Cl** 35.4527	18 **Ar** 39.948
19 **K** 39.0983	20 **Ca** 40.078	21 **Sc** 44.955910	22 **Ti** 47.867	23 **V** 50.9415	24 **Cr** 51.9961	25 **Mn** 54.938049	26 **Fe** 55.845	27 **Co** 58.933200	28 **Ni** 58.6934	29 **Cu** 63.546	30 **Zn** 65.39	31 **Ga** 69.723	32 **Ge** 72.61	33 **As** 74.92160	34 **Se** 78.96	35 **Br** 79.904	36 **Kr** 83.80
37 **Rb** 85.4678	38 **Sr** 87.62	39 **Y** 88.90585	40 **Zr** 91.224	41 **Nb** 92.90638	42 **Mo** 95.94	43 **Tc** (98)	44 **Ru** 101.07	45 **Rh** 102.90550	46 **Pd** 106.42	47 **Ag** 107.8682	48 **Cd** 112.411	49 **In** 114.818	50 **Sn** 118.710	51 **Sb** 121.760	52 **Te** 127.60	53 **I** 126.90447	54 **Xe** 131.29
55 **Cs** 132.90545	56 **Ba** 137.327	57 **La*** 138.9055	72 **Hf** 178.49	73 **Ta** 180.9479	74 **W** 183.84	75 **Re** 186.207	76 **Os** 190.23	77 **Ir** 192.217	78 **Pt** 195.078	79 **Au** 196.96655	80 **Hg** 200.59	81 **Tl** 204.3833	82 **Pb** 207.2	83 **Bi** 208.98038	84 **Po** (209)	85 **At** (210)	86 **Rn** (222)
87 **Fr** (223)	88 **Ra** (226)	89 **Ac**** (227)	104 **Rf** (261)	105 **Db** (262)	106 **Sg** (263)	107 **Bh** (262)	108 **Hs** (265)	109 **Mt** (266)	110 **Ds** (269)	111 **Uuu** (272)	112 **Uub** (277)		114 **Uug** (289) (287)		116 **Uuh** (289)		118 **Uuo** (293)

* **Lanthanide series**	58 **Ce** 140.116	59 **Pr** 140.90765	60 **Nd** 144.24	61 **Pm** (145)	62 **Sm** 150.36	63 **Eu** 151.964	64 **Gd** 157.25	65 **Tb** 158.92534	66 **Dy** 162.50	67 **Ho** 164.93032	68 **Er** 167.26	69 **Tm** 168.93421	70 **Yb** 173.04	71 **Lu** 174.967
** **Actinide series**	90 **Th** 232.0381	91 **Pa** 231.03588	92 **U** 238.0289	93 **Np** (237)	94 **Pu** (244)	95 **Am** (243)	96 **Cm** (247)	97 **Bk** (247)	98 **Cf** (251)	99 **Es** (252)	100 **Fm** (257)	101 **Md** (258)	102 **No** (259)	103 **Lr** (262)

1. Give the number of protons, neutrons, and electrons of this isotope of oxygen: ${}_8O^{17}$

a. 8 protons, 8 neutrons, 17 electrons
b. 8 protons, 8 neutrons, 9 electrons
c. 8 protons, 9 neutrons, 8 electrons
d. 8 protons, 17 neutrons, 8 electrons

2. What are the spectator ions in the following equation?
$Ca(NO_3)_2$ (aq) + 2KCl (aq) ➔ $CaCl_2$ (sol) + $2KNO_3$ (aq)

a. Ca^{2+} (aq), $2NO_3^-$ (aq), $2K^+$(aq), $2Cl^-$(aq)
b. Ca^{2+} (aq), $2NO_3^-$ (aq)
c. Ca^{2+} (aq), $2K^+$ (aq), $2Cl^-$ (aq)
d. $2NO_3^-$ (aq), $2K^+$ (aq)

3. What are the products of the following equation?
sodium chloride (aq) + lead(II) nitrate (aq) ➔

a. sodium nitrate + lead(II) chloride
b. sodium + chloride
c. sodium + chloride + lead(II) + nitrate
d. sodium(II) nitrate + lead chloride

4. What is the net ionic equation of the following transformations?
$Ca(NO_3)_2$ (aq) + 2KCl (aq) ➔ $CaCl_2$ (sol) + $2KNO_3$ (aq)

a. $2NO_3^-$ (aq) + $2K^+$ (aq) ➔ $2KNO_3$ (aq)
b. Ca^{2+} (aq) + $2Cl^-$ (aq) ➔ $CaCl_2$ (sol)
c. Ca^{2+} (aq) + $2NO_3^-$ (aq) + $2K^+$ (aq) + $2Cl^-$ (aq) ➔ $CaCl_2$ (sol) + $2K^+$ (aq) + $2NO_3^-$ (aq)
d. Ca^{2+} (aq) +$2NO_3^-$ (aq) + $2K^+$ (aq)+$2Cl^-$ (aq) ➔ Ca^{2+} (aq)+$2Cl^-$ (aq)+$2K^+$ (aq)+$2NO_3^-$ (aq)

5. Complete the following precipitation reaction knowing that nitrate ions remain in solution:
$Hg_2(NO_3)_2$ (aq) + KI (aq) ➔ ______ + ______

a. Hg_2I_2 (sol) + $2K^+$ (aq) + $2(NO_3)^-$ (aq)
b. Hg_2I_2 (sol) + $2KNO_3$ (sol)
c. Hg_2^{2+} (aq) + $2(NO_3)^-$ (aq) + $2K^+$ (aq) + $2(NO_3)^-$ (aq)
d. Hg_2I_2 (aq) + $2K^+$ (aq) + $2(NO_3)^-$ (aq)

6. Identify the oxidizing agent and the reducing agent in the following reaction:
$8NH_3$ (g) + $6NO_2$ (g) ➔ $7N_2$ (g) + $12H_2O$ (l)

a. oxidizing agent: $7N_2$ (g), reducing agent: $12H_2O$ (l)
b. oxidizing agent: $8NH_2$ (g), reducing agent: $6NO_2$ (g)
c. oxidizing agent: NO_2 (g), reducing agent: NH_2 (g)
d. oxidizing agent: $6NO_2$ (g), reducing agent: $8NH_2$ (g)

7. Identify the oxidizing agent and the reducing agent in the following reaction:
$8H^+$ (aq) + $6Cl^-$ (aq) + Sn (s) + $4NO_3^-$ (aq) ➔ $SnCl_6^{2-}$ (aq) + $4NO_2$ (g) + $4H_2O$ (l)

a. oxidizing agent: $8H^+$(aq), reducing agent: Sn(s)
b. oxidizing agent: $4NO_3^-$(aq), reducing agent: Sn(s) (g)
c. oxidizing agent: $4NO_3^-$(aq), reducing agent: $4NO_2$ (g)
d. oxidizing agent: $4NO_3^-$(aq), reducing agent: $8H^+$(aq)

8. Balance the following redox reaction:
Mg (s) + H_2O (g) ➔ $Mg(OH)_2$ (s) + H_2 (g)

a. Mg (s) + H_2O (g) ➔ $Mg(OH)_2$ (s) + H_2 (g)
b. Mg (s) + $4H_2O$ (g) ➔ $Mg(OH)_2$ (s) + H_2 (g)
c. Mg (s) + $2H_2O$ (g) ➔ $Mg(OH)_2$ (s) + H_2 (g)
d. Mg (s) + H_2O (g) ➔ $Mg(OH)_2$ (s) + $\frac{1}{2}H_2$ (g)

9. Classify the following reaction as combination, decomposition, or single or double displacement reaction:
$Cr(NO_3)_3$ (aq) + Al (s) ➔ $Al(NO_3)_3$ (aq) + Cr (s)

a. combination
b. decomposition
c. double displacement
d. single displacement

10. Classify the following reaction as combination, decomposition, or single or double displacement reaction:
PF_3 (g) + F_2 (g) → PF_5 (g)
a. decomposition
b. combination
c. simple displacement
d. double displacement

11. Balance the following equation:
$Ba(OH)_2$(aq) + HNO_3(aq) → $Ba(NO_3)_2$(aq) + H_2O(l)
a. $Ba(OH)_2$ (aq) + 2HNO_3 (aq) → $Ba(NO_3)_2$ (aq) + 2H_2O (l)
b. $Ba(OH)_2$ (aq) + 2HNO_3 (aq) → $Ba(NO_3)_2$ (aq) + 4H_2O (l)
c. $Ba(OH)_2$ (aq) + 2HNO_3 (aq) → $Ba(NO_3)_2$ (aq) + H_2O (l)
d. $Ba(OH)_2$ (aq) + HNO_3 (aq) → $Ba(NO_3)_2$ (aq) + H_2O (l)

12. Which reactant is oxidized and which is reduced in the following reacton?
Si (s) + 2Cl_2 (g) → $SiCl_4$ (l)
a. oxidized: 2Cl_2 (g), reduced: Si (s)
b. oxidized: Si (s), reduced: 2Cl_2 (g)
c. oxidized: 2Cl_2 (g), reduced: $SiCl_4$ (l)
d. oxidized: $SiCl_4$ (l), reduced: Si (s)

13. Which reactant is oxidized and which is reduced in the following reacton?
C_2H_4 (g) + 3O_2 (g) → 2CO_2 (g) + 2H_2O (g)
a. oxidized: C_2H_4 (g), reduced: 3O_2 (g)
b. oxidized: C_2H_4 (g), reduced: 2H_2O (g)
c. oxidized: C_2H_4 (g), reduced: 2CO_2 (g)
d. oxidized: 2CO_2 (g), reduced: C_2H_4 (g)

14. Which one of the following compounds is a nonelectrolyte when dissolved in water?
a. KOH
b. NH_3
c. NaBr
d. $CaCl_2$

15. Which of the following solutions will have the highest electrical conductivity?
a. 0.1M $AlCl_3$
b. 0.15M $SrBr_2$
c. 0.2M NaBr
d. 0.25M $Mg(NO_3)_2$

16. A precipitate will form when an aqueous solution of $Ba(NO_3)_2$ is added to an aqueous solution of Na_2SO_4. How many moles of sodium sulfate are required to produce 10.0 g of the precipitate?
a. 1 mole
b. 10.0 mole
c. 0.04 mole
d. 0.4 mole

17. Which of the following is an element ?
A) NO B) Ca C) Na D) Xe
a. A, B, and C
b. B, C, and D
c. A and D
d. B and C

18. Which of the following is a compound?
A) NO B) Ca C) Na D) Xe
a. A, B, and C
b. A and C
c. C and D
d. A

19. What ions form NaCl?
a. Na and Cl
b. Na^+ and Cl^+
c. Na^+ and Cl^-
d. Na^- and Cl^+

20. The density of acetic acid is 1.05 g/mL. What is the volume of 275 g of acetic acid?
a. 275 mL
b. ~262 mL
c. ~100 mL
d. 22.4 L

21. The correct formula for converting Fahrenheit to Celsius is given by: $°\,C = \frac{5}{9}(°\,F - 32)$. Convert 72° F into temperature in Celsius.
a. 72° C
b. 40° C
c. 25° C
d. 22.2° C

22. Chemical reactions are often studied at 25° C. What is this temperature in Fahrenheit?
a. 47° F
b. 77° F
c. 25° F
d. 57° F

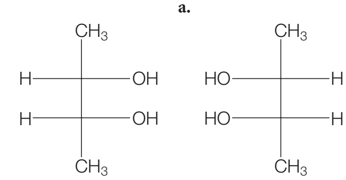
23. Convert 4.50×10^2 nm into ______ m.
a. 4.50×10^2 m
b. 4.50×10^{11} m
c. 4.50×10^{-7} m
d. 4.50×10^8 m

24. Convert 4.50×10^2 nm into ______ pm.
a. 4.50×10^2 pm
b. 4.50×10^{-2} pm
c. 4.50×10^{11} pm
d. 4.50×10^5 pm

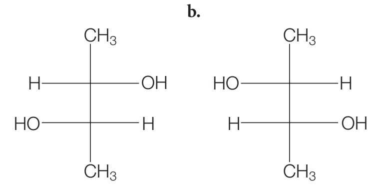
25. Find all the enantiomeric pairs (i.e. mirror-image) among the following sets of stereoisomers (a, b, c, d, e, f, g, h).
a. a, b, c, e, h
b. b, c, d, h
c. a, c, f
d. d, e, g

26. Find all the diastereomeric pairs among the preceding sets (Pb 25) of stereoisomers?
a. b, d, g
b. b, d
c. g
d. h

a.



b.



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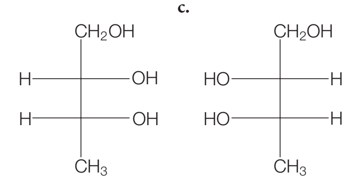

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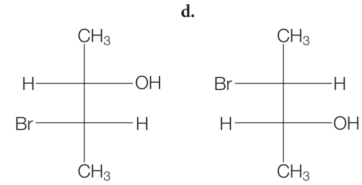

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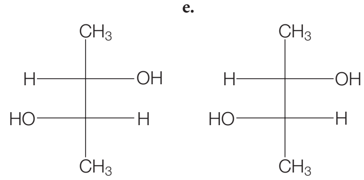

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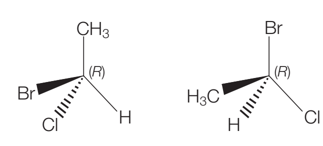

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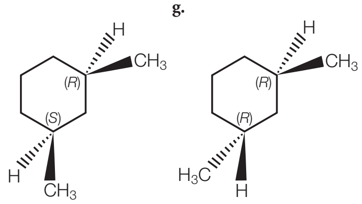

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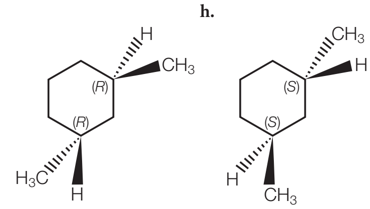
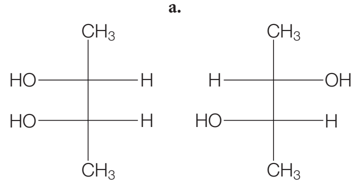


27. Write the correct answer (correct number of significant figures) for the following calculation:
$3.33 \times 10^{-5} + 8.13 \times 10^{-7}$
a. 3.41×10^{-5}
b. 11.46×10^{-7}
c. 11.46×10^{-5}
d. 11.46×10^{-12}

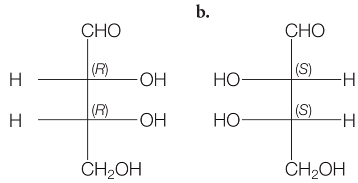
28. Express 0.05620 in exponential notation.
a. 0.057×10^{-3}
b. 57×10^{-3}
c. 563×10^{-4}
d. 5.62×10^{-2}

29. Which pairs of stereoisomers represent diastereomers?

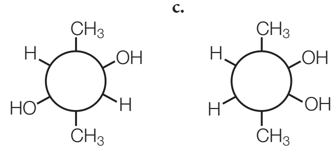
a.



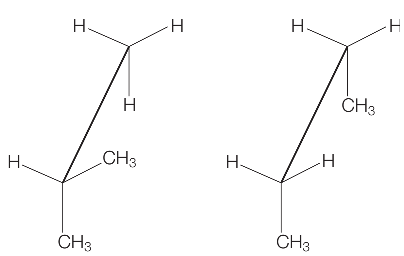
b.



c.



d.



a. a, b
b. a, c
c. a, d
d. a

30. Write the correct answer (correct number of significant figures) for the following calculation:
$(27 + 93) \times 5.1558$
a. 618.697
b. 618.7
c. 619
d. 618.6970

31. A balloon is filled with H_2 gas to a volume of 2.60 L at 27° C. The balloon is then placed in liquid nitrogen until its temperature reaches –125° C. What is the volume of the cooled balloon?
a. 2.0 L
b. 3.0 L
c. 3.5 L
d. 2.5 L

32. How would you characterize the following reaction?
$Zn^{2+} + 2e^- \rightarrow Zn$
a. an oxidation
b. a reduction
c. neither an oxidation nor a reduction
d. a precipitation

33. Identify the following as an oxidation, a reduction, a decomposition, or a dismutation reaction.
$Cl_2 + 2e^- \rightarrow 2Cl^-$
a. a reduction
b. an oxidation
c. a decomposition
d. a dismutation

34. When linoleic acid, an unsaturated fatty acid, reacts with hydrogen, it forms a saturated fatty acid.
$C_{18}H_{32}O_2 + 2H_2 \rightarrow C_{18}H_{36}O_2$
Is linoleic acid oxidized, reduced, or hydrogenated in the reaction?
a. oxidized
b. reduced
c. hydrogenated
d. **b** and **c** above

35. When linoleic acid, an unsaturated fatty acid, reacts with hydrogen, it forms a saturated fatty acid.
$C_{18}H_{32}O_2 + 2H_2 \rightarrow C_{18}H_{36}O_2$
How many moles of hydrogen H_2 are required to hydrogenate 5.0g of unsaturated linoleic acid?
a. 1 mol
b. 10 mol
c. $\frac{1}{5}$ mol
d. $\frac{1}{28}$ mol

36. Valence electrons are those in the outermost shell of an atom. Indicate the number of valence electrons for the following atom (using the periodic table):
Sc (Scandium)
a. 1
b. 2
c. 4
d. 3

37. What are the names of orbitals in the following atomic shell: 2nd shell
a. 1s, 2s
b. 2s, 2p
c. s, p, d
d. p_x, p_y, p_z

38. What are the names of orbitals in the following atomic shell: 3rd shell
a. 1s, 2s, 3s
b. s, p, d
c. 3s, 3p, 3d
d. 1s, 2p, 3d

39. Knowing the *group* of an atom in the periodic table, how would you find the number of *valence electron(s)* for that atom?
a. The group number is equal to number of valence electron(s) for that atom.
b. The group number is equal to the number of bond(s) an atom can form.
c. The group number indicates the number of orbitals for an atom.
d. The group number is equal to the number of shells in the atom.

40. Knowing the *period* of an atom in the periodic table, what could you say about the number of *electron shell(s)* of that atom ?
a. The period number indicates the number of bond(s) an atom can form.
b. The period number is equal to the number of valence electron(s) in that atom.
c. The period number is equal to the number of electron shell(s) in that atom.
d. The period number changes from left to right of the periodic table.

41. When a chemical reaction occurs between two atoms, their valence electrons are reorganized so that an attractive force, called a *chemical bond*, occurs between atoms. Name the type of bond that is formed when *electrons are transferred* from one atom to another.
a. molecular bond
b. covalent bond
c. ionic bond
d. transfer bond

42. Name the type of bond that is formed when *electrons are shared* between two atoms.
a. shared bond
b. ionic bond
c. covalent bond
d. multiple bond

43. In bonding, what would happen between the electrons of K and Br?
a. transfer
b. sharing
c. none of the above
d. both transfer and sharing

44. From the periodic table, which of K and Br is larger?
a. K is larger.
b. Br is larger.
c. They are the same size.
d. We cannot know which one is larger.

45. Give the number of valence electrons for the following atom: Boron (B).
a. 5
b. 3
c. 2
d. 13

46. Form a molecule comprised of one atom of C, one atom of N, and one atom of another element so that the valence electrons are all shared, showing perfect octet around C and N.
a. HCN
b. NCN
c. CNH
d. NCO

47. Which of the following molecules is nonpolar?
a. NH_3
b. H_2O, NO_2
c. PCl_3
d. N_2

48. Write the Lewis electron dot structures for the following compound: Kitchen salt (NaCl).
a. $\text{Na}{:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{\text{Cl}}}{:}$
b. $\text{Na}{:}\text{Cl}$
c. ${:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{\text{Na}}}{:}\underset{\cdot\cdot}{\overset{\cdot\cdot}{\text{Cl}}}{:}$
d. Na-Cl

49. In a storage area where the temperature has reached 55° C, the pressure of oxygen gas in a 15.0 L steel cylinder is 965 torr. To what temperature would the gas have to be cooled to reduce the pressure to 850 torr?
a. 40° C
b. 30° C
c. 15° C
d. 50° C

50. What is the volume of 64.0 g of oxygen gas (O_2) at the standard temperature and pressure (STP) conditions?
a. 4 L
b. 2 L
c. 22.4 L
d. 44.8 L

▶ Answers

Section 1: Verbal Ability

1. a. abscessed
2. d. parallel
3. b. fundamentally
4. a. tonsillitis
5. d. excelled
6. d. guardian
7. a. accustomed
8. b. pasteurized
9. a. delirious
10. c. plead
11. a. inundated
12. c. laziness
13. b. inconspicuous
14. a. prosecuted
15. d. counterfeit
16. d. symmetrically
17. d. delaying
18. a. vacuum
19. d. accommodate
20. c. colleagues
21. d. souvenirs
22. c. marriageable
23. b. illegible
24. b. penicillin
25. c. adolescence
26. b. nuisance
27. d. no mistakes
28. c. peaceable
29. c. luxuriant
30. a. gullible
31. b. gratitude
32. c. trafficable
33. a. flies
34. b. bulletin
35. c. embassy
36. d. no mistakes
37. b. questionnaire
38. a. pungent
39. c. hygienic
40. b. illegal
41. b. corrosiveness
42. c. gymnast
43. a. woeful
44. b. wasting
45. a. panicky
46. c. craziness
47. d. no mistakes
48. a. chaise
49. a. extremely
50. b. friendly

Section 2: Reading Comprehension

1. c. The third paragraph states that immunoglobulin E is an antibody, while the fourth paragraph says that the *interaction of an allergen with two IgE molecules triggers enzymes.*

2. b. See the second paragraph: *Cells called macrophages engulf the invader* (i.e., pollen).

3. d. The fourth paragraph states that histamines (chemicals) are stored in and released from granules. The fifth paragraph says that histamines can constrict the lungs' airways.

4. a. In the fifth paragraph, anaphylactic shock is mentioned, but no symptoms are stated. To assume that lung constriction is a symptom is to read beyond the content of the passage. Basophils circulate in the blood (see the third paragraph), IL-4 is the molecule released by Thelper cells (see the second paragraph), and when mast cells emit messengers, symptoms are prolonged (see the fifth and sixth paragraphs).

5. d. The fifth paragraph says that mast cells secrete chemical messengers that recruit other cells into the tissues. As a result (according to the sixth paragraph), *some of the recently arrived cells release substances that can increase and prolong early symptoms.*

6. b. See the fourth paragraph, which states, *When the same allergen next enters the person's body, it binds to the arms of the IgE molecules protruding from the surfaces of mast cells and basophils*. Macrophages cut the allergen the first time it enters the body. The same is true for T-helper cells detecting fragments of the allergen.

7. a. The first paragraph notes that an allergic disease results from *the immune system reacting to a normally innocuous substance . . .*

8. d. The second sentence of the first paragraph states that probes record responses. The second pargraph says that electrodes *accumulate much data*.

9. c. The tone throughout the passage suggests the potential for microprobes. They can be permanently implanted, have advantages over electrodes, are promising candidates for neural prostheses, will have great accuracy, and are flexible.

10. d. According to the fifth paragraph, people who *lack* biochemicals could receive doses via prostheses. However, there is no suggestion that removing biochemicals would be viable.

11. a. The first sentence of the third paragraph says that microprobes have channels that *open the way for delivery of drugs*.

12. b. The second sentence of the sixth paragraph states that the wires *must be tethered to prevent damage to surrounding tissue*.

13. c. See the sixth paragraph, in which it is understood that long-term implantation has to rely on *satisfactory connections to the outside world*.

14. b. *Susceptible* means being *liable to be affected by something*. According to the third paragraph, some patients are genetically predisposed, or susceptible, to some diseases.

15. a. The next-to-last sentence of the second paragraph indicates that the report *advised caution in using . . . predictive tests*.

16. b. See the last sentence of the fifth paragraph, which states that *effective treatment can be started in a few hundred infants*.

17. d. The first paragraph says that the report addressed concerns about *protecting confidentiality*.

18. c. The last sentence of the fourth paragraph states that *careful pilot studies . . . need to be done first*.

19. d. See the fifth paragraph: *Newborn screening is the most common type of genetic screening today*.

20. a. According to the first sentence of the third paragraph, the new MRI *detects not water but inert gases*.

21. d. See the second sentence of the second paragraph, which states that X rays cannot provide a clear view of air passages.

22. c. See the fifth paragraph: Radio signals knock nuclei out of position, but as they are realigned, they transmit faint radio signals.

23. b. The first sentence of the third paragraph states the equivalency: nuclei are *aligned, or hyperpolarized*.

24. a. The last paragraph says that light, rather than a magnet, is used to align nuclei, suggesting that the two serve equivalent purposes in the two MRI processes.

25. c. See the last sentence of the passage. Since lesser gases lose their alignment more quickly, a shorter period of alignment would lead to poorer clarity. A higher number of aligned nuclei would theoretically lead to a better image.

26. a. The author contrasts the public's dismissal of the arcane practice of wearing garlic with its increasing acceptance of herbal remedies.

27. b. In this context, *conventional* refers to the established system of Western medicine or biomedicine.

28. d. Choice **a** is overly general and choice **b** is too negative to be inferred from the survey's findings. Choice **c** is incorrect—the author does not mention the "baby boom" age group, but that does not imply that the survey does not include it.

29. a. The statistic illustrates the popularity of alternative therapies without giving any specific information as to why.

30. d. The author states that Americans are not replacing conventional healthcare but are adding to or supplementing it with alternative care.

31. d. The shortcomings of conventional healthcare mentioned in paragraph four are the *time constraints of managed care, focus on technology, and inability to relieve the symptoms associated with chronic disease*.

32. b. The second paragraph states that *muscle atrophy can be kept largely at bay with appropriate exercise*.

33. c. According to the fifth paragraph, levels of vitamin D were elevated in drug recipients.

34. d. According to information in the third paragraph, a pressure device *does nothing to avert loss of calcium*.

35. a. The last paragraph states that high urinary calcium concentrations can cause kidney stones. Treatment that inhibits urinary discharge of calcium, such as use of alendronate, could therefore help in the treatment of kidney stones.

36. c. The last sentence of the fourth paragraph states that volunteers are given alendronate for two weeks plus three weeks.

37. b. The last sentence of the third paragraph states that 56% of "laser-first" and 70% of "medication-first" patients (over half) needed new or extra medications *to control pressure inside the eye*.

38. d. The passage focuses primarily on the effects of both laser and medication treatments. It does not advocate either method.

39. a. See the second and third sentences of the first paragraph.

40. c. The third sentence of the third paragraph states that *initial treatment with laser surgery is at least as effective as initial treatment with eyedrops*.

41. a. The second paragraph says that the patients were *newly diagnosed*.

42. c. Nowhere in the passage does the author speculate about whether teenagers can change their exercise habits.

43. c. One meaning of *sedentary* is settled; another meaning is doing or requiring much sitting. *Stationary,* defined as fixed in a course or mode, is closest in meaning.

44. d. The last sentence illustrates factors that motivate teenagers to exercise by using the results of a national survey to provide specific examples.

45. d. The passage promotes change in teenagers' exercise habits by emphasizing the benefits of exercise, the moderate amount of exercise needed to achieve benefits, and some factors that may encourage teenagers to exercise.

Section 3: Quantitative Ability

1. a. To solve this problem, you must first convert yards to inches. There are 36 inches in a yard. $36 \times 3\frac{1}{3} = 120$.

2. d. The least common denominator is 28. When the fractions are converted, the problem is $\frac{21}{28} + \frac{20}{28} = \frac{41}{28}$. When the answer is reduced, it is $1\frac{13}{28}$.

3. a. 0.97 multiplied by 100 is 97; therefore, the correct answer is 97%.

4. c. The sum of the measure of the angles in a triangle is 180 degrees; 70 degrees + 30 degrees = 100 degrees; 180 degrees – 100 degrees = 80 degrees. Therefore, angle C is 80 degrees.

5. **d.** 6^3 is equal to $6 \times 6 \times 6$, or 216.

6. **a.** The ratio of Drake's charge to Jean's charge is 3 to 4, or $\frac{3}{4}$. To find what Jean charges, you must use the proportion $\frac{3}{4} = \frac{36}{x}$, or $3x = 4 \times 36$; $4 \times 36 = 144$, which is then divided by 3 to arrive at $x = 48$.

7. **b.** To find the average time for the three baths, you must add the times for all the baths and divide by the number of baths: $20 + 17 + 14 = 51$; $51 \div 3 = 17$.

8. **c.** A percentage is a portion of 100, or $\frac{x}{100}$. The proportion here is $\frac{x}{100} = \frac{12}{50}$, or $12 \times 100 = 50x$. Divide both sides by 50 to get $x = 24\%$.

9. **d.** The area is the width times the length—in this case, 10×8, or 80 square feet.

10. **b.** Use the formula beginning with the operation in parentheses: $98 - 32 = 66$. After that, multiply 66 by $\frac{5}{9}$, first multiplying 66 by 5 to get 330; 330 divded by 9 is $36.\overline{6}$, which is rounded up to 36.7.

11. **a.** To multiply fractions, you must multiply the numerators to reach the numerator of the answer ($2 \times 3 = 6$) and multiply the denominitors to reach the denominator of the answer ($5 \times 7 = 35$), so the answer is $\frac{6}{35}$.

12. **c.** Perform the operation in parentheses first: $14 \times 7 = 98$, and then add 12 to get 110.

13. **b.** Convert the percentage to a decimal: $232 \times 0.14 = 32.48$.

14. **d.** The perimeter is the total length of all sides. In a square, all four sides are of equal length, so the perimeter is $4 + 4 + 4 + 4$, or 16.

15. **a.** Perform the operation in parentheses first, just so you will not forget to do so in the next problem (even though in this case, it doesn't matter because all the operations are multiplication): $9 \times 4 = 36$; $36 \times 12 = 432$.

16. **c.** The proportion is $\frac{12}{100} = \frac{33}{x}$, or $100 \times 33 = 12x$; $3{,}300 \div 12 = 275$; therefore, $x = 275$.

17. **c.** It is important to keep the decimal values straight. Divide as usual, and then bring the decimal point straight up into the answer in order to get 39.4.

18. **d.** Perform the operations in the order presented, from left to right; $72 + 98 = 170$; $170 - 17 = 153$.

19. **c.** The formula for finding the area of a circle is $A = \pi r^2$. First, square the radius: $13 \times 13 = 169$. Then, multiply by the approximate value of π, 3.14, to get 530.66.

20. **a.** In order to subtract fractions, you must first find the least common denominator, in this case, 40. The problem is then $\frac{35}{40} - \frac{24}{40}$, or $\frac{11}{40}$.

21. **c.** Each 9-foot wall has an area of 9×8 or 72 square feet. There are two such walls, so those two walls combined have an area of 72×2 or 144 square feet. Each 11-foot wall has an area of 11×8 or 88 square feet, and again, there are two such walls: $88 \times 2 = 176$. Finally, add 144 and 176 to get 320 square feet.

22. **b.** $195.6 \div 7.2$ yields a repeating decimal, 27.1666666 . . . , which rounded up to the nearest hundredth is 27.17.

23. **d.** 17^2 is equivalent to 17×17, which equals 289.

24. **a.** The first step is to convert 3 to a fraction, which is $\frac{3}{1}$. Divide by inverting the second fraction, making it $\frac{1}{3}$, and multiplying: $\frac{5}{8} \times \frac{1}{3} = \frac{5}{24}$.

25. **c.** To find the average, first find the total number of patients: $8 + 5 + 9 + 10 + 10 + 14 + 7 = 63$. Then, divide the number of patients by the number of nursing assistants: $63 \div 7 = 9$.

26. **b.** Perform the operations within the parentheses first: $25 + 17 = 42$; $64 - 49 = 15$; $42 \times 15 = 630$.

27. **d.** A percentage is a portion of 100, or $\frac{x}{100}$. The equation here is $\frac{x}{100} = \frac{234}{18{,}000}$, or $234 \times 100 = 18{,}000x$; $23{,}400 \div 18{,}000 = 1.3$.

28. **a.** There are 60 minutes in an hour. Multiply $60 \times 7\frac{1}{6}$ by multiplying $60 \times 7 = 420$ and $60 \times \frac{1}{6} = 10$. Then add $420 + 10$ to get 430 minutes.

29. **b.** Think of 145.29 as 145.290, and then line up the decimal points and add the numbers to get the correct answer, 217.977.

30. **d.** Perform the operations in parentheses first, left to right: 84 – 5 = 79. Now, multiply 12(79) = 948. Next, do the other parenthetical operation: 3 × 54 = 162. Now, do the final operation: 948 – 162 = 786.

31. **c.** This is a simple multiplication problem; the correct answer is 30,400.

32. **a.** The correct answer is 31.75. Not lining up the decimal points when multiplying is the most common error in this type of problem.

33. **a.** This is a simple multiplication problem. The correct answer is 9,092.

34. **a.** The correct choice is 5,870. If you got a different answer, you probably simply made an error in multiplication or subtraction.

35. **c.** The correct answer is 256,595. When multiplying three-digit numbers, you have to be careful in computation and in aligning numbers.

36. **b.** The correct answer is $8\frac{9}{10}$. Incorrect answers include adding both the numerator and the denominator and not converting fifths to tenths properly.

37. **d.** The correct answer is 12,407. If you got answer **a**, you disregarded the zero in 62,035. The other answers represent mistakes in computation.

38. **b.** The correct answer is $88\frac{1}{3}$. To work the problem, you must first convert $\frac{1}{2}$ to $\frac{3}{6}$.

39. **d.** This is a simple subtraction problem with decimals. The correct answer is 1.734.

40. **c.** The correct answer is 12. One of the most common errors is found in answer **d**, where the numbers were multiplied rather than divided.

41. **b.** The correct answer has only two decimal places: 96.32.

42. **c.** The number 74 goes into 7,400 100 times.

43. **a.** Remember that two negatives multiplied yield a positive. Invert the second fraction and multiply: $-\frac{3}{10} \times (-5) = \frac{3}{2} = 1\frac{1}{2}$.

44. **b.** To find the answer, divide 14 by 0.35 to get 40.

45. **c.** Three feet 4 inches equals 40 inches; 40 divided by 5 is 8.

46. **a.** Choice **b** is rounded up instead of down; choice **c** is rounded to the nearest hundredth; choice **d** is rounded to the nearest whole number.

47. **a.** In choice **b**, the 9 is in the hundredths place; in choice **c**, it is in the tenths place; and in choice **d**, it is in the ten thousandths place.

48. **d.** Eighty out of 100 is 80%. Eighty percent of 30,000 is 24,000.

49. **a.** The expression $5n$ means 5 times n. The addition sign before the 7 indicates the phrase *more than*.

50. **d.** Substitute 3 for x in the expression $5 + 4x$ to determine that $y = 17$.

Section 4: General Science

1. **b.** A partially molten inner core of mostly iron is at Earth's center.

2. **a.** It was 4.6 billion years ago, which we know from radioactive dating of meteorites, which all come in about that age.

3. **b.** The lithosphere has a light density and "floats" on the more dense layers of Earth that are below.

4. **b.** Mountains are within the crust of the Earth.

5. **d.** The deepest parts of the ocean are remarkably uniform in depth, from 3–5 km deep, for an average of 4 km, or about 2.5 miles.

6. **a.** The mantle is the thick zone beneath Earth's crust but not as deep as the inner core.

7. **a.** Most of Earth's surface is sedimentary rock, in other words, recycled rock. Bedrock is simply surface rock as a definition, so that answer contains no content and therefore makes no sense.

8. **a.** The hardness scale reaches a maximum at 10, the hardness of diamond.

9. **b.** Slate is metamorphosed shale.

10. **c.** Granite came from magma, so it is igneous. It might have originated from magma deep within the mantle, but it is not itself mantle rock.

11. **b.** All the rocks are classic types of sedimentary rock, except for basalt, which is an igneous rock.

12. **b.** In about one year, the entire atmosphere mixes, even between northern and southern hemispheres.

13. **b.** The energy of the Sun that falls upon the land and ocean creates difference in temperature, which drive the circulation of atmosphere and ocean.

14. **a.** Earth has only a tiny amount of the greenhouse gas, carbon dioxide. In the atmospheres of Mars and Venus, carbon dioxide is the dominant gas.

15. **c.** The mixing time for the entire world's ocean is about one thousand years.

16. **d.** Life is part of the biosphere and has profound effects on the chemistry of both air and ocean. Only the lithosphere, of rock, is relatively unaffected by life.

17. **b.** Temperature is the main determinant of bacterial activity in the soil, which decomposes organic matter. Where it is cold, bacterial activity is low, and that explains the famously thick soils of the arctic tundra, often called peat. Moisture comes into play as well, but temperature is influence number one.

18. **a.** Insects are the most species rich type of creature on Earth. In fact, most of the estimated millions of species yet to be discovered and classified are insects.

19. **c.** If 100 species live in the canopy and those are only half of the total that are specialized for that species of tree (because the other half live underground in and around the roots), then twice the number from the canopy must be the total for the tree. Twice 100 is 200.

20. **b.** Paradoxically, though tundra has a low amount of plants because of the cold, lack of sunlight, and short growing season, is has a huge amount of organic matter in its soil.

21. **d.** Boreal forests, with their evergreens of fir and pine, sport tough needles with lots of lignin to give them strength to endure the winds and freezing of winter in the very high latitudes.

22. **d.** A genus consists of many species (usually, in rare cases, a genus might only have one living species, but would have had more in the past). A family consists of many genera.

23. **b.** The theory of island biogeography was developed by studying the factors that determined the number of species on islands of various sizes.

24. **b.** What good are males? That is the major question about sex, because females in sexual species put only half their genes into offspring, in contrast to asexual species in which the females (or mother cells) put all their genes into offspring.

25. **d.** Meiosis is the process in which parent sex cells from males and females create four gametes (eggs or sperm in the case of animals) with half the genes and chromosomes of the parents. (Note that it's not a simple process of splitting in half.)

26. **a.** Preserving the owl means preserving the old growth forests and thereby all other species that require the old growth forests. Preserving the owl acts like an umbrella for many other species, protecting them all from extinction as a group.

27. **a.** A nonnative species introduced from elsewhere and that spreads is called an invasive species (also called an *introduced* or *alien species*). *Endemic* means extremely native (occurring no where else), so **c** makes no sense. Choice **b** is untrue to the definition of an invasive species and **d** simply makes no sense.

28. b. Sunlight is the energy source for photosynthesis, which becomes embodied in the organic molecules made by photosynthesis.

29. d. Both in the ocean and in the soil, bacteria recycle nutrients from their organic forms into their inorganic forms.

30. b. A community is made of populations of various species, so the population is not larger than a community.

31. c. The carrying capacity is the limit asked for in the question. Words with "yield" usually refer to the human harvesting of creatures, such as fish.

32. a. The only supply of marine protein that is growing is aquaculture, or "farms" of fish and various kinds of shellfish.

33. d. Photosynthesis creates simple sugars, but to create more complex molecules needed for their plants, plants must also perform respiration.

34. b. Bacteria (different kinds) make the gases carbon dioxide and methane as wastes from their metabolisms.

35. d. Bacteria in root nodules are the famous nitrogen fixers.

36. d. Proteins contain nitrogen, because nitrogen is a part of the amino acids from which proteins are made.

37. d. Rivers carry the most phosphorus to the sea. There is some phosphorus in the dust carried by wind, which is less than the phosphorus in rivers. Regardless, the phosphorus in dust is not in the dissolved ion form, which was asked for.

38. c. Although you wouldn't be expected to memorize numbers, it should be noted that carbon is the most abundant and iron is a micronutrient. In between these two, hydrogen is in all organic molecules, while phosphorus has specialized uses in cells. Therefore, it is logical that carbon is first, followed by hydrogen, then phosphorus, then iron.

39. a. Copper is needed by cells in only trace amounts; it is therefore not a macronutrient but a micronutrient.

40. d. Estimates place the preagricultural population at about ten million. The other answers are either definitely too little or too big.

41. c. The global growth rate of 80–90 million people per year is about one-third of the population of the United States (Actually, it's a little less than one-third, but this is by far the closest answer.)

42. a. The over-65 proportion of the population is growing everywhere, because people everywhere are living longer.

43. b. Land already used for agriculture tends to be prime land that was formerly grasslands and prairies in Europe, the United States, Russia, and China. Remaining land still convertible to agriculture includes land in the Amazon with thin soils and land in Africa with workable but still less than ideal soils.

44. a. The urbanized land use is about 1% of the world's land.

45. b. Carbon dioxide, at 370+ ppm, is less abundant than relatively scarce argon (thus, **a** and **c** cannot be true). It absorbs IR radiation (thus, **d** cannot be true). It is, in fact, a greenhouse gas.

46. b. The burning creates all those items except stratospheric ozone. Natural processes high in Earth's atmosphere creates that kind of ozone.

47. c. A greenhouse gas traps heat because it absorbs outgoing long-wave radiation and is transparent to incoming short-wave radiation.

48. c. Ozone has three oxygen atoms in a single molecule.

49. b. Acid rain comes when nitrates and sulfates in clouds fall to Earth as nitric and sulfuric acids in rainwater.

50. a. Carbon monoxide is the number one deadly killer, an odorless gas lethal in very small quantities.

Section 5: Biology

1. b. Vitamin K is important in the clotting of blood, vitamin A is important in vision, and vitamin D is important in the formation of bone.

2. a. Any salts or esters with the NO_2^- ion are called nitrites and are found in such cured meat products as bacon and hot dogs.

3. c. The other actions are controlled by skeletal muscles (choices **a** and **d**) or cardiac muscles (choice **b**).

4. a. The resting potential of a neuron is –70 millivolts (mV).

5. d. Glucose production (glycolysis) is done primarily in the leaf chloroplasts, breakdown of organic compounds is primarily done in the mitochondria, and roots do not release carbon dioxide.

6. a. Carbohydrates are digested more easily and absorbed more quickly than fats. Choice **b** is incorrect because amino acids are the building blocks of proteins. Choices **c** and **d** are not true of carbohydrates.

7. c. White blood cells protect the body against foreign invaders such as bacteria and viruses.

8. d. Meiosis results in four reproductive cells, each with half the number of chromosomes found in the parent cell. This is often confused with mitosis, the result of which is two daughter cells with the same number of chromosomes as the parent cell.

9. d. Choices **a** and **b** are incorrect because the superior and inferior vena cava are not chambers of the heart. Choice **c** is incorrect because the functions of the atrium and ventricle are reversed.

10. a. A weak spot in a main artery, such as the aorta, causes an aneurysm, or swelling.

11. a. Gymnosperms produce pine cones with seeds, not flowers; mosses are not vascular plants and do not produce flowers; fungi are not plants and produce spores from fruiting bodies, not flowers.

12. b. Adrenaline causes an increase in blood sugar by releasing stored carbohydrates. Choice **d** is incorrect because adrenaline does inhibit these muscles, even though it stimulates muscles in the spleen, hair follicles, and eyes.

13. d. Goiter is an enlargement of the thyroid gland.

14. a. Oncology is the study and treatment of tumors.

15. b. The ulna is a bone in the lower arm.

16. a. The medulla oblongata controls many involuntary responses including heart and breathing rates.

17. b. This strand has all of the correct complementary bases; the other strands are nonsense strands.

18. c. Organelles are structures within a plant or animal cell that perform specific functions. Mitochondria, present in most cells, convert food to energy. The spleen is an organ, not an organelle; it has many tissues and even more cells. A neuron is a nerve cell and not a specialized structure inside a cell. Fibrin is a protein used in blood clotting.

19. d. Antigens are chemicals recognized as foreign by the immune system. Viruses and bacteria are typically antigenic because of their structure.

20. a. Cell membranes are generally composed of phospholipids—molecules arranged in two layers with the phosphate ends pointing in towards the cell's center in one layer and to the outside environment in the other layer; the lipid ends of the molecules are sandwiched in the middle of the membrane.

21. d. The snake is the only vertebrate—that is, it is the only one of the four animals that has a backbone.

22. a. The Punnett square is a grid that represents all of the possible genotypic combinations in the F_2 generation produced by a male (gametes listed horizontally) and a female (gametes listed vertically).

23. a. Ligaments are the dense parallel bundles of collagen fibers that hold bones together at a joint.

24. a. Mosses are bryophytes, which are characterized by their lack of a vascular system.

25. b. Adrenaline is a hormone, acetylcholine is a neurotransmitter, and amino acids are the building block molecules of proteins.

26. b. Adrenaline, also known as epinephrine, is a hormone produced by the adrenal gland that prepares the body for "fight or flight" behavior.

27. c. Abiotic factors are nonliving aspects of the environment, such as water, which interact with the organisms in an ecosystem; the other choices are biotic factors.

28. a. Tropism means the growth towards or away from an external stimulus. Growth of a plant part toward the stimulus (the Sun) is a positive tropism, while growth away from the stimulus is a negative tropism.

29. c. Choice **a** is incorrect because a community includes the protists, plants, and animals living in a particular area. Choice **b** is incorrect because an ecosystem includes all the organisms in a particular area plus the abiotic factors with which they interact. Choice **d** is incorrect because a kingdom is a much broader classification than a species.

30. b. A mountain is not a biome. A biome is a major ecological community type, such as tundra, desert, savanna, taiga, rain forest, and so on.

31. b. A tapeworm is a parasite. It causes harm to its host. Commensalism is a relationship in which one organism benefits from a host but neither is harmed; mutualism is an interaction in which two organisms depend on each other.

32. c. The Eustachian tube allows the air pressure in the middle ear to remain equal to that on the outside of the tympanic membrane.

33. d. Osteocytes are living cells within the minerals of bone. *Osteo* is the combining form for *bone*.

34. a. Although much of the trapped food particles gleaned by plankton is dead matter, filter feeding is the proper term for this type of feeding.

35. b. In binomial nomenclature, the genus name (*Aptenodytes*) precedes the species name (*forsteri*).

36. b. The correct answer is lactose. Most enzymes are named according to the substance that they act on plus the suffix *-ase*. For example, choice **c** is incorrect because sucr*ase* is an enzyme that degrades sucrose.

37. c. The brainstem consists of the midbrain, the pons, and the medulla oblongata.

38. b. Pheromones are chemical signals that may be released either in a secretion or as an odor.

39. c. A codon is a triplet of nucleotides that, together during protein synthesis, usually represent a genetic code for an amino acid.

40. c. Vertebrate digits are also referred to as phalanges.

41. c. An anticoagulant is any substance that stops the blood from forming clots.

42. b. Veins carry blood in the direction of the heart.

43. c. In humans, an embryo's sex is always determined by the sperm. The egg always contributes an X chromosome, while the sperm contributes either an X (for a female) or a Y (for a male).

44. b. The hydrostatic skeleton works by muscles pressing against a fluid-filled area to produce movement. Humans have internal skeletons. Insects have exoskeletons, otherwise known as external skeletons.

45. a. In a cold environment, warm-blooded animals may shiver involuntarily in order to thermoregulate or raise their body temperature. Choice **c**, osmoregulation, is an organism's way of keeping a constant internal water level.

46. c. The junction of two nerve cells is called a synapse.

47. a. Oogenesis is the name of the process in which the ova (egg cells) are produced and grow in the ovary. Special ovarian cells called oogonia divide repeatedly to make large numbers of prospective eggs called oocytes.

48. d. Asexual reproduction occurs when a single animal alone produces genetically identical offspring. *In vivo* fertilization occurs when one animal fertilizes another internally.

49. c. The ossicles, utricle, and cochlea are all components of the human ear.

50. c. Alcohol acts as a depressant, not as a stimulant.

Section 6: Chemistry

1. c. # electrons = # protons for atomic neutrality, # neutrons = mass number – # protons.

2. d. Spectator ions (in bold in the equation below) stay in solution (i.e. aqueous) before and after the reaction.
Ca^{2+} (aq) + $\mathbf{2NO_3^-}$ (aq) + $\mathbf{2K^+}$ (aq) + $2Cl^-$ (aq) ➔ $CaCl_2$ (sol) + $\mathbf{2K^+}$ (aq) + $\mathbf{2NO_3^-}$ (aq)

3. a. Sodium nitrate + lead(II) chloride. A double displacement reaction: $A^+B^- + C^+D^-$ ➔ $A^+D^- + B^-C^+$.

4. b. A precipitation reaction produces solid $CaCl_2$ from Ca^{2+} and $2Cl^-$ ions.

5. a. Nitrate ions recombine with potassium ions while mercury[II] ions and iodide ions form the precipitate in this double displacement reaction.
Hg_2^{2+} (aq) + $2(NO_3)^-$ (aq) + $2K^+$ (aq) + $2I^-$ (aq) ➔ Hg_2I_2 (sol) + $2K^+$ (aq) + $2(NO_3)^-$ (aq)

6. d. Oxidation: increase of the oxidation # of N from NH_3 [–3] to N_2 [0]. Oxidizing agent: $6NO_2$ (g); the other reactant, $8NH_2$ (g) is the reducing agent.

7. b. Oxidation: increase of the oxidation # of Sn from Sn [0] to $SnCl_6^{2-}$ [+4]. Oxidizing agent: $4NO_3^-$ (aq), while Sn (s) is the reducing agent (it is oxidized).

8. c. Balance Mg first [1 in Mg(s) for 1 in $Mg(OH)_2$], then O [2 in $2H_2O$ for 2 in $Mg(OH)_2$], and finally H [4 in $2H_2O$ for 2 in $Mg(OH)_2$ and 2 in H_2].

9. d. Cr in $Cr(NO_3)_3$ is displaced by Al.

10. b. Combination of PF_3 (g) and F_2 (g).

11. a. $Ba(OH)_2$ (aq) + $2HNO_3$ (aq) ➔ $Ba(NO_3)_2$ (aq) + $2H_2O$ (l)
The left side of the equation must equal the right side of the equation for all atoms:
1 Ba [in $Ba(OH)_2$] for 1 Ba [in $Ba(NO_3)_2$],
2 N (in 2 HNO_3) for 2 N [in $Ba(NO_3)_2$],
8 O [2 in $Ba(OH)_2$ and 6 in $2HNO_3$] for 8 O [6 in $Ba(NO_3)_2$ and 2 in $2H_2O$]
4 H [2 in $Ba(OH)_2$ and 2 in $2HNO_3$] for 4 H [4 in $2H_2O$]

12. b. Oxidation: increase of the oxidation # of Si from [0] in Si (s) to [+4] in $SiCl_4$ (l) and reduction: decrease of the oxidation # of Cl_2 from [0] in Cl_2 (g) to [–4] in $SiCl_4$ (l).

13. a. C_2H_4(g) + $3O_2$(g) ($2CO_2$(g) + $2H_2O$(g)
Oxidation: increase of the oxidation # of C from [–2] in C_2H_4 (g) to [+4] in CO_2 (g) and reduction: decrease of the oxidation # of O from [0] in O_2(g) to [–4] in CO_2 (g).

14. b. Only NH_3 is not ionic and cannot be broken into ions.

15. d. 3 ions: 2 NO_3^- and 1 Mg^{2+}: 3 × 0.25M = 0.75M greater than 0.4M (Al^{3+} and 3 Cl^-), 0.45M (Sr^{2+} and 2 Br^-), 0.4M (Na^+ and Br^-).

16. c. In the equation $Ba(NO_3)_2$ + Na_2SO_4 ➔ $BaSO_4$ (sol) + $2NaNO_3$, 1 mole of sodium sulfate produces 1 mole of the precipitate barium sulfate [137.3 (Ba) + 32 (S) + 4 × 16 (4O) = 233.3 g]. So, to produce 10.0 g of barium sulfate, only $(\frac{10.0}{233.3}) \times 1$ mol= 0.04 mol of sodium sulfate.

17. b. Only NO is not a simple element.

18. d. NO is the only compound, made of N and O atoms.

19. c. Na^+ and Cl^-

20. b. $d = \frac{m}{v}$ implies that $v = \frac{m}{d} = \frac{275\text{g}}{1.05}$ g/mL^{-1} ~ 262 mL.

21. d. $\frac{5}{9}(72 - 32) = \frac{5}{9} \times 40 = 22.2°$ C

22. b. ° C $= \frac{5}{9}$(° F – 32) so that ° F $= 32 + \frac{9}{5}$ ° C $= 32 + \frac{9}{5}(25) = 77°$ F.

23. c. $4.50 \times 10^2 \times 10^{-9}$ m$= 4.50 \times 10^{-7}$ m

24. d. $4.50 \times 10^2 \times 10^3$ pm$= 4.50 \times 10^5$ pm

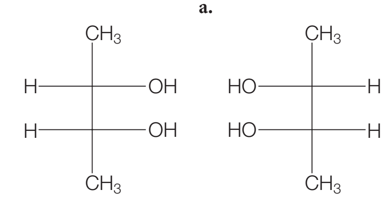
25. b. Mirror-images are two structures that are not superposable (upon rotation/flipping of the structure or not). In (a), (e), (f), we have the same structure: On rotating the *second* structure (in plane strictly for (a) and (e) since these are Fischer projections and out of plane for (f)) by 180°, we obtain the *first* structure: (a), (e), (f) are not constituted by pairs of enantiomers or mirror-images. Set (g) is labelled (R),(S) for one and (R),(R) for the other structure and cannot therefore constitute a set of enantiomers (in which absolute configuration shouldn't be the same for same chiral carbon of the structures).
(b), (c), (d), (h) are sets of enantiomers or mirror-images by the same procedure, (h) showing (R),(R) and (S),(S) that is characteristic of enantiomeric pairs.

26. c. Since (g) is labelled (R),(S) for one and (R),(R) for the other structure and cannot therefore constitute a set of enantiomers, it's a set of diastereomers.

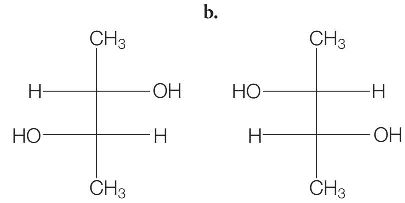
27. a. $3.33 \times 10^{-5} + 8.13 \times (10^{-5} \times 10^{-2}) = (3.33 + 8.13 \times 10^{-2}) \times 10^{-5} = 3.41 \times 10^{-5}$ (2 decimal digits as in 3.33 and 8.13)

28. d. $0.05620 = 0.5620 \times 10^{-1} = 5.620 \times 10^{-2} = 56.20 \times 10^{-3}$

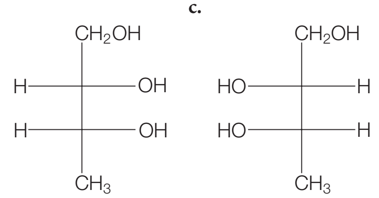
a.



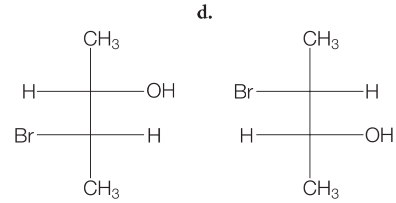
b.



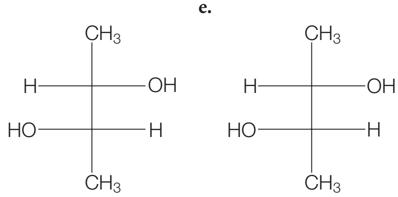
c.



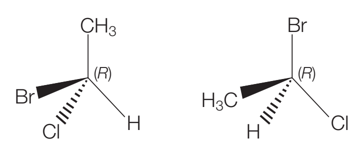
d.



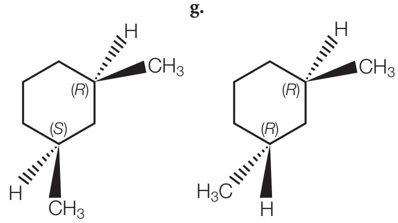
e.



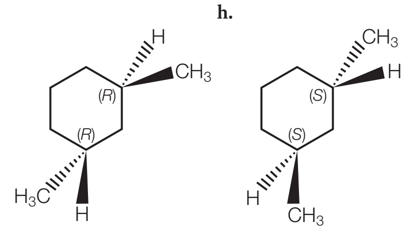
f.



g.



h.



29. b. By assigning the absolute configurations, set (a) is (R),(S) and (S),(S) and therefore clearly a pair of diastereomers and set (c) shows groups that are not symmetrical by a mirror located between the two Newman projections.

30. c. $120 \times 5.1558 = 618.696$ which gives 619 as the correct answer (no decimal digit as in 27 and 93).

31. c. $\frac{V_i}{T_i} = \frac{V_f}{T_f}$ implies that, in Kelvins, $V_f = (\frac{T_f}{T_i})V_i = (\frac{398.15}{300.15}) \times 2.60 \text{ L} \approx 3.5 \text{ L}$.

32. b. Decrease the oxidation number of Zn from [+2] in Zn^{2+} to [0] in Zn.

33. a. Decrease the oxidation number of Cl from [0] in Cl_2 to [–1] in Cl.

34. d. The unsaturation has been *reduced* while hydrogen atoms have been incorporated, i.e. *hydrogenation*.

35. d. 2 mol of H_2 react with 1 mol (280g) of linoleic acid. To form 5.0 g of linoleic acid, the required amount of H_2 is $(\frac{5.0}{280}) \times 2 \text{ mol} = \frac{1}{28}$ mol.

36. d. Sc has 3 valence electrons ($3d^14s^2$) and is therefore in group III B (transition metals).

37. b. 2nd shell: 2 for 'second' (s and p are the types of orbitals found in the second shell).

38. c. 3rd shell: 3 for 'third' (s, p, and d are the types of orbitals found in the third atomic shell).

39. a. The group number of an atom corresponds to the number of valence electron(s) for that atom.

40. c. The period number of an atom is equal to the number of electron shell(s) in that atom.

41. c. An ionic bond forms when electrons are transferred from one atom (now a cation) to another (which becomes an anion).

42. c. A covalent bond is formed when electrons are shared between two atoms.

43. a. K is transfering its valence electron (1 electron) to Br (which becomes Br^- with 8 valence electrons, a complete octet).

44. a. The size of atoms decreases from left to right in the same period and increases from top to bottom in the same group of the periodic table.

45. b. Boron is in group III, so it has 3 valence electrons.

46. a. Only the following structure (HCN) (H:C:::N:) shows 8 dots (2 + 6) around C and 8 dots (6 + 2) around N.

47. d. N≡N

N_2 is nonpolar since both N atoms are similar in nature and physical properties being the same atom.

48. a. $\text{Na}:\ddot{\underset{\cdot\cdot}{\text{Cl}}}:$ displays 8 dots (a complete octet) around Cl and 2 dots around Na (the particular "He" octet for group I atoms is 2 electrons). In NaCl, Na has transfered its lone valence electron to Cl (which has added it to its original 7 to make a complete octet).

49. c. At constant V, $\frac{P_i}{T_i} = \frac{P_f}{T_f}$ implies that, in Kelvins $T_f = P_f \frac{T_i}{P_i} = (\frac{850}{965}) \times 328 \text{ K} = 288.64 \text{ K} = 15° \text{ C}$.

50. d. At STP conditions, the molar volume of 1 mole (i.e., 32 g) of O_2 is 22.4 L. Thus, 64.0 g (2 moles) of O_2 gas will occupy $2 \times 22.4 \text{ L} = 44.8 \text{ L}$ volume.

▶ Scoring

Your scores on the six sections of the exam and on the test as a whole will be reported both as scaled scores and as percentiles. A scaled score is a way of converting the number you got right on this test to a number that can be compared with the number other people got right on other forms of the test, which may have been harder or easier. A percentile is a comparison of your scaled score with the scaled scores of other test takers. If your percentile score is 60, you scored higher than 60% of all test takers; if your percentile score is 84, you scored higher than 84% of all test takers. By definition, a scaled score of 200 is a percentile score of 50.

There is no "passing" scale or percentile score. Individual schools set their own standards, and it's worth your while to find out what scores the schools you want to apply to will accept.

The testing agency uses complicated formulas to come up with scaled and percentile scores. A more meaningful way for you to look at your performance on this practice test is to convert your scores to percentages so that you will be able to compare how you did on the six sections of the test. A *percentage* is not the same as the *percentile* that will appear on your score report. The percentage is simply the number you would have gotten right if there had been 100 questions in the section; it will enable you to compare your scores among the various sections. The *percentile* compares your score with that of other candidates.

In order to find your percentage scores, first add up the number you got right in each section and write it in the following blanks. Questions you didn't answer or got wrong don't count; only count the ones you got right. Then add up the total number of questions you got right.

Section 1: ________ of 50 questions right
Section 2: ________ of 45 questions right
Section 3: ________ of 50 questions right
Section 4: ________ of 50 questions right
Section 5: ________ of 50 questions right
Section 6: ________ of 50 questions right

To figure the percentages for each section and for your total, divide your raw score by the number of questions, and then move the decimal point two places to the right to arrive at a percentage.

Now that you know what percentage of the questions on each section you got right, you can diagnose your strengths and weaknesses. The sections on which you got the lowest percentages are the ones you should plan on studying hardest. Sections on which you got higher percentages may not need as much of your time. However, unless you scored over 90% on a given section, you can't afford to skip studying that section altogether. After all, you want the highest score you can manage in the time left before the exam.

Having taken this practice exam is one important step toward that high score. Simply knowing what to expect is a big help in taking a standardized exam. You are now familiar with the format and content of the HOEE. Since the HOEE is a relatively new exam, that's an advantage many test takers don't have. Make the most of this advantage by using your scores to help you focus your additional study.