A Note from Mr. Bauman

Hi,

I'm so excited that you have decided to join my AP Biology class. I promise to make it worth your time and effort. I have designed this packet in the hopes that it will help acclimate you to the class and give you some skills that will help you succeed in it. All items in this packet should be completed for the first day of class.

Need Help?

I'm happy to help you with any or all of these assignments over the summer months. Your can...

> Email questions to mbauman@mckasd.net
> Contact me via the course website www.mrbatmanmck.weebly.com
> Set up an appointment to meet in person at the High School.

You are welcome to submit this in person or electronically on our class website Electronic copies are also available on the website.

Contents: *Please complete all assignments in **BOLD***

- A letter from the District explaining the expectations for AP classes and summer assignments
- A copy of our tentative 2017 syllabus

- A Copy of Ch. 2 of our primary text. - *This will be our topic in the first week*
- **Ch. 2 note guide.**

- **Graphing on Excel** *–be sure to email me for the work file.*

- Reading and Taking Notes on Scholarly Journal Articles-
- **Nonmedical Vaccine Exemptions and Pertussis in California, 2010**
  -Read and "mark-up" this document as described in the previous article
- **Contemporary Biology Article Assignment** – *An assessment of your academic writing skills*
- General Turabain Guidelines *–We will use this format on all major writing assignments*

I hope you enjoy your summer months and look forward to working with you in the fall.

Mr. Bauman

McKeesport Area High School

Advanced Level Courses

McKeesport Area High School designates select courses as Honors, Pre-AP or AP level for the main purpose of preparing students for future advanced level classes in high school, college and other post-secondary educational experiences. Honors level courses are most often designed as a preparatory gateway into either Pre-AP or AP level courses. Pre-AP and AP level courses are certified by the National College Board which requires that students experience a college-like class setting involving rigorous instruction and personal expectations. AP level courses are devised with a goal of mastering the Advanced Placement Exams administered at the conclusion of the year. Therefore, students who elect to take AP level courses are expected to take these exams.

Students who choose to take *any* of the advanced courses must strive to exceed expectations at all times. The work load in all advanced level courses is more challenging and demanding (both in and out of class) than other classes. Many courses require independent reading, projects, research and writing over weekends and breaks. Time management skills are needed to accommodate the work load. Responsibility and self-motivation are needed to be able to adhere to strict and non-negotiable due dates.   Excellent yearly attendance is required to handle the rigorous pace of instruction. Absences result in missing graded activities that may not be made up as in other classes.

These requirements are put forth in order to foster self-motivated and independent learners who are ready for the rigor of post-secondary education. For more information on one of McKeesport High School's advanced courses, please contact the instructor of the class.

McKeesport Area High School

SUMMER ASSIGNMENT POLICY

DISTRIBUTION DURING THE SCHOOL YEAR:

Summer assignments are distributed in May. Students are responsible for obtaining the assignment once an announcement concerning distribution details is made.

DISTRIBUTION OVER THE SUMMER:

Students who add a class over the summer are responsible for visiting the school and/or contacting the instructor to obtain the assignment. Original due dates are upheld for those who add a class over the summer unless an agreement is made with the instructor.

DUE DATES:

Summer assignments are due on or before the third day of school. After the third day, a 10-20% penalty (set by the instructor) is given. After the sixth day of school, summer work is NOT accepted. In this case, the student runs the likely risk of removal from the class since summer work is the first gage of whether a student is responsible enough to take the advanced class AND is oftentimes necessary for success in the first few weeks of class. In addition, if a student's schedule is changed for this reason, s/he is placed in the corresponding content area class offered the same period which could be a regular level class. A student's schedule is never completely changed to accommodate this situation.

QUESTIONS:

Any and all questions regarding summer work should be directed to the instructor of the course. If s/he is not available, a guidance counselor or principal may be able to assist.

AP Biology Syllabus 2017-2018

Course Name: Advanced Placement Biology
Instructor: M. Bauman
E-Mail: mbauman@mckasd.net
Class Website: www.mrbatmanmck.weebly.com
Phone: 412-664-3650

Course Readings:
Biology in Focus. Boston: Pearson, 2014.
Biology: Openstax Online Textbook 2016
Additional Scientific Abstracts, Papers and Periodical Readings

Course Description:
AP Biology is a year-long course designed to be taken by students after the successful completion of both high school biology and chemistry. The course provides the opportunity for students to experience college-level Science within the high school setting. AP Biology includes those topics regularly covered in a college introductory biology course. The class is constructed around four Big Ideas as established by The College Board. Each of these Big Ideas is subsequently broken into a series of Enduring Understandings that will serve as the units of study within the class. Class time will include a combination of lecture, group work, group discussion, and hands-on activities. The Class will utilize two primary texts, Campbell Biology (9[th]ed.) and Openstax Online Biology Textbook (2016). Additional supplemental materials will be used throughout the class including but not limited to scientific and medical journals as well as newspapers and other periodical articles. The goal of all assigned readings, in addition to supplementing class lecture and discussion, is to foster critical thinking, develop an understanding for the practices of the field of Biology, and develop the field specific literacy. Labs and Group activities, such as case studies and simulations, will help students to formulate a more definitive understanding of abstract ideas. Throughout the course student will engage in a series of extension projects meant to bridge the gap between academic topics and real world application. During these projects students will look at topics through the lens of Medicine, Nutrition, Statistics, Material Culture, Geology, Climatology, and Public Policy This course is designed to prepare students for the Biology College Board Advanced Placement Exam.

Assessments

Grades are calculated based on a point system. The value of each individual assignment varies but in general the proportions will remain consistent throughout the class. Students earn a grade based on the quality, accuracy, and timely completion of assignments.

Exams and Quizzes 50%

Labs, Lab Reports & Projects 25%

Homework / Readings 25%

Exams

Three types of exams will be utilized during this course. A multiple-choice open-book test will be assigned at the beginning of each section; this will be due upon the completion of that material. Open-ended essay tests will be given at the end of each section. A comprehensive mid-term and final exam comprised of both multiple choice and open-ended elements will be given following of the second and fourth nine weeks respectively. These will mimic the AP Exam including limited testing time. **Students that take the AP Biology Exam are excused from taking the Final Exam.**

Quizzes

Will be used to check for understanding of key concepts before major Labs and Activities and may be prerequisites for these assignments. Some quizzes will be announced and others will not. Quizzes will vary in format depending on the topic being covered.

Lab & Lab Reports

Laboratory activities will be an integral part of the class and will account for at least 25% of class time. (Class will meet six times a week for 42 minutes each session. Lab will consist of at least two of these class periods, for a total of 84 minutes, or approximately 33% of class time). Students will be provided with pre-lab information and expected to successfully complete a pre-lab assessment in order to foster critical thinking and comprehension of all parts of the lab activity. After working in groups to complete the lab, students will complete a lab report and will share their data with the class. This will serve as a model of Academia where work is developed then submitted for peer review.

Lab reports are required for each of the recommended Inquiry-Based AP Biology Labs. These reports may include: title, introduction/background information, purpose, hypothesis, procedure, data/results, analysis, question, and conclusion. Students work in pairs to complete lab procedures, but are responsible for turning in individual lab reports. Students are encouraged to produce a high quality report and are given a week from the conclusion of the lab to submit their report.

During the course, students will complete the recommended laboratories in the *AP Biology Investigative Labs: An Inquiry-Based Approach*. The topics covered in these labs are:

Investigation 1	Artificial Selection
Investigation 2:	Mathematical Modeling; Hardy-Weinberg
Investigation 3:	Comparing DNA Sequences to Understand Evolutionary Relationship with BLAST
Investigation 4:	Diffusion and Osmosis
Investigation 5:	Photosynthesis
Investigation 6:	Cellular Respiration
Investigation 7:	Cell Division: Mitosis and Meiosis
Investigation 8:	Biotechnology: Bacterial Transformation
Investigation 9:	Biotechnology: Restriction Enzyme Analysis

Investigation 10:	Energy Dynamics
Investigation 11:	Transpiration
Investigation 12:	Fruit Fly Behavior
Investigation 13:	Enzyme Activity

Additional lab activities may be assigned to provide additional experience or emphasize key concepts within the class.

Extension Projects

Throughout the year students will complete a series of projects outside of the Lab that will ask them to examine Biological concepts in more detail through the lens of other fields of study. These Extension Projects will be graded with the same weight as a lab and be scored based on assigned project rubrics.

Extension Project 1	Curricular Connection: Big Idea: 2 Enduring Understanding: *Growth, reproduction and maintenance of the organization of living systems require free energy and matter*	Changing American Diet Literature Review Once instructed on key strategies required to read and interpret scholarly journals the students will be provided with articles from leading publications in the field, including the *Journal of the Academy of Nutrition and Dietetics, Preventative Medicine, American Journal of Clinical Nutrition, & Journal of Nutritional Biochemistry.* Students will be asked to analyze their works and then to contribute to the preparation of a larger literature review presentation encompassing all of the works provided to the class.
Extension Project 2	Curricular Connection: Big Idea: 2 Enduring Understanding:	Collaborative Diabetes Project Students will research the biochemical components of Diabetes and develop informational materials to be distributed to the school's Allied Health Program. In return the Allied Health Students will provide a presentation of the anecdotal realities of the condition.

	Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.	
Extension Project 3	Curricular Connection: Big Idea: 3 Enduring Understanding: *Heritable information provides for the continuity of life.*	**Development of Historical Genograms** After reading sample passages from Monica McGoldrick and Randy Gerson's work *Genograms: Assessment and Intervention* (1985) Students will develop Genograms with data obtained their local history museum.
Extension Project 4	Curricular Connection: Big Idea: 3 Enduring Understanding: *The processing of genetic information is imperfect and is a source of genetic variation.*	**Medical Museums Virtual Tour** Students will examine the importance of Medical Museums and Libraries as early tools of Medical Education and Genetic Research. They will read *The Age of Museum Medicine: The Rise and Fall of the Medical Museum at Birmingham's School of Medicine Soc Hist Med (December 2005) 18 (3): 419-437.* And take part in a class discussion of the article. The class will then participate in a virtual tour of the University of Edinburgh's Anatomical Museum.

Extension Project 5	Curricular Connection: Big Idea: 1 Enduring Understanding: *Life continues to evolve within a changing environment.*	Demographic Gene Diversity Using US census data provided ceusus.gov and the *datamapper* program students will examine the distribution of various traits in the continental United States.
Extension Project 6	Curricular Connection: Big Idea: 1 Enduring Understanding: *The origin of living systems is explained by natural processes.*	Examination of Geologic Time Through a series of tiered activities students will develop an understanding for the complexities of the geologic time scale the culminating task of which will be the construction of a scaled timeline within the classroom.
Extension Project 7	Curricular Connection: Big Idea: 4 Enduring Understanding: *Interactions within biological systems lead to complex properties*	Climate Data Evaluation Using data provided by the National Climatic Data Center and the resources of the US Climate Resilience Toolkit students will examine patterns and projected trends in the climate of the United States and their own community.

Extension Project 8	Curricular Connection: Big Idea: 4 Enduring Understanding: *Interactions within biological systems lead to complex properties*	Architecture and Environmental Sustainability Project Students will research trends in the field of sustainable architecture and its impact on the environment. They will then tour a gold LEED certified building.

Homework & Readings

Throughout the course of the year outlines of this AP Biology course, including assignments and readings, will be given to the students. This information will also be posted in class website. When appropriate, PDFs of assignments are provided on the website along with links to related references. It is the student's responsibility to complete all homework and readings in good faith and on time.

Topic Outline

The AP Biology Curriculum is framed around four Big Ideas. For each of these Big Ideas, there is a set of core concepts called Enduring Understanding, which will be used to guide the AP Biology course curriculum. Below is an outline of the AP Biology Curriculum Big Ideas and the Enduring Understandings topics covered in this course in the general order they will be taught. *AP Biology is a rigorous course that demands personal responsibility from the student.* In order for students to plan effectively, they will be provided with due dates for all major projects, labs and tests. They are strongly encouraged to complete nightly readings and study each day's lecture notes on their own time.

Big Idea	Associated Readings	Topics	Enduring Understandings
1st. Nine Weeks/ Big Idea 2: Biological systems utilize free energy and molecular building blocks to grow, to reproduce, and to maintain	*Biology In Focus* Unit 1: Ch. 1-9 *Openstax Biology*	Principals of Scientific Inquiry and Communication Properties of Matter and Bonding Principles Special Properties of	A: Growth, reproduction and maintenance of the organization of living systems require free energy and matter
			B: Growth, reproduction and dynamic homeostasis require that cells create and maintain internal environments that are different from their external environments.

dynamic homeostasis.	Units 1-2: Ch. 1-10	Water Carbon and Biological Molecules Macromolecules The structure and functions within eukaryotic cells Metabolic pathways, ATP, enzymes Cellular respiration, fermentation Photosynthesis & alternative methods of carbon fixation Receptor proteins, signal transduction, signal response ECM The structure of the cell membrane, selective permeability, cell transport. Metabolism: energy production and conversions, ATP, enzyme activity Cell division	C: Organisms use feedback mechanisms to regulate growth and reproduction, and to maintain dynamic homeostasis.
			D: Growth and dynamic homeostasis of a biological system are influenced by changes in the system's environment.
			E: Many biological processes involved in growth, reproduction and dynamic homeostasis include temporal regulation and coordination.
2nd. Nine Weeks Big Idea 3: Living systems store, retrieve, transmit and respond to information essential to life	*Biology In Focus* Unit 2: Ch. 10-18 *Openstax Biology* Unit 3: Ch. 11-16	Meiosis & genetic variation Mendel's Laws of Inheritance Non-Mendelian Inheritance Human genetics Chromosomes Sex-linked inheritance Linked genes	A: Heritable information provides for the continuity of life.
			B: Expression of genetic information involves cellular and molecular mechanisms.
			C: The processing of genetic information is imperfect and is a source of genetic variation.
			D: Cells communicate by generating, transmitting, and

processes.		Genetic Disorders DNA and chromosome structure 10.) DNA replication 11.) Genetic engineering 12.) DNA transcription and translation 13.) Mutations 14.) Control of prokaryotic gene expression 415.) Control of eukaryotic gene expression 16.) miRNA, siRNA, RNA interference 17.) Cell differentiation 18.) Stem cells 19.) Cancer 20.) Virus structure 21.) Viral replication 22.) Viral Diseases 23.) Human Genome Project 24.) Bioinformatics 25.) Genome variations 26.) Functions of noncoding DNA 27.) Mutations and genome evolution 28.) Genome comparison in evolution and development	receiving chemical signals.
			E: Transmission of information results in changes within and between biological systems.
3rd. Nine Weeks Big Idea 1: The process of evolution drives the diversity and unity of life.	*Biology In Focus* Units 3-6: Ch. 19-39 *Openstax Biology* Units 4-7: Ch. 17-43	1.) Darwinism 2.) Descent with modification by natural selection 3.) Evidence for evolution 4.) Phylogeny and evolutionary relationships 5.) Morphological and molecular data in support of phylogenies 6.) Phylogenetic Trees 7.) Molecular clocks 8.) Genetic Variation	A: Change in the genetic makeup of a population over time is evolution.
			B: organisms are linked by lines of descent from common ancestry
			C: Life continues to evolve within a changing environment.
			D: The origin of living systems is explained by natural processes.

		9.) Hardy-Weinberg 10.) Natural selection, gene flow, genetic drift 11.) Reproductive Isolation 12.) Speciation 13.) Fossil Record 14.) Speciation and Extinction Rates 15.) Changes in Developmental Genes lead to major body changes 1.) Origin of Life 2.) Structural and Metabolic adaptations in Prokaryotes 3.) Sources of genetic diversity in prokaryotes 4.) Prokaryotes' role in the biosphere 5.) Endosymbiosis 6.) Origins of multicellularity 7.) "Supergroups" of eukaryotes 8.) Single-celled eukaryotes 9.) Colonization of earth by plants 10.) Fungi and the colonization of land 11.) Radiation of early land plants 12.) Seeds and pollen as adaptations to land life 13.) Land plants and fungi and chemical cycling and biotic interactions 14.) Origin of animal 15.) Cambrian explosion 16.) Radiation in aquatic environments 17.) Adaptations for living on land 18.) How animals have	

		altered the ecosystem and change evolution	
		1.) Adaptations of vascular plants 2.) Transportation systems in vascular plants 3.) Functioning of plant roots 4.) Plant nutrition and symbiosis 5.) Transpiration and regulation of transpiration 6.) Glucose transport in plants 7.) Angiosperm life cycle 8.) Sexual and aesexual reproduction in plants 9.) Genetic engineering in crops 10.) Plant hormones 11.) Plant responses to light and other stimuli 1.) Feedback Mechanisms 2.) Endocrine System and Homeostasis 3.) Osmoregulation and Excretion 4.) Hormonal circuits 5.) Animals' Diets and Food Processing 6.) Organs of Food Processing 97.) Digestive Adaptations 8.) Digestive Feedback Circuits 9.) Gas exchange in the body 10.) Double circulation in mammals 11.) Blood vessels and blood pressure and flow 12.) Blood components 13.) Breathing mechanisms 14.) Adaptations for gas exchange 15.) Innate immunity	

		16.) Adaptive immunity 17.) Asexual and sexual reproduction 18.) Reproductive organs and gametes 19.) Tropic and sex hormones and reproduction in mammals 20.) Embryonic Development 21.) Neuron structure and organization 22.) Resting potential and ion pumps 23.) Action potentials 24.) Neuronal communication 25.) Neurons and supporting cells 26.) Vertebrate Brain 27.) Sensory Receptors 28.) Hearing and equilibrium mechanisms 29.) Muscle Function 30.) Skeletal System 31.) Learning and Behaviors	
4th. Nine Weeks Big Idea 4: Biological systems interact, and these systems and their interactions possess complex properties.	27 *Biology In Focus* Unit 7: Ch. 40-43 *Openstax Biology* Unit 8: Ch. 44-47	1.) Climate and biomes 2.) Organism interaction and distribution 3.) Population density and demographics 4.) Population growth 5.) Population dynamics 6.) Species' interactions 7.) Diversity in communities 8.) Disturbance and diversity 9.) Biogeographic factors, pathogens and diversity 10.) Energy flow and chemical cycling 11.) Limiting factors on populations 12.) Energy transfers	A: Interactions within biological systems lead to complex properties. B: Competition and cooperation are important aspects of biological systems. C: Naturally occurring diversity among and between components within biological systems affects interactions with the environment.

		13.) Nutrient and water cycles 14.) Restoration 15.) Human activity and biodiversity 16.) Population and landscape conservation 17.) Sustainable development	

The Chemical Context of Life

OVERVIEW

A Chemical Connection to Biology

Like other animals, beetles have structures and mechanisms that defend them from attack. The soil-dwelling bombardier beetle **(Figure 2.1)** has a particularly effective mechanism for dealing with the ants that plague it. Upon detecting an ant on its body, the beetle ejects a spray of boiling hot liquid from glands in its abdomen, aiming the spray directly at the ant. (In the photograph, the beetle aims its spray at a scientist's forceps.) The spray contains irritating chemicals that are generated at the moment of ejection by the explosive reaction of two sets of chemicals stored separately in the glands. The reaction produces heat and an audible pop.

Research on the bombardier beetle is only one example of the relevance of chemistry to the study of life. Unlike a list of college courses, nature is not neatly packaged into the individual natural sciences—biology, chemistry, physics, and so forth. Biologists specialize in the study of life, but organisms and their environment are natural systems to which the concepts of chemistry and physics apply. Biology is a multidisciplinary science.

This unit of chapters starts with some basic concepts of chemistry that apply to the study of life. In this unit, we will travel from atoms to molecules to cells and their main activities. Somewhere in the transition from molecules to cells, we will cross the blurry boundary between nonlife and life. This chapter introduces the chemical components that make up all matter, with a final section on the substance that supports all of life—water.

▼ **Figure 2.1** What is this bombardier beetle doing?
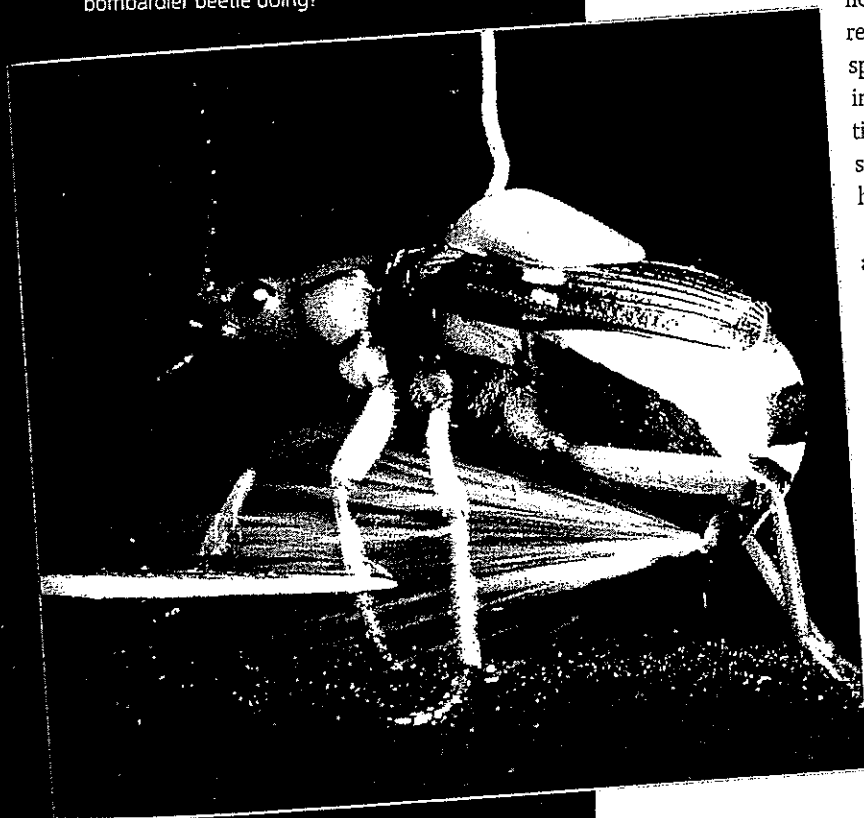
Make Connections Specific chemical reactions can be used as strategies that communicate information **(Big Idea 3)** vital to natural selection and evolution **(Big Idea 1)** and can be mechanisms that enable populations to interact **(Big Idea 4)**.

CONCEPT 2.1

Matter consists of chemical elements in pure form and in combinations called compounds

Organisms are composed of **matter**, which is defined as anything that takes up space and has mass. Matter exists in many diverse forms. Rocks, metals, oils, gases, and living organisms are just a few examples of what seems an endless assortment of matter.

Sodium   Chlorine   Sodium chloride
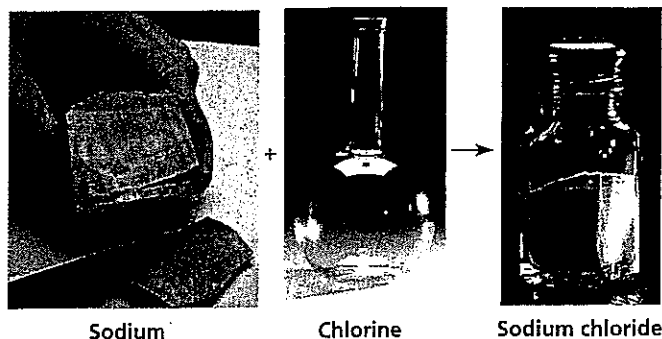
▲ **Figure 2.2 The emergent properties of a compound.** The metal sodium combines with the poisonous gas chlorine, forming the edible compound sodium chloride, or table salt.

Elements and Compounds

Matter is made up of elements. An **element** is a substance that cannot be broken down to other substances by chemical reactions. Today, chemists recognize 92 elements occurring in nature; gold, copper, carbon, and oxygen are examples. Each element has a symbol, usually the first letter or two of its name. Some symbols are derived from Latin or German; for instance, the symbol for sodium is Na, from the Latin word *natrium*.

A **compound** is a substance consisting of two or more different elements combined in a fixed ratio. Table salt, for example, is sodium chloride (NaCl), a compound composed of the elements sodium (Na) and chlorine (Cl) in a 1:1 ratio. Pure sodium is a metal, and pure chlorine is a poisonous gas. When combined, however, sodium and chlorine form an edible compound. Water (H_2O), another compound, consists of the elements hydrogen (H) and oxygen (O) in a 2:1 ratio. These compounds provide simple examples of organized matter having *emergent properties*, ones not possessed by its constituents: A compound has chemical and physical characteristics different from those of its elements **(Figure 2.2)**.

The Elements of Life

Of the 92 natural elements, about 20–25% are **essential elements** that an organism needs to live a healthy life and reproduce. The essential elements are similar among organisms, but there is some variation—for example, humans need 25 elements, but plants need only 17.

Just four elements—oxygen (O), carbon (C), hydrogen (H), and nitrogen (N)—make up 96% of living matter. Calcium (Ca), phosphorus (P), potassium (K), sulfur (S), and a few other elements account for most of the remaining 4% of an organism's mass. **Trace elements** are required by an organism in only minute quantities. Some trace elements, such as iron (Fe), are needed by all forms of life; others are required only by certain species. For example, in vertebrates (animals with backbones), the element iodine (I) is an essential ingredient of a hormone produced by the thyroid gland. A daily intake of only 0.15 milligram (mg) of iodine is adequate for

normal activity of the human thyroid. An iodine deficiency in the diet causes the thyroid gland to grow to abnormal size, a condition called goiter. Consuming seafood or iodized salt reduces the incidence of goiter.

Evolution of Tolerance to Toxic Elements

EVOLUTION Some naturally occurring elements are toxic to organisms. In humans, for instance, the element arsenic has been linked to numerous diseases and can be lethal. Some species, however, have become adapted to environments containing elements that are usually toxic. For example, sunflower plants can take up lead, zinc, and other heavy metals in concentrations that would kill most organisms. (This capability enabled sunflowers to be used to detoxify contaminated soils after Hurricane Katrina.) Presumably, variants of ancestral sunflower species arose in heavy metal-laden soils, and subsequent natural selection resulted in their survival and reproduction.

CONCEPT CHECK 2.1

1. Is a trace element an essential element? Explain.
2. **WHAT IF?** In humans, iron is a trace element required for the proper functioning of hemoglobin, the molecule that carries oxygen in red blood cells. What might be the effects of an iron deficiency?

For suggested answers, see Appendix A.

CONCEPT 2.2

An element's properties depend on the structure of its atoms

Each element consists of a certain type of atom that is different from the atoms of any other element. An **atom** is the smallest unit of matter that still retains the properties of an element. Atoms are so small that it would take about a million of them to stretch across the period at the end of this sentence. We symbolize atoms with the same abbreviation used for the element that is made up of those atoms. For example, C stands for both the element carbon and a single carbon atom.

Subatomic Particles

Although the atom is the smallest unit having the properties of an element, these tiny bits of matter are composed of even smaller parts, called *subatomic particles*. Using high-energy collisions, physicists have produced more than a hundred types of particles from the atom, but only three kinds of particles are relevant here: **neutrons, protons,** and **electrons.** Protons and electrons are electrically charged. Each proton has one unit of positive charge, and each electron has one unit of negative charge. A neutron, as its name implies, is electrically neutral.
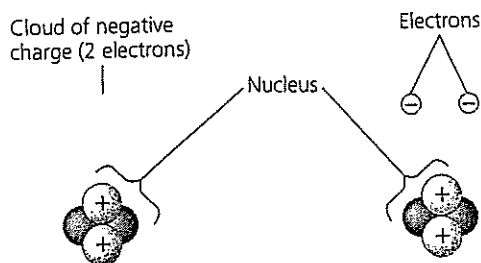
(a) This model represents the two electrons as a cloud of negative charge.

(b) In this more simplified model, the electrons are shown as two small yellow spheres on a circle around the nucleus.

▲ **Figure 2.3 Simplified models of a helium (He) atom.** The helium nucleus consists of 2 neutrons (brown) and 2 protons (pink). Two electrons (yellow) exist outside the nucleus. These models are not to scale; they greatly overestimate the size of the nucleus in relation to the electron cloud.

Protons and neutrons are packed together in a dense core, or **atomic nucleus**, at the center of an atom. Protons give the nucleus a positive charge. The electrons form a cloud of negative charge around the nucleus, and it is the attraction between opposite charges that keeps the electrons in the vicinity of the nucleus. **Figure 2.3** shows two commonly used models for the structure of the helium atom as an example.

The neutron and proton are almost identical in mass, each about 1.7×10^{-24} gram (g). Grams and other conventional units are not very useful for describing the mass of objects so minuscule. Thus, for atoms and subatomic particles (and for molecules, too), we use a unit of measurement called the **dalton** (the same as the *atomic mass unit,* or *amu*). Neutrons and protons have masses close to 1 dalton. Because the mass of an electron is only about 1/2,000 that of a neutron or proton, we can ignore electrons when computing the total mass of an atom.

Atomic Number and Atomic Mass

Atoms of the various elements differ in their number of sub-atomic particles. All atoms of a particular element have the same number of protons in their nuclei. This number of protons, which is unique to that element, is called the **atomic number** and is written as a subscript to the left of the symbol for the element. The abbreviation $_2$He, for example, tells us that an atom of the element helium has 2 protons in its nucleus. Unless otherwise indicated, an atom is neutral in electrical charge, which means that its protons must be balanced by an equal number of electrons. Therefore, the atomic number tells us the number of protons and also the number of electrons in an electrically neutral atom.

We can deduce the number of neutrons from a second quantity, the **mass number**, which is the sum of protons plus neutrons in the nucleus of an atom. The mass number is

written as a superscript to the left of an element's symbol. For example, we can use this shorthand to write an atom of helium as $_2^4$He. Because the atomic number indicates how many protons there are, we can determine the number of neutrons by subtracting the atomic number from the mass number: The helium atom $_2^4$He has 2 neutrons. For sodium (Na):

$$_{11}^{23}\text{Na}$$

Mass number = number of protons + neutrons
= 23 for sodium

Atomic number = number of protons
= 11 for sodium

Number of neutrons = mass number − atomic number
= 23 − 11 = 12 for sodium

The simplest atom is hydrogen $_1^1$H, which has no neutrons; it consists of a single proton with a single electron.

As we've seen, almost all of an atom's mass is concentrated in its nucleus. And because neutrons and protons each have a mass very close to 1 dalton, the mass number is an approximation of the total mass of an atom, called its **atomic mass**. So we might say that the atomic mass of sodium ($_{11}^{23}$Na) is 23 daltons, although more precisely it is 22.9898 daltons.

Isotopes

All atoms of a given element have the same number of protons, but some atoms have more neutrons than other atoms of the same element. These different atomic forms of the sam element are called **isotopes** of the element. In nature, an element occurs as a mixture of its isotopes. For example, consid the three naturally occurring isotopes of the element carbon, which has the atomic number 6. The most common isotope i carbon-12, $_6^{12}$C, which accounts for about 99% of the carbon : nature. The isotope $_6^{12}$C has 6 neutrons. Most of the remainin 1% of carbon consists of atoms of the isotope $_6^{13}$C, with 7 neu trons. A third, even rarer isotope, $_6^{14}$C, has 8 neutrons. Notice that all three isotopes of carbon have 6 protons; otherwise, they would not be carbon. Although the isotopes of an element have slightly different masses, they behave identically ir chemical reactions.

Both ^{12}C and ^{13}C are stable isotopes, meaning that their nu clei do not have a tendency to lose particles. The isotope ^{14}C, however, is unstable, or radioactive. A **radioactive isotope** is one in which the nucleus decays spontaneously, giving off particles and energy. When the decay leads to a change in the number of protons, it transforms the atom to an atom of a di ferent element. For example, when an atom of ^{14}C decays, it becomes an atom of nitrogen.

Radioactive isotopes have many useful applications in biology. For example, researchers use measurements of radio activity in fossils to date these relics of past life (see Chapter 23). Radioactive isotopes are also useful as tracers to follow atoms through metabolism, the chemical processes of an organism. Cells use the radioactive atoms as they would use
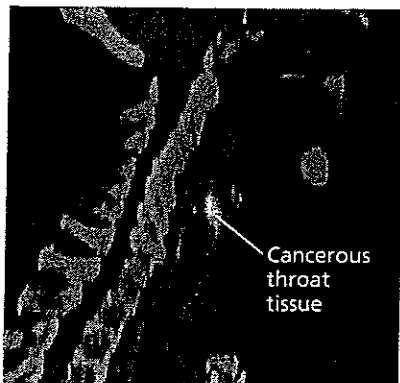
◀ **Figure 2.4 A PET scan, a medical use for radioactive isotopes.** PET, an acronym for positron-emission tomography, detects locations of intense chemical activity in the body. The bright yellow spot marks an area with an elevated level of radioactively labeled glucose, which in turn indicates the presence of cancerous tissue.

nonradioactive isotopes of the same element, but the radioactive tracers can be readily detected.

Radioactive tracers are important diagnostic tools in medicine. For example, certain kidney disorders can be diagnosed by injecting small doses of substances containing radioactive isotopes into the blood and then measuring the amount of tracer excreted in the urine. Radioactive tracers are also used in combination with sophisticated imaging instruments. PET scanners, for instance, can monitor chemical processes, such as those involved in cancerous growth, as they actually occur in the body **(Figure 2.4)**.

Although radioactive isotopes are useful in research and medicine, radiation from decaying isotopes also poses a hazard to life by damaging cellular molecules. The severity of this damage depends on the type and amount of radiation an organism absorbs. One of the most serious environmental threats is radioactive fallout from nuclear accidents. The doses of isotopes used in medical diagnosis, however, are relatively safe.

The Energy Levels of Electrons

The simplified models of the atom in Figure 2.3 greatly exaggerate the size of the nucleus relative to the volume of the whole atom. If an atom of helium were the size of a typical football stadium, the nucleus would be the size of a pencil eraser in the center of the field. Moreover, the electrons would be like two tiny gnats buzzing around the stadium. Atoms are mostly empty space.

When two atoms approach each other during a chemical reaction, their nuclei do not come close enough to interact. Of the three kinds of subatomic particles we have discussed, only electrons are directly involved in the chemical reactions between atoms.

An atom's electrons vary in the amount of energy they possess. **Energy** is defined as the capacity to cause change—for instance, by doing work. **Potential energy** is the energy that matter possesses because of its location or structure. For example, water in a reservoir on a hill has potential energy because of its altitude. When the gates of the reservoir's dam are opened and the water runs downhill, the energy can be used to do work, such as moving the blades of turbines to generate

electricity. Because energy has been expended, the water has less energy at the bottom of the hill than it did in the reservoir. Matter has a natural tendency to move to the lowest possible state of potential energy; in this example, the water runs downhill. To restore the potential energy of a reservoir, work must be done to elevate the water against gravity.

The electrons of an atom have potential energy because of how they are arranged in relation to the nucleus. The negatively charged electrons are attracted to the positively charged nucleus. It takes work to move a given electron farther away from the nucleus, so the more distant an electron is from the nucleus, the greater its potential energy. Unlike the continuous flow of water downhill, changes in the potential energy of electrons can occur only in steps of fixed amounts. An electron having a certain amount of energy is something like a ball on a staircase **(Figure 2.5a)**. The ball can have different amounts of potential energy, depending on which step it is on, but it cannot spend much time between the steps. Similarly, an electron's potential energy is determined by its energy level. An electron cannot exist between energy levels.

An electron's energy level is correlated with its average distance from the nucleus. Electrons are found in different **electron shells**, each with a characteristic average distance and energy level. In diagrams, shells can be represented by concentric circles **(Figure 2.5b)**. The first shell is closest to the nucleus, and electrons in this shell have the lowest potential energy. Electrons in the second shell have more energy, and electrons in the third shell even more energy. An electron can change the shell it occupies, but only by absorbing or losing an

(a) A ball bouncing down a flight of stairs provides an analogy for energy levels of electrons, because the ball can come to rest only on each step, not between steps.
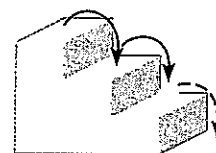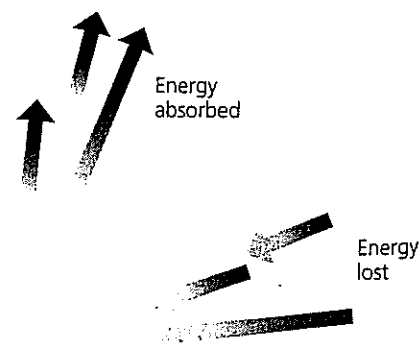

Third shell (highest energy level in this model)

Second shell (higher energy level)

First shell (lowest energy level)

Energy absorbed

Energy lost

Atomic nucleus

(b) An electron can move from one shell to another only if the energy it gains or loses is exactly equal to the difference in energy between the energy levels of the two shells. Arrows in this model indicate some of the stepwise changes in potential energy that are possible.

▲ **Figure 2.5 Energy levels of an atom's electrons.** Electrons exist only at fixed levels of potential energy called electron shells.

amount of energy equal to the difference in potential energy between its position in the old shell and that in the new shell. When an electron absorbs energy, it moves to a shell farther out from the nucleus. For example, light energy can excite an electron to a higher energy level. (Indeed, this is the first step taken when plants harness the energy of sunlight for photosynthesis, the process that produces food from carbon dioxide and water.) When an electron loses energy, it "falls back" to a shell closer to the nucleus, and the lost energy is usually released to the environment as heat.

Electron Distribution and Chemical Properties

The chemical behavior of an atom is determined by the distribution of electrons in the atom's electron shells. Beginning with hydrogen, the simplest atom, we can imagine building the atoms of the other elements by adding 1 proton and 1 electron at a time (along with an appropriate number of neutrons). **Figure 2.6**, an abbreviated version of what is called the *periodic table of the elements*, shows this distribution of electrons for the first 18 elements, from hydrogen ($_1$H) to argon ($_{18}$Ar). The elements are arranged in three rows, or periods, corresponding to the number of electron shells in their atoms. The left-to-right sequence of elements in each row corresponds to

the sequential addition of electrons and protons. (See Appendix B for the complete periodic table.)

Hydrogen's 1 electron and helium's 2 electrons are located in the first shell. Electrons, like all matter, tend to exist in the lowest available state of potential energy. In an atom, this state is in the first shell. However, the first shell can hold no more than 2 electrons; thus, hydrogen and helium are the only elements in the first row of the table. An atom with more than 2 electrons must use higher shells because the first shell is full. The next element, lithium, has 3 electrons. Two of these electrons fill the first shell, while the third electron occupies the second shell. The second shell holds a maximum of 8 electrons. Neon, at the end of the second row, has 8 electrons in the second shell, giving it a total of 10 electrons.

The chemical behavior of an atom depends mostly on the number of electrons in its *outermost* shell. We call those outer electrons **valence electrons** and the outermost electron shell the **valence shell**. In the case of lithium, there is only 1 valence electron, and the second shell is the valence shell. Atoms with the same number of electrons in their valence shells exhibit similar chemical behavior. For example, fluorine (F) and chlorine (Cl) both have 7 valence electrons, and both form compounds when combined with the element sodium (see
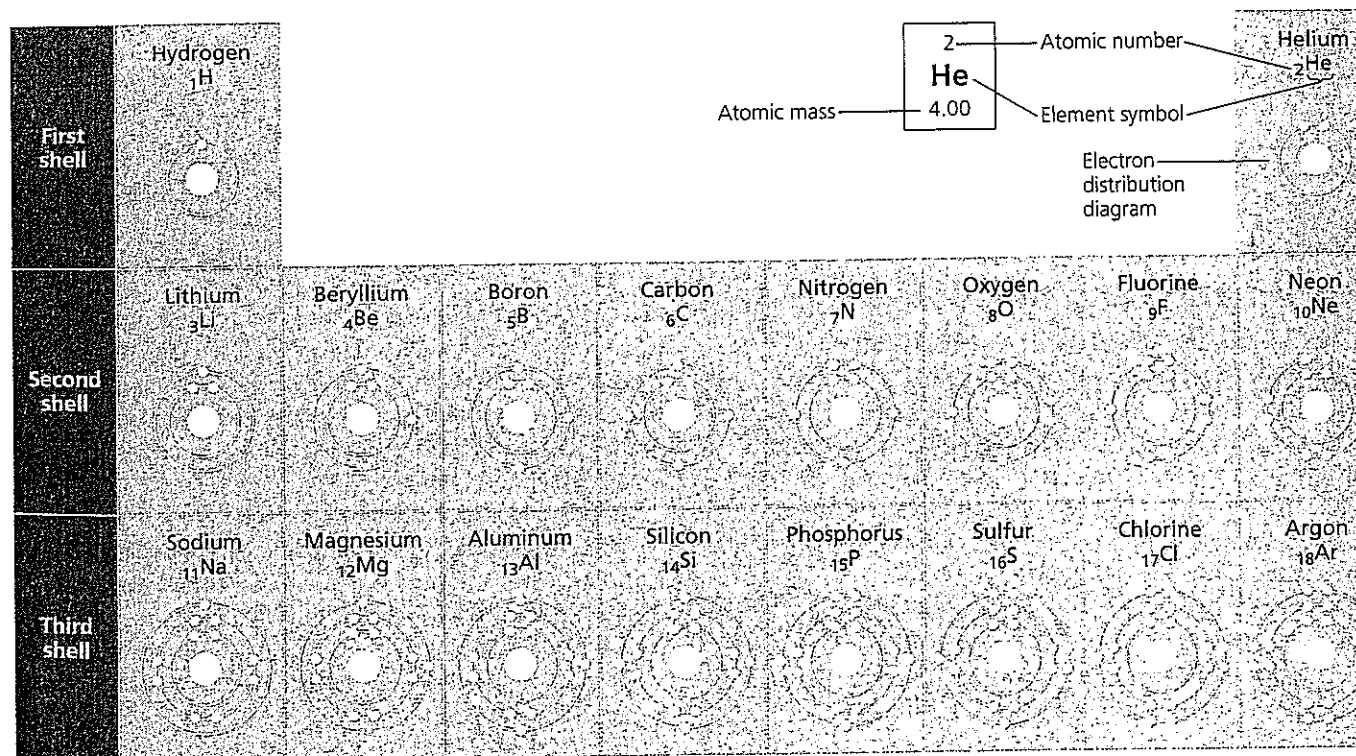
▲ **Figure 2.6 Electron distribution diagrams for the first 18 elements in the periodic table.** In a standard periodic table (see Appendix B), information for each element is presented as shown for helium in the inset. In the diagrams in this table, electrons are represented as yellow dots and electron shells as concentric circles. These diagrams are a convenient way to picture the distribution of an atom's electrons among its electron shells, but these simplified models do not accurately represent the shape of the atom or the location of its electrons. The elements are arranged in rows, each representing the filling of an electron shell. As electrons are added, they occupy the lowest available shell.

?️ *What is the atomic number of magnesium? How many protons and electrons does it have? How many electron shells? How many valence electrons?*

Figure 2.2). An atom with a completed valence shell is unreactive; that is, it will not interact readily with other atoms. At the far right of the periodic table are helium, neon, and argon, the only three elements shown in Figure 2.6 that have full valence shells. These elements are said to be *inert*, meaning chemically unreactive. All the other atoms in Figure 2.6 are chemically reactive because they have incomplete valence shells.

Notice that as we "build" the atoms in Figure 2.6, the first 4 electrons added to the second and third shells are not shown in pairs; only after 4 electrons are present do the next electrons complete pairs. The reactivity of an atom arises from the presence of one or more unpaired electrons in its valence shell. As you will see in the next section, atoms interact in a way that completes their valence shells. When they do so, it is the *unpaired* electrons that are involved.

CONCEPT CHECK 2.2

1. A nitrogen atom has 7 protons, and the most common isotope of nitrogen has 7 neutrons. A radioactive isotope of nitrogen has 8 neutrons. Write the atomic number and mass number of this radioactive nitrogen as a chemical symbol with a subscript and superscript.
2. How many electrons does fluorine have? How many electron shells? How many electrons are needed to fill the valence shell?
3. **WHAT IF?** In Figure 2.6, if two or more elements are in the same row, what do they have in common? If two or more elements are in the same column, what do they have in common?

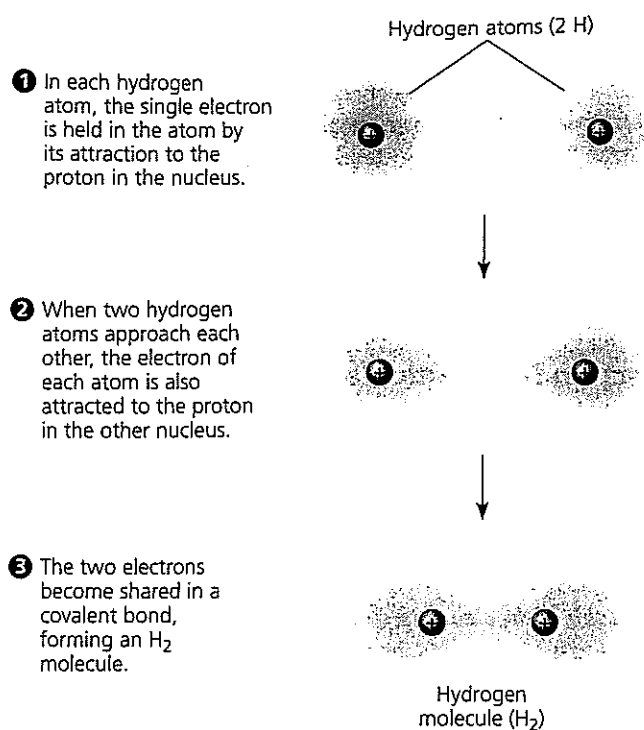For suggested answers, see Appendix A.

CONCEPT 2.3

The formation and function of molecules depend on chemical bonding between atoms

Now that we have looked at the structure of atoms, we can move up the hierarchy of organization and see how atoms combine to form molecules and ionic compounds. Atoms with incomplete valence shells can interact with certain other atoms in such a way that each partner completes its valence shell: The atoms either share or transfer valence electrons. These interactions usually result in atoms staying close together, held by attractions called **chemical bonds**. The strongest kinds of chemical bonds are covalent bonds and ionic bonds.

Covalent Bonds

A **covalent bond** is the sharing of a pair of valence electrons by two atoms. For example, let's consider what happens when two hydrogen atoms approach each other. Recall that hydrogen has 1 valence electron in the first shell, but the shell's capacity

Hydrogen atoms (2 H)

❶ In each hydrogen atom, the single electron is held in the atom by its attraction to the proton in the nucleus.

❷ When two hydrogen atoms approach each other, the electron of each atom is also attracted to the proton in the other nucleus.

❸ The two electrons become shared in a covalent bond, forming an H_2 molecule.

Hydrogen molecule (H_2)

▲ **Figure 2.7 Formation of a covalent bond.**

is 2 electrons. When the two hydrogen atoms come close enough for their electron shells to overlap, they can share their electrons (**Figure 2.7**). Each hydrogen atom is now associated with 2 electrons in what amounts to a completed valence shell. Two or more atoms held together by covalent bonds constitute a **molecule**, in this case a hydrogen molecule.

Figure 2.8a shows several ways of representing a hydrogen molecule. Its *molecular formula*, H_2, simply indicates that the molecule consists of two atoms of hydrogen. Electron sharing can be depicted by an electron distribution diagram or by a *structural formula*, H—H, where the line represents a **single bond**, a pair of shared electrons. A space-filling model comes closest to representing the actual shape of the molecule.

Oxygen has 6 electrons in its second electron shell and therefore needs 2 more electrons to complete its valence shell. Two oxygen atoms form a molecule by sharing *two* pairs of valence electrons (**Figure 2.8b**). The atoms are thus joined by a **double bond** ($O = O$).

Each atom that can share valence electrons has a bonding capacity corresponding to the number of covalent bonds the atom can form. When the bonds form, they give the atom a full complement of electrons in the valence shell. The bonding capacity of oxygen, for example, is 2. This bonding capacity is called the atom's **valence** and usually equals the number of electrons required to complete the atom's outermost (valence) shell. See if you can determine the valences of hydrogen, oxygen, nitrogen, and carbon by

Name and Molecular Formula	Electron Distribution Diagram	Structural Formula	Space-Filling Model
(a) Hydrogen (H_2). Two hydrogen atoms share one pair of electrons, forming a single bond.		H—H	
(b) Oxygen (O_2). Two oxygen atoms share two pairs of electrons, forming a double bond.		O=O	
(c) Water (H_2O). Two hydrogen atoms and one oxygen atom are joined by single bonds, forming a molecule of water.		O—H | H	
(d) Methane (CH_4). Four hydrogen atoms can satisfy the valence of one carbon atom, forming methane.		H | H—C—H | H	

▲ **Figure 2.8 Covalent bonding in four molecules.** The number of electrons required to complete an atom's valence shell generally determines how many covalent bonds that atom will form. This figure shows several ways of indicating covalent bonds.

studying the electron distribution diagrams in Figure 2.6. You can see that the valence of hydrogen is 1; oxygen, 2; nitrogen, 3; and carbon, 4. However, the situation is more complicated for elements in the third row of the periodic table. Phosphorus, for example, can have a valence of 3, as we would predict from the presence of 3 unpaired electrons in its valence shell. In some molecules that are biologically important, however, phosphorus can form three single bonds and one double bond. Therefore, it can also have a valence of 5.

The molecules H_2 and O_2 are pure elements rather than compounds because a compound is a combination of two or more *different* elements. Water, with the molecular formula H_2O, is a compound. Two atoms of hydrogen are needed to satisfy the valence of one oxygen atom. **Figure 2.8c** shows the structure of a water molecule. Water is so important to life that the last section of this chapter, Concept 2.5, is devoted to its structure and behavior.

Methane, the main component of natural gas, is a compound with the molecular formula CH_4. It takes four hydroge atoms, each with a valence of 1, to complement one atom of carbon, with its valence of 4 **(Figure 2.8d)**. (We will look at many other compounds of carbon in Chapter 3.)

Atoms in a molecule attract shared electrons to varying degrees, depending on the element. The attraction of a particular atom for the electrons of a covalent bond is called its **electronegativity**. The more electronegative an atom is, the more strongly it pulls shared electrons toward itself. In a cova lent bond between two atoms of the same element, the electrons are shared equally because the two atoms have the sam electronegativity—the tug-of-war is at a standoff. Such a bon is called a **nonpolar covalent bond**. For example, the single bond of H_2 is nonpolar, as is the double bond of O_2. Howeve when an atom is bonded to a more electronegative atom, the electrons of the bond are not shared equally. This type of bor is called a **polar covalent bond**. Such bonds vary in their po larity, depending on the relative electronegativity of the two atoms. For example, the bonds between the oxygen and hy-drogen atoms of a water molecule are quite polar **(Figure 2.9** Oxygen is one of the most electronegative of all the elements attracting shared electrons much more strongly than hydrog does. In a covalent bond between oxygen and hydrogen, the electrons spend more time near the oxygen nucleus than the do near the hydrogen nucleus. Because electrons have a negitive charge and are pulled toward oxygen in a water molecul the oxygen atom has a partial negative charge (indicated by t Greek letter δ with a minus sign, δ−, or "delta minus"), and each hydrogen atom has a partial positive charge (δ+, or "de plus"). In contrast, the individual bonds of methane (CH_4) ar much less polar because the electronegativities of carbon an hydrogen are similar.

Ionic Bonds

In some cases, two atoms are so unequal in their attraction f valence electrons that the more electronegative atom strips electron completely away from its partner. This is what happens when an atom of sodium ($_{11}Na$) encounters an atom of

Because oxygen (O) is more electronegative than hydrogen (H shared electrons are pulled more toward oxygen.
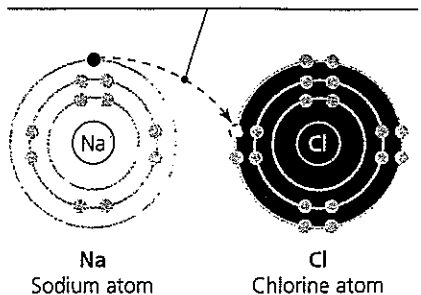
This results in a partial negative charge on the oxygen and a partial positive charge on the hydrogens.
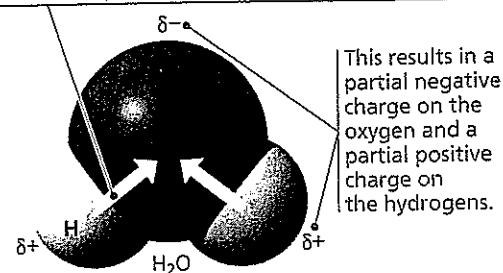
▲ **Figure 2.9 Polar covalent bonds in a water molecule.**

chlorine ($_{17}$Cl) **(Figure 2.10)**. A sodium atom has a total of 11 electrons, with its single valence electron in the third electron shell. A chlorine atom has a total of 17 electrons, with 7 electrons in its valence shell. When these two atoms meet, the lone valence electron of sodium is transferred to the chlorine atom, and both atoms end up with their valence shells complete. (Because sodium no longer has an electron in the third shell, the second shell is now the valence shell.)
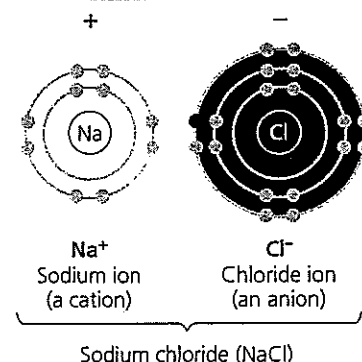
The electron transfer between the two atoms moves one unit of negative charge from sodium to chlorine. Sodium, now with 11 protons but only 10 electrons, has a net electrical charge of 1+. A charged atom (or molecule) is called an **ion**. When the charge is positive, the ion is specifically called a **cation**; the sodium atom has become a cation. Conversely, the chlorine atom, having gained an extra electron, now has 17 protons and 18 electrons, giving it a net electrical charge of 1−. It has become a chloride ion—an **anion**, or negatively charged ion. Because of their opposite charges, cations and anions attract each other; this attraction is called an **ionic bond**. The transfer of an electron is not the formation of a bond; rather, it allows a bond to form because it results in two ions of opposite charge. Any two ions of opposite charge can form an ionic bond. The ions do not need to have acquired their charge by an electron transfer with each other.

Compounds formed by ionic bonds are called **ionic compounds**, or **salts**. We know the ionic compound sodium chloride (NaCl) as table salt **(Figure 2.11)**. Salts are often found in nature as crystals of various sizes and shapes. Each salt crystal is an aggregate of vast numbers of cations and anions bonded by their electrical attraction and arranged in a three-dimensional lattice. Unlike a covalent compound, which consists of molecules having a definite size and number of atoms, an ionic compound does not consist of molecules. The formula for an

Na
Sodium atom

Cl
Chlorine atom

Na$^+$
Sodium ion
(a cation)

Cl$^-$
Chloride ion
(an anion)

Sodium chloride (NaCl)

▲ **Figure 2.10 Electron transfer and ionic bonding.** The attraction between oppositely charged atoms, or ions, is an ionic bond. An ionic bond can form between any two oppositely charged ions, even if they have not been formed by transfer of an electron from one to the other.

ionic compound, such as NaCl, indicates only the ratio of elements in a crystal of the salt. "NaCl" by itself is not a molecule.

Not all salts have equal numbers of cations and anions. For example, the ionic compound magnesium chloride (MgCl$_2$) has two chloride ions for each magnesium ion. Magnesium ($_{12}$Mg) must lose 2 outer electrons if the atom is to have a complete valence shell, so it tends to become a cation with a net charge of 2+ (Mg^{2+}). One magnesium cation can therefore form ionic bonds with two chloride anions.

The term *ion* also applies to entire molecules that are electrically charged. In the salt ammonium chloride (NH$_4$Cl), for instance, the anion is a single chloride ion (Cl$^-$), but the cation is ammonium (NH$_4^+$), a nitrogen atom covalently bonded to four hydrogen atoms. The whole ammonium ion has an electrical charge of 1+ because it is 1 electron short.
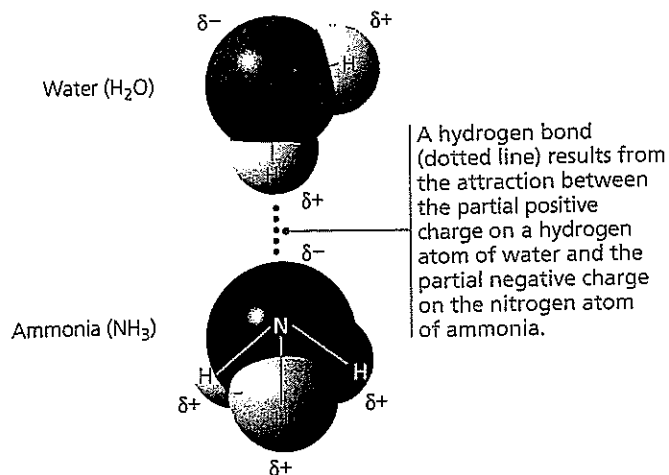
Environment affects the strength of ionic bonds. In a dry salt crystal, the bonds are so strong that it takes a hammer and chisel to break enough of them to crack the crystal in two. If the same salt crystal is dissolved in water, however, the ionic bonds are much weaker because each ion is partially shielded by its interactions with water molecules. Most drugs are manufactured as salts because they are quite stable when dry but can dissociate (come apart) easily in water.

Weak Chemical Bonds

In organisms, most of the strongest chemical bonds are covalent bonds, which link atoms to form a cell's molecules. But weaker bonding within and between molecules is also indispensable in the cell, contributing greatly to the properties of life. Many large biological molecules are held in their functional form by weak bonds. In addition, when two molecules in the cell make contact, they may adhere temporarily by weak bonds. The reversibility of weak bonding can be an advantage: Two molecules can come together, respond to one another in some way, and then separate.

— Na$^+$

— Cl$^-$
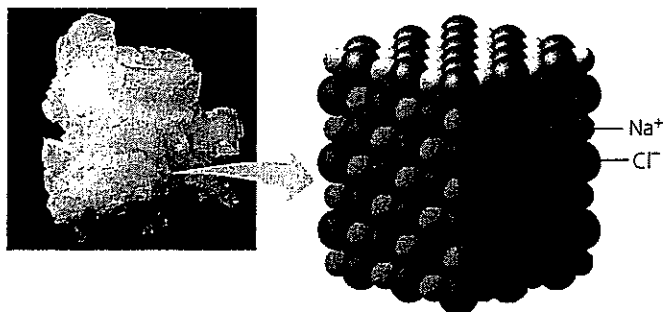
▲ **Figure 2.11 A sodium chloride (NaCl) crystal.** The sodium ions (Na$^+$) and chloride ions (Cl$^-$) are held together by ionic bonds. The formula NaCl tells us that the ratio of Na$^+$ to Cl$^-$ is 1:1.

Water (H_2O)

δ−   δ+

δ+

δ−

Ammonia (NH_3)

δ+   δ+

δ+

A hydrogen bond (dotted line) results from the attraction between the partial positive charge on a hydrogen atom of water and the partial negative charge on the nitrogen atom of ammonia.

▲ Figure 2.12 A hydrogen bond.

Several types of weak chemical bonds are important in organisms. One is the ionic bond as it exists between ions dissociated in water, which we just discussed. Hydrogen bonds and van der Waals interactions are also crucial to life.

Hydrogen Bonds

Among the various kinds of weak chemical bonds, hydrogen bonds are so important in the chemistry of life that they deserve special attention. The partial positive charge on a hydrogen atom that is covalently bonded to an electronegative atom allows the hydrogen to be attracted to a different electronegative atom nearby. This noncovalent attraction between a hydrogen and an electronegative atom is called a **hydrogen bond**. In living cells, the electronegative partners are usually oxygen or nitrogen atoms. Refer to **Figure 2.12** to examine the simple case of hydrogen bonding between water (H_2O) and ammonia (NH_3).

Van der Waals Interactions

Even a molecule with nonpolar covalent bonds may have positively and negatively charged regions. Electrons are not always symmetrically distributed in such a molecule; at any instant, they may accumulate by chance in one part of the molecule or another. The results are ever-changing regions of positive and negative charge that enable all atoms and molecules to stick to one another. These **van der Waals interactions** are individually weak and occur only when atoms and molecules are very close together. When many such interactions occur simultaneously, however, they can be powerful: Van der Waals interactions are the reason a gecko lizard (right) can walk straight up a wall! Each gecko toe has hundreds of thousands of tiny hairs, with multiple

projections at each hair's tip that increase surface area. Apparently, the van der Waals interactions between the hair tip molecules and the molecules of the wall's surface are so numerous that despite their individual weakness, together they can support the gecko's body weight.

Van der Waals interactions, hydrogen bonds, ionic bonds in water, and other weak bonds may form not only between molecules but also between parts of a large molecule, such as a protein. The cumulative effect of weak bonds is to reinforce the three-dimensional shape of the molecule. (You will learn more about the very important biological roles of weak bonds in Chapter 3.)

Molecular Shape and Function

A molecule has a characteristic size and shape. The precise shape of a molecule is usually very important to its function in the living cell.

A molecule consisting of two atoms, such as H_2 or O_2, is always linear, but most molecules with more than two atoms have more complicated shapes. To take a very simple example, a water molecule (H_2O) is shaped roughly like a V, with its two covalent bonds spread apart at an angle of 104.5° (**Figure 2.13**). A methane molecule (CH_4) has a geometric shape called a tetrahedron, a pyramid with a triangular base. The carbon nucleus is inside, at the center, with its four covalent bonds radiating to hydrogen nuclei at the corners of the tetrahedron. Larger molecules containing multiple carbon atoms, including many of the molecules that make up living matter, have more complex overall shapes. However, the tetrahedral shape of a carbon atom bonded to four other atoms is often a repeating motif within such molecules.

Space-Filling Model	Ball-and-Stick Model
Water (H_2O)	O, H, H, 104.5°
Methane (CH_4)	H, H, H, H
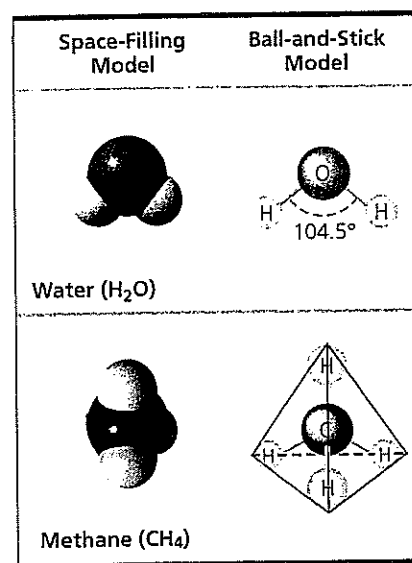
▲ Figure 2.13 Models showing the shapes of two small molecules. Each of the molecules, water and methane, is represented in two different ways.
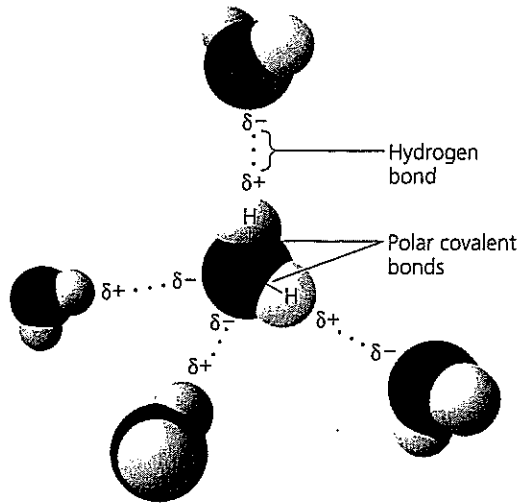
▲ Figure 2.16 Hydrogen bonds between water molecules. The charged regions in a water molecule are due to its polar covalent bonds. Oppositely charged regions of neighboring water molecules are attracted to each other, forming hydrogen bonds. Each molecule can hydrogen-bond to multiple partners, and these associations are constantly changing.

DRAW IT *Draw partial charges on all the atoms of the water molecule on the far left above, and draw two more water molecules hydrogen-bonded to it.*

of partners. Therefore, at any instant, a substantial percentage of all the water molecules are hydrogen-bonded to their neighbors **(Figure 2.16)**. The extraordinary qualities of water emerge in large part from the hydrogen bonding that organizes water molecules into a higher level of structural order. We will examine four emergent properties of water that contribute to Earth's suitability as an environment for life: cohesive behavior, ability to moderate temperature, expansion upon freezing, and versatility as a solvent. After that, we'll discuss a critical aspect of water chemistry—acids and bases.

Cohesion of Water Molecules

Water molecules stay close to each other as a result of hydrogen bonding. At any given moment, many of the molecules in liquid water are linked by multiple hydrogen bonds. These linkages make water more structured than most other liquids. Collectively, the hydrogen bonds hold the substance together, a phenomenon called **cohesion.**

Cohesion due to hydrogen bonding contributes to the transport of water and dissolved nutrients against gravity in plants **(Figure 2.17)**. Water from the roots reaches the leaves through a network of water-conducting cells. As water evaporates from a leaf, hydrogen bonds cause water molecules leaving the veins to tug on molecules farther down, and the upward pull is transmitted through the water-conducting cells all the way to the roots. **Adhesion,** the clinging of one substance to another, also plays a role. Adhesion of water to cell walls by hydrogen bonds helps counter the downward pull of gravity.
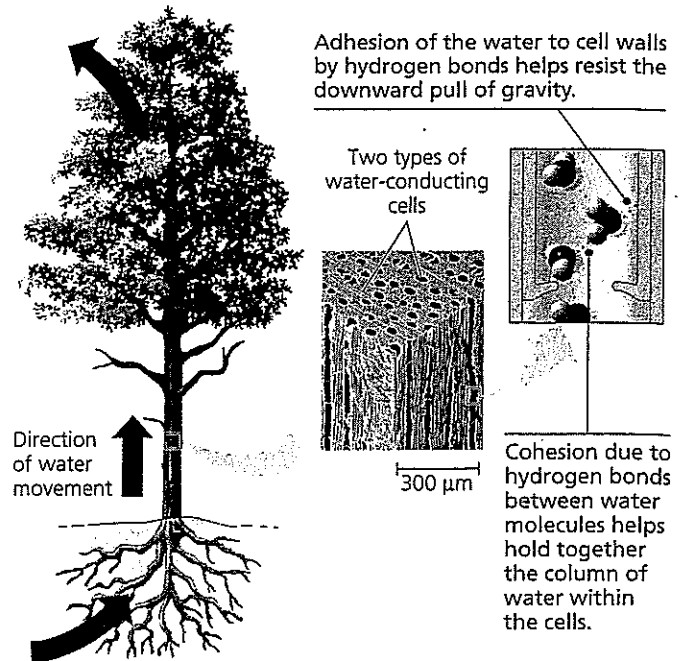
▲ Figure 2.17 Water transport in plants. Evaporation from leaves pulls water upward from the roots through water-conducting cells. Because of the properties of cohesion and adhesion, the tallest trees can transport water more than 100 m upward—approximately one-quarter the height of the Empire State Building in New York City.

ANIMATION *BioFlix* Visit the Study Area in MasteringBiology for the BioFlix® 3-D Animation on Water Transport in Plants.

Related to cohesion is **surface tension**, a measure of how difficult it is to stretch or break the surface of a liquid. The hydrogen bonds in water give it an unusually high surface tension, making it behave as though it were coated with an invisible film. You can observe the surface tension of water by slightly overfilling a drinking glass; the water will stand above the rim. The spider in **Figure 2.18** takes advantage of the surface tension of water to walk across a pond without breaking the surface.

Moderation of Temperature by Water

Water moderates air temperature by absorbing heat from air that is warmer and releasing the stored heat to air that is cooler. Water is effective as a heat bank because it can absorb or release a relatively large amount of heat with only a slight change in its own temperature. To understand this capability of water, we must first look briefly at temperature and heat.

Temperature and Heat

Anything that moves has **kinetic energy**, the energy of motion. Atoms and molecules have kinetic energy because they are always moving, although not necessarily in any particular direction. The faster a molecule moves, the greater its kinetic energy. The kinetic energy associated with the random movement of
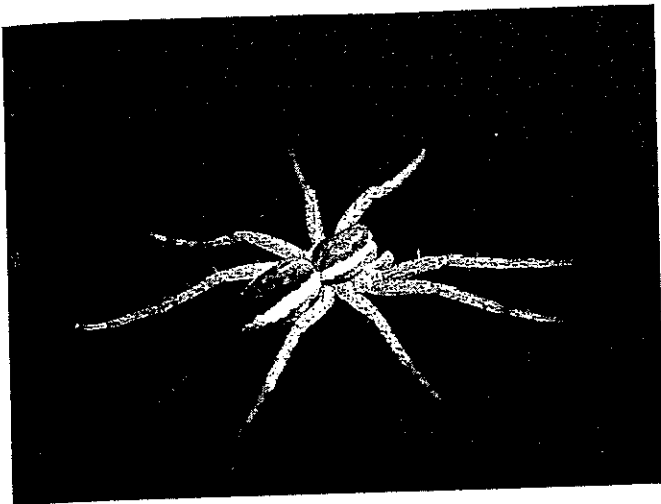
▲ **Figure 2.18 Walking on water.** The high surface tension of water, resulting from the collective strength of its hydrogen bonds, allows this raft spider to walk on the surface of a pond.

atoms or molecules is called **thermal energy**. The *total* thermal energy of a body of matter depends in part on the matter's volume. Although thermal energy is related to temperature, they are not the same thing. **Temperature** represents the *average* kinetic energy of the molecules, regardless of volume. When water is heated in a coffeemaker, the average speed of the molecules increases, and the thermometer records this as a rise in temperature of the liquid. The amount of thermal energy also increases in this case. Note, however, that although the pot of coffee has a much higher temperature than, say, the water in a swimming pool, the swimming pool contains more thermal energy because of its much greater volume.

Whenever two objects of different temperature are brought together, thermal energy passes from the warmer to the cooler object until the two are the same temperature. Molecules in the cooler object speed up at the expense of the thermal energy of the warmer object. An ice cube cools a drink not by adding coldness to the liquid, but by absorbing thermal energy from the liquid as the ice itself melts. Thermal energy in transfer from one body of matter to another is defined as **heat**.

One convenient unit of heat used in this book is the **calorie (cal)**. A calorie is the amount of heat it takes to raise the temperature of 1 g of water by 1°C. Conversely, a calorie is also the amount of heat that 1 g of water releases when it cools by 1°C. A **kilocalorie (kcal)**, 1,000 cal, is the quantity of heat required to raise the temperature of 1 kilogram (kg) of water by 1°C. (The "calories" on food packages are actually kilocalories.) Another energy unit used in this book is the **joule (J)**. One joule equals 0.239 cal; one calorie equals 4.184 J.
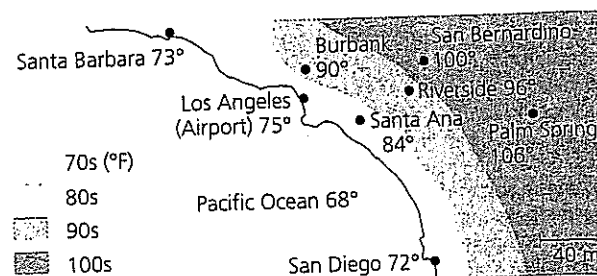
Water's High Specific Heat

The ability of water to stabilize temperature stems from its relatively high specific heat. The **specific heat** of a substance is defined as the amount of heat that must be absorbed or lost

for 1 g of that substance to change its temperature by 1°C. We already know water's specific heat because we have defined a calorie as the amount of heat that causes 1 g of water to change its temperature by 1°C. Therefore, the specific heat of water is 1 calorie per gram per degree Celsius, abbreviated as 1 cal/g·°C. Compared with most other substances, water has an unusually high specific heat. As a result, water will change its temperature less than other liquids when it absorbs or loses a given amount of heat. The reason you can burn your fingers by touching the side of an iron pot on the stove when the water in the pot is still lukewarm is that the specific heat water is ten times greater than that of iron. In other words, th same amount of heat will raise the temperature of 1 g of the iron much faster than it will raise the temperature of 1 g of th water. Specific heat can be thought of as a measure of how w a substance resists changing its temperature when it absorbs or releases heat. Water resists changing its temperature; whe it does change its temperature, it absorbs or loses a relatively large quantity of heat for each degree of change.

We can trace water's high specific heat, like many of its oth properties, to hydrogen bonding. Heat must be absorbed in o der to break hydrogen bonds; by the same token, heat is relea: when hydrogen bonds form. A calorie of heat causes a relativ small change in the temperature of water because much of th heat is used to disrupt hydrogen bonds before the water molecules can begin moving faster. And when the temperature o: water drops slightly, many additional hydrogen bonds form, r leasing a considerable amount of energy in the form of heat.

What is the relevance of water's high specific heat to life on Earth? A large body of water can absorb and store a hug amount of heat from the sun in the daytime and during sun mer while warming up only a few degrees. At night and dur winter, the gradually cooling water can warm the air. This is the reason coastal areas generally have milder climates than inland regions **(Figure 2.19)**. The high specific heat of wate also tends to stabilize ocean temperatures, creating a favora environment for marine life. Thus, because of its high speci heat, the water that covers most of Earth keeps temperatur fluctuations on land and in water within limits that permit

Santa Barbara 73°
Burbank
San Bernardino
100°
90°
Los Angeles (Airport) 75°
Riverside 96°
Santa Ana 84°
Palm Springs 106°
70s (°F)
80s
Pacific Ocean 68°
90s
100s
San Diego 72°
40 mi

▲ **Figure 2.19 Effect of a large body of water on climate.** By absorbing or releasing heat, oceans moderate coastal climates. I this example from an August day in Southern California, the relativ cool ocean reduces coastal air temperatures by absorbing heat. (Th temperatures are in degrees Fahrenheit.)

Also, because organisms are made primarily of water, they are better able to resist changes in their own temperature than if they were made of a liquid with a lower specific heat.

Evaporative Cooling

Molecules of any liquid stay close together because they are attracted to one another. Molecules moving fast enough to overcome these attractions can depart the liquid and enter the air as a gas. This transformation from a liquid to a gas is called vaporization, or *evaporation*. Recall that the speed of molecular movement varies and that temperature is the *average* kinetic energy of molecules. Even at low temperatures, the speediest molecules can escape into the air. Some evaporation occurs at any temperature; a glass of water at room temperature, for example, will eventually evaporate completely. If a liquid is heated, the average kinetic energy of molecules increases and the liquid evaporates more rapidly.

Heat of vaporization is the quantity of heat a liquid must absorb for 1 g of it to be converted from the liquid to the gaseous state. For the same reason that water has a high specific heat, it also has a high heat of vaporization relative to most other liquids. To evaporate 1 g of water at 25°C, about 580 cal of heat is needed—nearly double the amount needed to vaporize a gram of alcohol, for example. Water's high heat of vaporization is another property emerging from the strength of its hydrogen bonds, which must be broken before the molecules can make their exodus from the liquid.

The high amount of energy required to vaporize water has a wide range of effects. On a global scale, for example, it helps moderate Earth's climate. A considerable amount of solar heat absorbed by tropical seas is consumed during the evaporation of surface water. Then, as moist tropical air circulates poleward, it releases heat as it condenses and forms rain. On an organismal level, water's high heat of vaporization accounts for the severity of steam burns. These burns are caused by the heat energy released when steam condenses into liquid on the skin.

As a liquid evaporates, the surface of the liquid that remains behind cools down. This **evaporative cooling** occurs because the "hottest" molecules, those with the greatest kinetic energy, are the ones most likely to leave as gas. It is as if the hundred fastest runners at a college transferred to another school; the average speed of the remaining students would decline.

Evaporative cooling of water contributes to the stability of temperature in lakes and ponds and also provides a mechanism that prevents terrestrial organisms from overheating. For example, evaporation of water from the leaves of a plant helps keep the tissues in the leaves from becoming too warm in the sunlight. Evaporation of sweat from human skin dissipates body heat and helps prevent overheating on a hot day or when excess heat is generated by strenuous activity. High humidity on a hot day increases discomfort because the high concentration of water vapor in the air inhibits the evaporation of sweat from the body.

Floating of Ice on Liquid Water

Water is one of the few substances that are less dense as a solid than as a liquid. In other words, ice floats on liquid water. While other materials contract and become denser when they solidify, water expands. The cause of this exotic behavior is, once again, hydrogen bonding. At temperatures above 4°C, water behaves like other liquids, expanding as it warms and contracting as it cools. As the temperature falls from 4°C to 0°C, water begins to freeze because more and more of its molecules are moving too slowly to break hydrogen bonds. At 0°C, the molecules become locked into a crystalline lattice, each water molecule hydrogen-bonded to four partners **(Figure 2.20)**. The hydrogen bonds keep the molecules at "arm's length," far enough apart to make ice about 10% less dense than liquid water at 4°C. When ice absorbs enough heat for its temperature to rise above 0°C, hydrogen bonds between molecules are disrupted. As the crystal collapses, the ice melts, and molecules are free to slip closer together. Water reaches its greatest density at 4°C and then begins to expand as the molecules move faster.

The ability of ice to float due to its lower density is an important factor in the suitability of the environment for life.

▶ **Figure 2.20 Ice: crystalline structure and floating barrier.** In ice, each molecule is hydrogen-bonded to four neighbors in a three-dimensional crystal. Because the crystal is spacious, ice has fewer molecules than an equal volume of liquid water. In other words, ice is less dense than liquid water. Floating ice becomes a barrier that protects the liquid water below from the colder air. The marine organism shown here is a type of shrimp called krill; it was photographed beneath floating ice in the Southern Ocean near Antarctica.

WHAT IF? *If water did not form hydrogen bonds, what would happen to the shrimp's environment?*

Hydrogen bond

Liquid water: Hydrogen bonds break and re-form
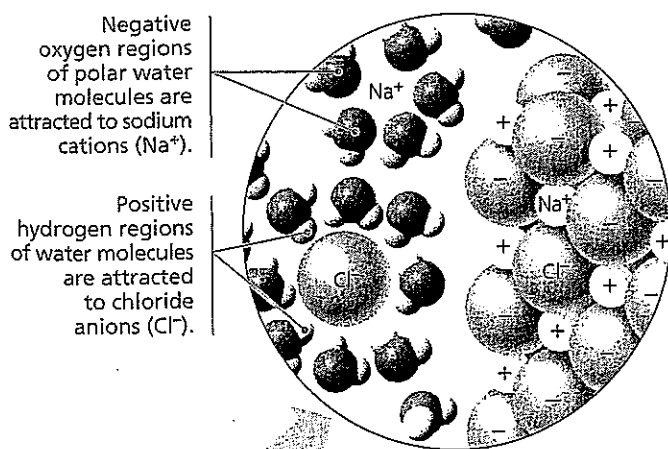
Ice: Hydrogen bonds are stable
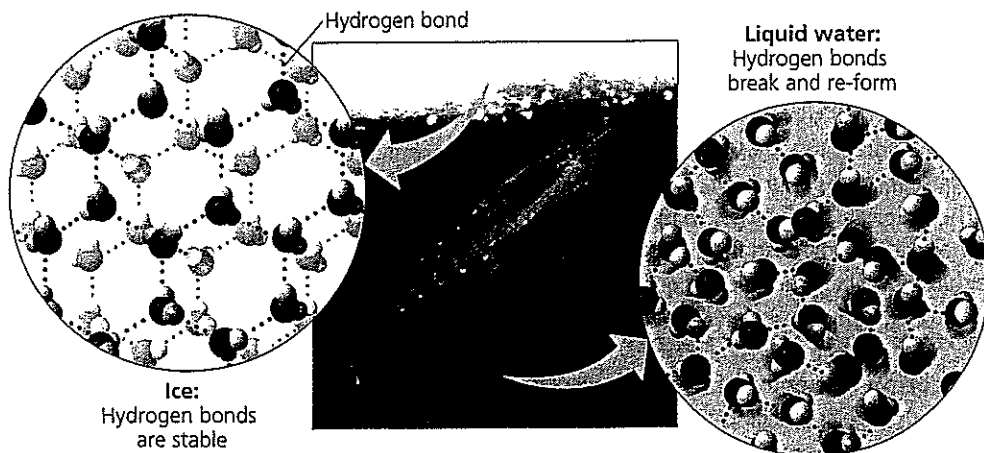
If ice sank, then eventually all ponds, lakes, and even oceans would freeze solid, making life as we know it impossible on Earth. During summer, only the upper few inches of the ocean would thaw. Instead, when a deep body of water cools, the floating ice insulates the liquid water below, preventing it from freezing and allowing life to exist under the frozen surface, as shown in the photo in Figure 2.20.

Water: The Solvent of Life

A sugar cube placed in a glass of water will dissolve. Eventually, the glass will contain a uniform mixture of sugar and water; the concentration of dissolved sugar will be the same everywhere in the mixture. A liquid that is a completely homogeneous mixture of two or more substances is called a **solution**. The dissolving agent of a solution is the **solvent**, and the substance that is dissolved is the **solute**. In this case, water is the solvent and sugar is the solute. An **aqueous solution** is one in which water is the solvent.

Water is a very versatile solvent, a quality we can trace to the polarity of the water molecule. Suppose, for example, that a spoonful of table salt, the ionic compound sodium chloride (NaCl), is placed in water (**Figure 2.21**). At the surface of each grain, or crystal, of salt, the sodium and chloride ions are exposed to the solvent. These ions and regions of the water molecules are attracted to each other owing to their opposite charges. The oxygen regions of the water molecules are negatively charged and are attracted to sodium cations. The hydrogen regions are positively charged and are attracted to chloride

anions. As a result, water molecules surround the individua sodium and chloride ions, separating and shielding them fr one another. The sphere of water molecules around each di solved ion is called a **hydration shell**. Working inward fron the surface of each salt crystal, water eventually dissolves al the ions. The result is a solution of two solutes, sodium cati and chloride anions, homogeneously mixed with water, the solvent. Other ionic compounds also dissolve in water. Seawater, for instance, contains a great variety of dissolved ion: as do living cells.

A compound does not need to be ionic to dissolve in wa many compounds made up of nonionic polar molecules, su as sugars, are also water-soluble. Such compounds dissolve when water molecules surround each of the solute molecul forming hydrogen bonds with them. Even molecules as larg as proteins can dissolve in water if they have ionic and pola regions on their surface (**Figure 2.22**). Many different kind polar compounds are dissolved (along with ions) in the wat of such biological fluids as blood, the sap of plants, and the uid within all cells. Water is the solvent of life.

Hydrophilic and Hydrophobic Substances

Any substance that has an affinity for water is said to be **hydrophilic** (from the Greek *hydro*, water, and *philos*, lovi In some cases, substances can be hydrophilic without actu: dissolving. For example, some molecules in cells are so larg that they do not dissolve. Another example of a hydrophilic substance that does not dissolve is cotton, a plant product. Cotton consists of giant molecules of cellulose, a compoun with numerous regions of partial positive and partial negat charges that can form hydrogen bonds with water. Water a heres to the cellulose fibers. Thus, a cotton towel does a gre job of drying the body, yet it does not dissolve in the washi

Negative oxygen regions of polar water molecules are attracted to sodium cations (Na⁺).

Positive hydrogen regions of water molecules are attracted to chloride anions (Cl⁻).

▲ **Figure 2.21 Table salt dissolving in water.** A sphere of water molecules, called a hydration shell, surrounds each solute ion.
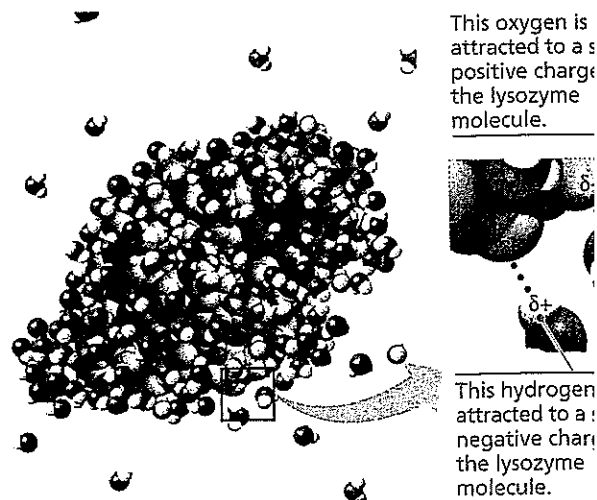
WHAT IF? *What would happen if you heated this solution for a long time?*

This oxygen is attracted to a : positive charge the lysozyme molecule.

This hydrogen attracted to a : negative char(the lysozyme molecule.

▲ **Figure 2.22 A water-soluble protein.** Human lysozyme is a protein found in tears and saliva that has antibacterial action. This r shows the lysozyme molecule (purple) in an aqueous environment. and polar regions on the protein's surface attract water molecules.

machine. Cellulose is also present in the walls of plant cells that conduct water; you read earlier how the adhesion of water to these hydrophilic walls helps water move up the plant against gravity.

There are, of course, substances that do not have an affinity for water. Substances that are nonionic and nonpolar (or otherwise cannot form hydrogen bonds) actually seem to repel water; these substances are said to be **hydrophobic** (from the Greek *phobos*, fearing). An example from the kitchen is vegetable oil, which, as you know, does not mix stably with water-based substances such as vinegar. The hydrophobic behavior of the oil molecules results from a prevalence of relatively nonpolar covalent bonds, in this case bonds between carbon and hydrogen, which share electrons almost equally. Hydrophobic molecules related to oils are major ingredients of cell membranes. (Imagine what would happen to a cell if its membrane dissolved!)

Solute Concentration in Aqueous Solutions

Most of the chemical reactions in organisms involve solutes dissolved in water. To understand such reactions, we must know how many atoms and molecules are involved and be able to calculate the concentration of solutes in an aqueous solution (the number of solute molecules in a volume of solution).

When carrying out experiments, we use mass to calculate the number of molecules. We first calculate the **molecular mass**, which is simply the sum of the masses of all the atoms in a molecule. As an example, let's calculate the molecular mass of table sugar (sucrose), $C_{12}H_{22}O_{11}$. In round numbers, sucrose has a molecular mass of $(12 \times 12) + (22 \times 1) + (11 \times 16) = 342$ daltons. Because we can't measure out small numbers of molecules, we usually measure substances in units called moles. Just as a dozen always means 12 objects, a **mole (mol)** represents an exact number of objects: 6.02×10^{23}, which is called Avogadro's number. There are 6.02×10^{23} daltons in 1 g. Once we determine the molecular mass of a molecule such as sucrose, we can use the same number (342), but with the unit *gram*, to represent the mass of 6.02×10^{23} molecules of sucrose, or 1 mol of sucrose. To obtain 1 mol of sucrose in the lab, therefore, we weigh out 342 g.

The practical advantage of measuring a quantity of chemicals in moles is that a mole of one substance has exactly the same number of molecules as a mole of any other substance. Measuring in moles makes it convenient for scientists working in the laboratory to combine substances in fixed ratios of molecules.

How would we make a liter (L) of solution consisting of 1 mol of sucrose dissolved in water? We would measure out 342 g of sucrose and then add enough water to bring the total volume of the solution up to 1 L. At that point, we would have a 1-molar (1 M) solution of sucrose. **Molarity**—the number of moles of solute per liter of solution—is the unit of concentration most often used by biologists for aqueous solutions.

Acids and Bases

Occasionally, a hydrogen atom participating in a hydrogen bond between two water molecules shifts from one molecule to the other. When this happens, the hydrogen atom leaves its electron behind, and what is actually transferred is a **hydrogen ion** (H^+), a single proton with a charge of $1+$. The water molecule that lost a proton is now a **hydroxide ion** (OH^-), which has a charge of $1-$. The proton binds to the other water molecule, making that molecule a **hydronium ion** (H_3O^+).

2 H_2O Hydronium ion (H_3O^+)   Hydroxide ion (OH^-)
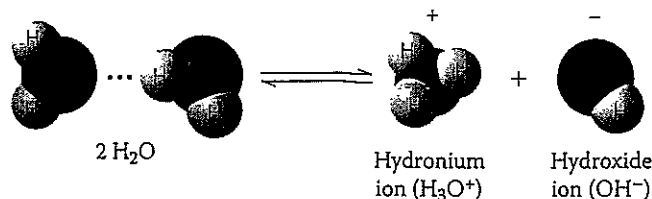
By convention, H^+ (the hydrogen ion) is used to represent H_3O^+ (the hydronium ion), and we follow that practice here. Keep in mind, though, that H^+ does not exist on its own in an aqueous solution. It is always associated with another water molecule in the form of H_3O^+.

As indicated by the double arrows, this is a reversible reaction that reaches a state of dynamic equilibrium when water molecules dissociate at the same rate that they are being re-formed from H^+ and OH^-. At this equilibrium point, the concentration of water molecules greatly exceeds the concentrations of H^+ and OH^-. In pure water, only one water molecule in every 554 million is dissociated; the concentration of each ion in pure water is $10^{-7} M$ (at 25°C). This means there is only one ten-millionth of a mole of hydrogen ions per liter of pure water and an equal number of hydroxide ions.

Although the dissociation of water is reversible and statistically rare, it is exceedingly important in the chemistry of life. H^+ and OH^- are very reactive. Changes in their concentrations can drastically affect a cell's proteins and other complex molecules. As we have seen, the concentrations of H^+ and OH^- are equal in pure water, but adding certain kinds of solutes, called acids and bases, disrupts this balance.

What would cause an aqueous solution to have an imbalance in H^+ and OH^- concentrations? When acids dissolve in water, they donate additional H^+ to the solution. An **acid** is a substance that increases the hydrogen ion concentration of a solution. For example, when hydrochloric acid (HCl) is added to water, hydrogen ions dissociate from chloride ions:

$$HCl \rightarrow H^+ + Cl^-$$
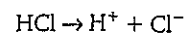
This source of H^+ (dissociation of water is the other source) results in an acidic solution—one having more H^+ than OH^-.

A substance that *reduces* the hydrogen ion concentration of a solution is called a **base**. Some bases reduce the H^+ concentration directly by accepting hydrogen ions. Ammonia (NH_3), for instance, acts as a base when the unshared electron pair in

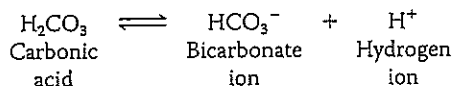nitrogen's valence shell attracts a hydrogen ion from the solution, resulting in an ammonium ion (NH_4^+):

$$NH_3 + H^+ \rightleftharpoons NH_4^+$$
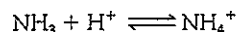
Other bases reduce the H^+ concentration indirectly by dissociating to form hydroxide ions, which combine with hydrogen ions and form water. One such base is sodium hydroxide (NaOH), which in water dissociates into its ions:

$$NaOH \rightarrow Na^+ + OH^-$$
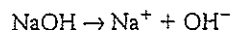
In either case, the base reduces the H^+ concentration. Solutions with a higher concentration of OH^- than H^+ are known as basic solutions. A solution in which the H^+ and OH^- concentrations are equal is said to be neutral.

Notice that single arrows were used in the reactions for HCl and NaOH. These compounds dissociate completely when mixed with water, so hydrochloric acid is called a strong acid and sodium hydroxide a strong base. In contrast, ammonia is a relatively weak base. The double arrows in the reaction for ammonia indicate that the binding and release of hydrogen ions are reversible reactions, although at equilibrium there will be a fixed ratio of NH_4^+ to NH_3.

There are also weak acids, which reversibly release and accept back hydrogen ions. An example is carbonic acid:

$$\underset{\substack{\text{Carbonic} \\ \text{acid}}}{H_2CO_3} \rightleftharpoons \underset{\substack{\text{Bicarbonate} \\ \text{ion}}}{HCO_3^-} + \underset{\substack{\text{Hydrogen} \\ \text{ion}}}{H^+}$$

Here the equilibrium so favors the reaction in the left direction that when carbonic acid is added to pure water, only 1% of the molecules are dissociated at any particular time. Still, that is enough to shift the balance of H^+ and OH^- from neutrality.

The pH Scale

In any aqueous solution at 25°C, the *product* of the H^+ and OH^- concentrations is constant at 10^{-14}. This can be written

$$[H^+][OH^-] = 10^{-14}$$

In such an equation, brackets indicate molar concentration. In a neutral solution at room temperature (25°C), $[H^+] = 10^{-7}$ and $[OH^-] = 10^{-7}$, so in this case, 10^{-14} is the product of $10^{-7} \times 10^{-7}$. If enough acid is added to a solution to increase $[H^+]$ to $10^{-5} M$, then $[OH^-]$ will decline by an equivalent amount to $10^{-9} M$ (note that $10^{-5} \times 10^{-9} = 10^{-14}$). This constant relationship expresses the behavior of acids and bases in an aqueous solution. An acid not only adds hydrogen ions to a solution, but also removes hydroxide ions because of the tendency for H^+ to combine with OH^-, forming water. A base has the opposite effect, increasing OH^- concentration but also reducing H^+ concentration by the formation of water. If enough of a base is added to raise the OH^- concentration to $10^{-4} M$, it will cause the H^+ concentration to drop to $10^{-10} M$. Whenever we know the concentration of either H^+ or OH^- in an aqueous solution, we can deduce the concentration of the other ion.

Because the H^+ and OH^- concentrations of solutions can vary by a factor of 100 trillion or more, scientists have developed a way to express this variation more conveniently than in moles per liter. The pH scale (**Figure 2.23**) compresses the range of H^+ and OH^- concentrations by employing logarithms. The pH of a solution is defined as the negative logarithm (base 10) of the hydrogen ion concentration:
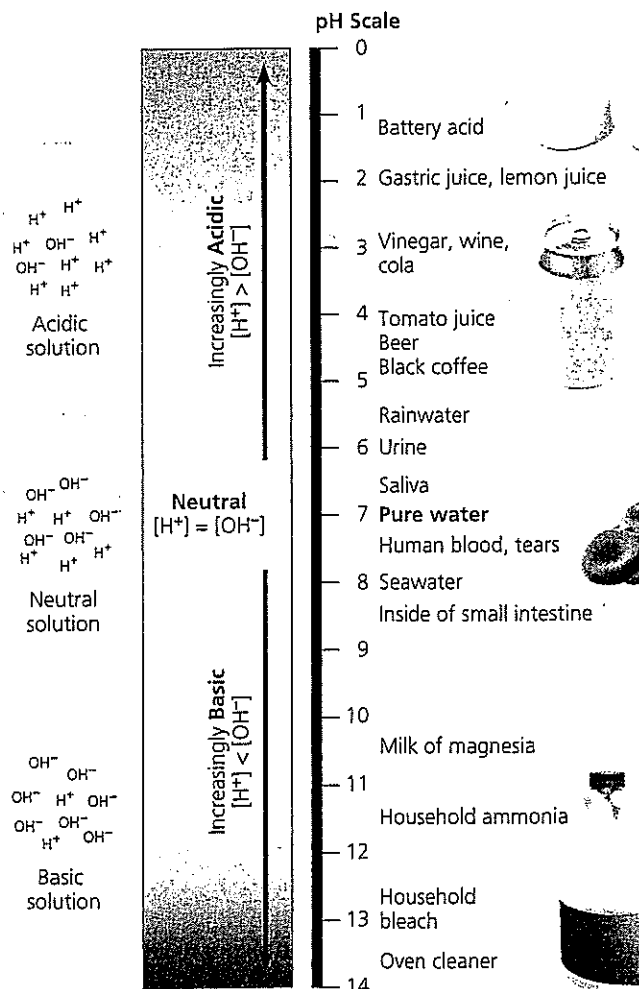
$$pH = -\log [H^+]$$

For a neutral aqueous solution, $[H^+]$ is $10^{-7} M$, giving us

$$-\log 10^{-7} = -(-7) = 7$$

Notice that pH *declines* as H^+ concentration *increases*. Notice too, that although the pH scale is based on H^+ concentration it also implies OH^- concentration. A solution of pH 10 has a hydrogen ion concentration of $10^{-10} M$ and a hydroxide ion concentration of $10^{-4} M$.

The pH of a neutral aqueous solution at 25°C is 7, the midpoint of the pH scale. A pH value less than 7 denotes an acid solution; the lower the number, the more acidic the solution.

pH Scale

Acidic solution — Increasingly Acidic [H^+] > [OH^-]

Neutral solution — Neutral [H^+] = [OH^-]

Basic solution — Increasingly Basic [H^+] < [OH^-]

- 0
- 1 Battery acid
- 2 Gastric juice, lemon juice
- 3 Vinegar, wine, cola
- 4 Tomato juice Beer
- 5 Black coffee
  Rainwater
- 6 Urine
  Saliva
- 7 **Pure water**
  Human blood, tears
- 8 Seawater
  Inside of small intestine
- 9
- 10
  Milk of magnesia
- 11
  Household ammonia
- 12
- 13 Household bleach
  Oven cleaner
- 14

▲ Figure 2.23 The pH scale and pH values of some aqueous solutions.

The pH for basic solutions is above 7. Most biological fluids are within the range pH 6–8. There are a few exceptions, however, including the strongly acidic digestive juice of the human stomach, which has a pH of about 2.
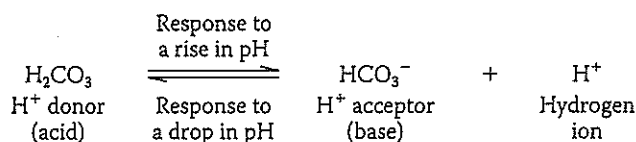
Remember that each pH unit represents a tenfold difference in H^+ and OH^- concentrations. It is this mathematical feature that makes the pH scale so compact. A solution of pH 3 is not twice as acidic as a solution of pH 6, but a thousand times ($10 \times 10 \times 10$) more acidic. When the pH of a solution changes slightly, the actual concentrations of H^+ and OH^- in the solution change substantially.

Buffers

The internal pH of most living cells is close to 7. Even a slight change in pH can be harmful because the chemical processes of the cell are very sensitive to the concentrations of hydrogen and hydroxide ions. The pH of human blood is very close to 7.4, which is slightly basic. A person cannot survive for more than a few minutes if the blood pH drops to 7 or rises to 7.8, and a chemical system exists in the blood that maintains a stable pH. If you add 0.01 mol of a strong acid to a liter of pure water, the pH drops from 7.0 to 2.0. If the same amount of acid is added to a liter of blood, however, the pH decrease is only from 7.4 to 7.3. Why does the addition of acid have so much less of an effect on the pH of blood than it does on the pH of water?

The presence of substances called buffers allows biological fluids to maintain a relatively constant pH despite the addition of acids or bases. A **buffer** is a substance that minimizes changes in the concentrations of H^+ and OH^- in a solution. It does so by accepting hydrogen ions from the solution when they are in excess and donating hydrogen ions to the solution when they have been depleted. Most buffer solutions contain a weak acid and its corresponding base, which combine reversibly with hydrogen ions.

There are several buffers that contribute to pH stability in human blood and many other biological solutions. One of these is carbonic acid (H_2CO_3), which is formed when CO_2 reacts with water in blood plasma. As mentioned earlier, carbonic acid dissociates to yield a bicarbonate ion (HCO_3^-) and a hydrogen ion (H^+):

$$\underset{\substack{H^+ \text{ donor} \\ \text{(acid)}}}{H_2CO_3} \xrightleftharpoons[\substack{\text{Response to} \\ \text{a drop in pH}}]{\substack{\text{Response to} \\ \text{a rise in pH}}} \underset{\substack{H^+ \text{ acceptor} \\ \text{(base)}}}{HCO_3^-} + \underset{\substack{\text{Hydrogen} \\ \text{ion}}}{H^+}$$

The chemical equilibrium between carbonic acid and bicarbonate acts as a pH regulator, the reaction shifting left or right as other processes in the solution add or remove hydrogen ions. If the H^+ concentration in blood begins to fall (that is, if pH rises), the reaction proceeds to the right and more carbonic acid dissociates, replenishing hydrogen ions. But when H^+ concentration in blood begins to rise (when pH drops), the
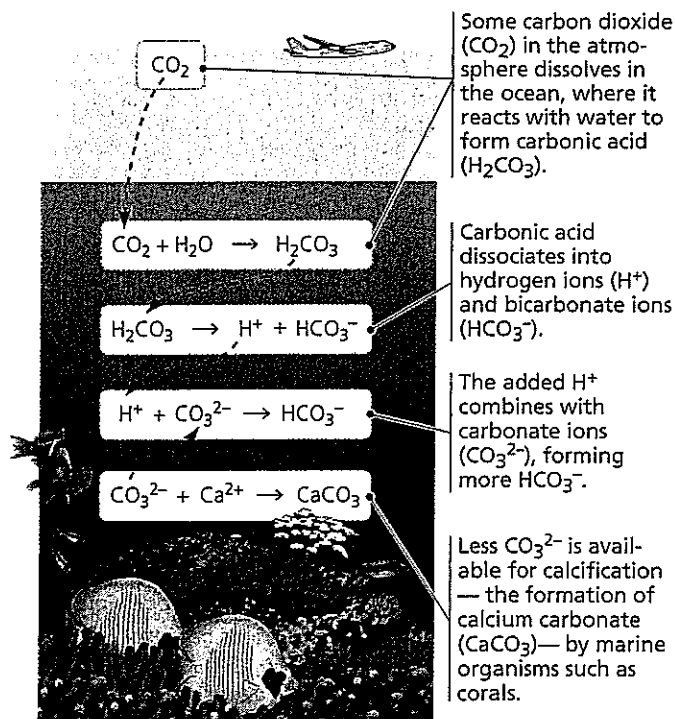
reaction proceeds to the left, with HCO_3^- (the base) removing the hydrogen ions from the solution and forming H_2CO_3. Thus, the carbonic acid–bicarbonate buffering system consists of an acid and a base in equilibrium with each other. Most other buffers are also acid-base pairs.

Acidification: A Threat to Our Oceans

Among the many threats to water quality posed by human activities is the burning of fossil fuels, which releases gaseous compounds into the atmosphere. When certain of these compounds react with water, the water becomes more acidic, altering the delicate balance of conditions for life on Earth.

Carbon dioxide is the main product of fossil fuel combustion. About 25% of human-generated CO_2 is absorbed by the oceans. In spite of the huge volume of water in the oceans, scientists worry that the absorption of so much CO_2 will harm marine ecosystems.

Recent data have shown that such fears are well founded. When CO_2 dissolves in seawater, it reacts with water to form carbonic acid, which lowers ocean pH, causing ocean acidification (see **Figure 2.24**). Based on measurements of CO_2 levels in air bubbles trapped in ice over thousands of years, scientists calculate that the pH of the oceans is 0.1 pH unit lower now than at any time in the past 420,000 years. Recent studies predict that it will drop another 0.3–0.5 pH unit by the end of this century.

$$CO_2 + H_2O \longrightarrow H_2CO_3$$

$$H_2CO_3 \longrightarrow H^+ + HCO_3^-$$

$$H^+ + CO_3^{2-} \longrightarrow HCO_3^-$$

$$CO_3^{2-} + Ca^{2+} \longrightarrow CaCO_3$$

Some carbon dioxide (CO_2) in the atmosphere dissolves in the ocean, where it reacts with water to form carbonic acid (H_2CO_3).

Carbonic acid dissociates into hydrogen ions (H^+) and bicarbonate ions (HCO_3^-).

The added H^+ combines with carbonate ions (CO_3^{2-}), forming more HCO_3^-.

Less CO_3^{2-} is available for calcification — the formation of calcium carbonate ($CaCO_3$)— by marine organisms such as corals.

▲ **Figure 2.24 Atmospheric CO_2 from human activities and its fate in the ocean.**

WHAT IF? *Would lowering the ocean's carbonate concentration have any effect, even indirectly, on organisms that don't form $CaCO_3$? Explain.*
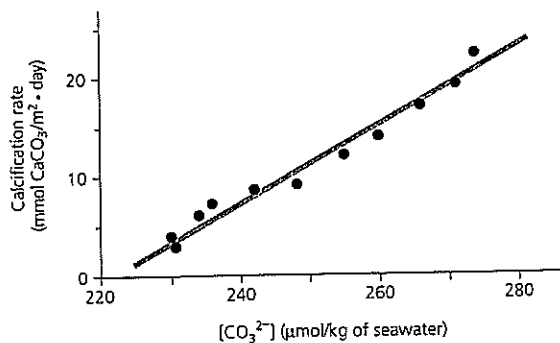
Interpreting a Scatter Plot with a Regression Line

How Does the Carbonate Ion Concentration of Seawater Affect the Calcification Rate of a Coral Reef? Scientists predict that acidification of the ocean due to higher levels of atmospheric CO_2 will lower the concentration of dissolved carbonate ions, which living corals use to build calcium carbonate reef structures. In this exercise, you will analyze data from a controlled experiment that examined the effect of carbonate ion concentration ($[CO_3^{2-}]$) on calcium carbonate deposition, a process called calcification.

How the Experiment Was Done The Biosphere 2 aquarium in Arizona contains a large coral reef system that behaves like a natural reef. For several years, a group of researchers measured the rate of calcification by the reef organisms and examined how the calcification rate changed with differing amounts of dissolved carbonate ions in the seawater.

Data from the Experiment The black data points in the graph below form a scatter plot. The red line, known as a linear regression line, is the best-fitting straight line for these points. These data are from one set of experiments, in which the pH, temperature, and calcium ion concentration of the seawater were held constant.

Calcification rate (mmol $CaCO_3$/m² · day) vs. $[CO_3^{2-}]$ (µmol/kg of seawater)

Interpret the Data

1. When presented with a graph of experimental data, the first step in analysis is to determine what each axis represents. (a) In words, explain what is being shown on the x-axis. Be sure to include the units. (b) What is being shown on the y-axis (including units)? (c) Which variable is the independent variable—the variable that was *manipulated* by the researchers? (d) Which variable is the dependent variable—the variable that responded to or depended on the treatment, which was *measured* by the researchers? (For additional information about graphs, see the Scientific Skills Review in Appendix F and in the Study Area in MasteringBiology.)

2. Based on the data shown in the graph, describe in words the relationship between carbonate ion concentration and calcification rate.

3. (a) If the seawater carbonate ion concentration is 270 µmol/kg, what is the approximate rate of calcification, and approximately how many days would it take 1 square meter of reef to accumulate 30 mmol of calcium carbonate ($CaCO_3$)? To determine the rate of calcification, draw a vertical line up from the x-axis at the value of 270 µmol/kg until it intersects the red line. Then draw a horizontal line from the intersection over to the y-axis to see wha the calcification rate is at that carbonate ion concentration. (b) If the seawater carbonate ion concentration is 250 µmol/kg, what is the approximate rate of calcification, and approximately how many days would it take 1 square meter of reef to accumulate 30 mmol of calcium carbonate? (c) If carbonate ion concentration decreases, how does the calcification rate change, and how does that affect the time it takes coral to grow?

4. (a) Referring to the equations in Figure 2.24, determine which step of the process is measured in this experiment. (b) Do the results of this experiment support the hypothesis that increased atmospheric $[CO_2]$ will slow the growth of coral reefs? Why or why not?

Data from C. Langdon et al., Effect of calcium carbonate saturation state on the calcification rate of an experimental coral reef, *Global Biogeochemical Cycles* 14:639–654 (2000).

(MB) A version of this Scientific Skills Exercise can be assigned in MasteringBiology.

As seawater acidifies, the extra hydrogen ions combine with carbonate ions (CO_3^{2-}) to form bicarbonate ions (HCO_3^-), thereby reducing the carbonate ion concentration (see Figure 2.24). Scientists predict that ocean acidification will cause the carbonate ion concentration to decrease by 40% by the year 2100. This is of great concern because carbonate ions are required for calcification, the production of calcium carbonate ($CaCO_3$), by many marine organisms, including reef-building corals and animals that build shells. The **Scientific Skills Exercise** gives you an opportunity to work with data from an experiment examining the effect of carbonate ion concentration on coral reefs. Coral reefs are sensitive ecosystems that act as havens for a great diversity of marine life. The disappearance of coral reef ecosystems would be a tragic loss of biological diversity.

CONCEPT CHECK 2.5

1. Describe how properties of water contribute to the upward movement of water in a tree.

2. How can the freezing of water crack boulders?

3. The concentration of the appetite-regulating hormone ghre is about 1.3×10^{-10} M in a fasting person. How many molecules of ghrelin are in 1 L of blood?

4. Compared with a basic solution at pH 9, the same volume c an acidic solution at pH 4 has ___ times as many hydrogen ions (H^+).

5. What would be the effect on the properties of the water molecule if oxygen and hydrogen had equal electronegativity?

For suggested answers, see Appendix A.

2 Chapter Review

SUMMARY OF KEY CONCEPTS

CONCEPT 2.1
Matter consists of chemical elements in pure form and in combinations called compounds (pp. 19–20)
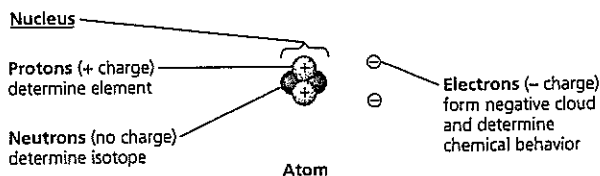
- **Elements** cannot be broken down chemically to other substances. A **compound** contains two or more different elements in a fixed ratio. Oxygen, carbon, hydrogen, and nitrogen make up approximately 96% of living matter.

> ❓ *In what way does the need for iodine or iron in your diet differ from your need for calcium or phosphorus?*

CONCEPT 2.2
An element's properties depend on the structure of its atoms (pp. 20–24)

- An **atom**, the smallest unit of an element, has the following components:

Nucleus

Protons (+ charge) determine element

Neutrons (no charge) determine isotope

Electrons (– charge) form negative cloud and determine chemical behavior

Atom

- An electrically neutral atom has equal numbers of electrons and protons; the number of protons determines the **atomic number**. **Isotopes** of an element differ from each other in neutron number and therefore mass. Unstable isotopes give off particles and energy as radioactivity.
- In an atom, electrons occupy specific **electron shells**; the electrons in a shell have a characteristic energy level. Electron distribution in shells determines the chemical behavior of an atom. An atom that has an incomplete outer shell, the **valence shell**, is reactive.

> 📝 *Draw the electron distribution diagrams for neon ($_{10}$Ne) and argon ($_{18}$Ar). Why are they chemically unreactive?*

CONCEPT 2.3
The formation and function of molecules depend on chemical bonding between atoms (pp. 24–28)

- **Chemical bonds** form when atoms interact and complete their valence shells. **Covalent bonds** form when pairs of electrons are shared. H_2 has a **single bond**: H — H. A **double bond** is the sharing of two pairs of electrons, as in O $=$ O.
- **Molecules** consist of two or more covalently bonded atoms. The attraction of an atom for the electrons of a covalent bond is its **electronegativity**. Electrons of a **polar covalent bond** are pulled closer to the more electronegative atom.
- An **ion** forms when an atom or molecule gains or loses an electron and becomes charged. An **ionic bond** is the attraction between two oppositely charged ions, such as Na^+ and Cl^-.
- Weak bonds reinforce the shapes of large molecules and help molecules adhere to each other. A **hydrogen bond** is an attraction between a hydrogen atom carrying a partial positive charge ($\delta+$) and an electronegative atom ($\delta-$). **Van der Waals interactions** occur between transiently positive and negative regions of molecules.

- Molecular shape is usually the basis for the recognition of one biological molecule by another.

> ❓ *In terms of electron sharing between atoms, compare nonpolar covalent bonds, polar covalent bonds, and the formation of ions.*

CONCEPT 2.4
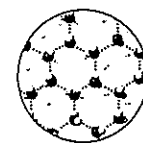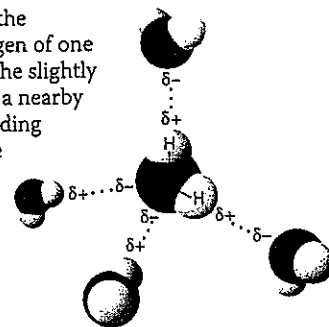### Chemical reactions make and break chemical bonds (pp. 28–29)

- **Chemical reactions** change **reactants** into **products** while conserving matter. All chemical reactions are theoretically reversible. **Chemical equilibrium** is reached when the forward and reverse reaction rates are equal.

> ❓ *What would happen to the concentration of products if more reactants were added to a reaction that was in chemical equilibrium? How would this addition affect the equilibrium?*
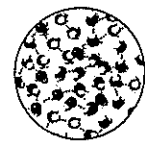
CONCEPT 2.5
Hydrogen bonding gives water properties that help make life possible on Earth (pp. 29–37)

- A hydrogen bond forms when the slightly negatively charged oxygen of one water molecule is attracted to the slightly positively charged hydrogen of a nearby water molecule. Hydrogen bonding between water molecules is the basis for water's properties.
- Hydrogen bonding keeps water molecules close to each other, giving water **cohesion**. Hydrogen bonding is also responsible for water's **surface tension**.
- Water has a high **specific heat**: Heat is absorbed when hydrogen bonds break and is released when hydrogen bonds form. This helps keep temperatures relatively steady, within limits that permit life. **Evaporative cooling** is based on water's high **heat of vaporization**. The evaporative loss of the most energetic water molecules cools a surface.
- Ice floats because it is less dense than liquid water. This property allows life to exist under the frozen surfaces of lakes and seas.

Ice: stable hydrogen bonds

Liquid water: transient hydrogen bonds

- Water is an unusually versatile **solvent** because its polar molecules are attracted to ions and polar substances that can form hydrogen bonds. **Hydrophilic** substances have an affinity for water; **hydrophobic** substances do not. **Molarity**, the number of moles of **solute** per liter of **solution**, is used as a measure of solute concentration in solutions. A **mole** is a certain number of molecules of a substance. The mass of a mole of a substance in grams is the same as the **molecular mass** in daltons.
- A water molecule can transfer an H^+ to another water molecule to form H_3O^+ (represented simply by H^+) and OH^-.
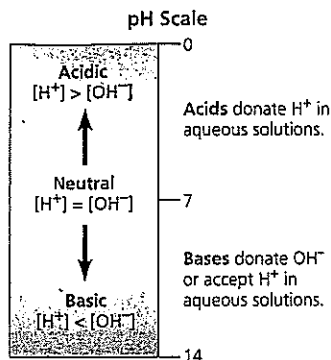
- The concentration of H^+ is expressed as **pH**; $pH = -\log [H^+]$. A **buffer** consists of an acid-base pair that combines reversibly with hydrogen ions, allowing it to resist pH changes.
- The burning of fossil fuels increases the amount of CO_2 in the atmosphere. Some CO_2 dissolves in the oceans, causing ocean acidification, which has potentially grave consequences for coral reefs.

pH Scale

Acidic
$[H^+] > [OH^-]$

Acids donate H^+ in aqueous solutions.

Neutral
$[H^+] = [OH^-]$

Bases donate OH^- or accept H^+ in aqueous solutions.

Basic
$[H^+] < [OH^-]$

Describe how the properties of water result from the molecule's polar covalent bonds and how these properties contribute to Earth's suitability for life.

TEST YOUR UNDERSTANDING

Level 1: Knowledge/Comprehension

1. The reactivity of an atom arises from
   (A) the average distance of the outermost electron shell from the nucleus.
   (B) the existence of unpaired electrons in the valence shell.
   (C) the sum of the potential energies of all the electron shells.
   (D) the potential energy of the valence shell.

2. Which of the following statements correctly describes any chemical reaction that has reached equilibrium?
   (A) The concentrations of products and reactants are equal.
   (B) The reaction is now irreversible.
   (C) Both forward and reverse reactions have halted.
   (D) The rates of the forward and reverse reactions are equal.

3. Many mammals control their body temperature by sweating. Which property of water is most directly responsible for the ability of sweat to lower body temperature?
   (A) water's change in density when it condenses
   (B) water's ability to dissolve molecules in the air
   (C) the release of heat by the formation of hydrogen bonds
   (D) the absorption of heat by the breaking of hydrogen bonds

4. We can be sure that a mole of table sugar and a mole of vitamin C are equal in their
   (A) mass in daltons.
   (B) mass in grams.
   (C) volume.
   (D) number of molecules.

5. Measurements show that the pH of a particular lake is 4.0. What is the hydrogen ion concentration of the lake?
   (A) $4.0 M$ (B) $10^{-10} M$ (C) $10^{-4} M$ (D) $10^4 M$

Level 2: Application/Analysis

6. The atomic number of sulfur is 16. Sulfur combines with hydrogen by covalent bonding to form a compound, hydrogen sulfide. Based on the number of valence electrons in a sulfur atom, predict the molecular formula of the compound.
   (A) HS   (B) HS_2 (C) H_2S (D) H_3S_2

7. What coefficients must be placed in the following blanks so that all atoms are accounted for in the products?
$$C_6H_{12}O_6 \rightarrow \underline{\quad} C_2H_6O + \underline{\quad} CO_2$$
   (A) 1; 2   (B) 3; 1   (C) 1; 3   (D) 2; 2

8. A slice of pizza has 500 kcal. If we could burn the pizza and use all the heat to warm a 50-L container of cold water, what would be the approximate increase in the temperature of the water? (*Note:* A liter of cold water weighs about 1 kg.)
   (A) 50°C   (B) 5°C   (C) 1°C   (D) 10°C

9. **DRAW IT** Draw the hydration shells that form around a potassium ion and a chloride ion when potassium chloride (KCl) dissolves in water. Label the positive, negative, and partial charges on the atoms.

Level 3: Synthesis/Evaluation

10. **SCIENTIFIC INQUIRY/Science Practices 3 & 4**
    Female silkworm moths (*Bombyx mori*) attract males by emitting chemical signals that spread through the air. A male hundreds of meters away can detect these molecules and fly toward their source. The sensory organs responsible for this behavior are the comblike antennae visible in the photograph shown here. Each filament of an antenna is equipped with thousands of receptor cells that detect the sex attractant.

    (a) Based on what you learned in this chapter, **formulate a hypothesis** to account for the ability of the male moth to detect a specific molecule in the presence of many other molecules in the air.
    (b) **Describe** the predictions your hypothesis enables you to make.
    (c) **Design an experiment** to test one of these predictions.

11. **FOCUS ON BIG IDEA 1**
    The percentages of naturally occurring elements making up the human body are similar to the percentages of these elements found in other organisms. How could you account for this similarity among organisms? **Explain** your thinking.

12. **FOCUS ON BIG IDEA 4**
    Several emergent properties of water contribute to the suitability of the environment for life. In a short essay (100–150 words), **describe** how the ability of water to function as a versatile solvent arises from the structure of water molecules.
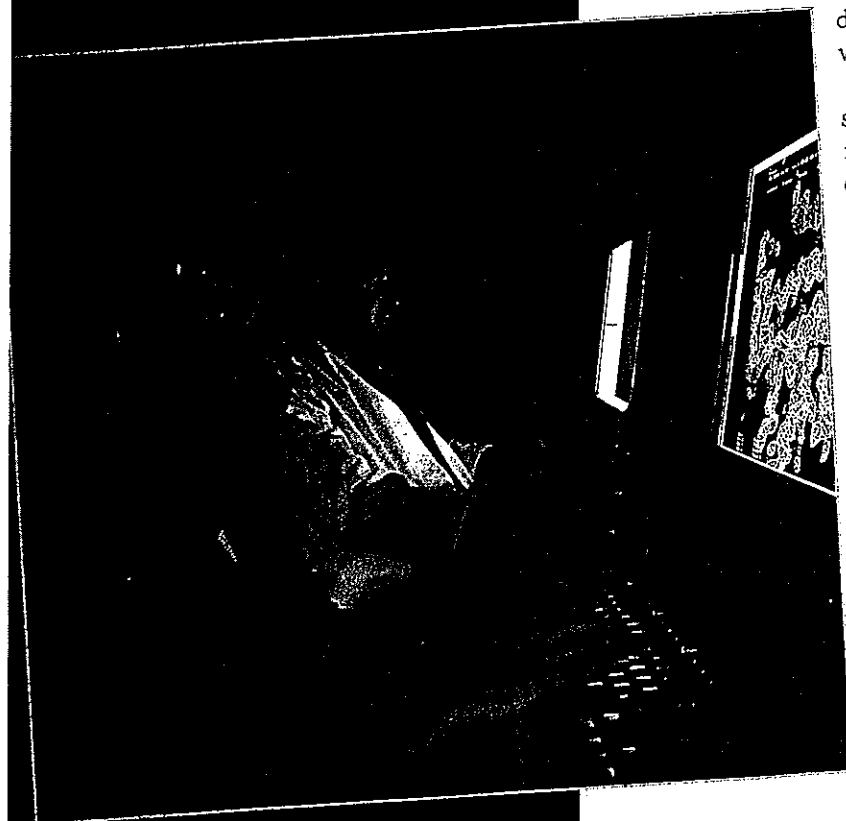
For selected answers, see Appendix A.

MasteringBiology®

Students Go to **MasteringBiology** for assignments, the eText, and the Study Area with practice tests, animations, and activities.

Instructors Go to **MasteringBiology** for automatically graded tutorials and questions that you can assign to your students, plus Instructor Resources.

Carbon and the Molecular Diversity of Life

OVERVIEW

Carbon Compounds and Life

Water is the universal medium for life on Earth, but water aside, living organisms are made up of chemicals based mostly on the element carbon. Of all chemical elements, carbon is unparalleled in its ability to form molecules that are large, complex, and varied. Hydrogen (H), oxygen (O), nitrogen (N), sulfur (S), and phosphorus (P) are other common ingredients of these compounds, but it is the element carbon (C) that accounts for the enormous variety of biological molecules. For historical reasons, a compound containing carbon is said to be an **organic compound**; furthermore, almost all organic compounds associated with life contain hydrogen atoms in addition to carbon atoms. Different species of organisms and even different individuals within a species are distinguished by variations in their large organic compounds.

Given the rich complexity of life on Earth, it may surprise you to learn that the critically important large molecules of all living things—from bacteria to elephants—fall into just four main classes: carbohydrates, lipids, proteins, and nucleic acids. On the molecular scale, members of three of these classes—carbohydrates, proteins, and nucleic acids—are huge and are therefore called **macromolecules**. For example, a protein may consist of thousands of atoms that form a molecular colossus with a mass well over 100,000 daltons. Considering the size and complexity of macromolecules, it is noteworthy that biochemists have determined the detailed structure of so many of them. The scientist in the foreground of **Figure 3.1** is using 3-D glasses to help her visualize the structure of the protein displayed on her screen. The structures of macromolecules can provide important information about their functions.

In this chapter, we'll first investigate the properties of small organic molecules and then go on to discuss the larger biological molecules. After considering how macromolecules are built, we'll examine the structure and function of all four classes of large biological molecules. The architecture of a large biological molecule helps explain how that molecule works. Like small molecules, large biological molecules exhibit unique emergent properties arising from the orderly arrangement of their atoms.

▽ **Figure 3.1** Why do scientists study the structures of macromolecules?

Make Connections All life-forms on Earth share biochemical similarities **(Big Idea 1)** that include large, complex molecules with common building blocks **(Big Idea 4).**

Chapter 2: The Chemical Context of Life

I.   Matter: _____

_____

   A. element:

      _____

      1. _____: needed by an organism to
         live a healthy lifestyle and reproduce.
            a) Examples:
      2. _____: required by an organism in minute
         quantities.
            a) examples:
      3. _____: elements that can harm or kill an
         organism
            a) examples:
   B. Compound: _____

_____

      1. Sodium Chloride (NaCl)
      2. Water (H2O)
II. Atom:

_____

   A. _____: positive charge, located in the nucleus, mass of 1 dalton
   (1amu)
   B. _____: neutral, located in the nucleus, mass of 1 dalton (1 amu)
   C. _____: negative charge, located in shells outside of the nucleus,
   negligible mass
   D. _____: total number of protons plus neutrons in the nucleus
   E. _____: number of protons in an atom
III. Isotopes:

_____

   A. _____: an isotope in which the nucleus decays spontaneously,
      giving off particles and energy.
         1. uses of radioactive isotopes:
            a. _____ (Carbon dating)
            b. _____
      2. dangers of radioactive isotopes:
      a. damage to cellular molecules

IV. Energy Levels of Electrons
    A. Electrons are the subatomic particle responsible for _____
    B. Energy: _____
        1. _____: the energy that matter possesses because
            of its location or structure.
            a. ex: water on a hill has potential energy due to its altitude.
        2. potential energy of an electron
            a. negatively charged electrons are attracted to positively charged nucleus.
            b. the greater the distance between the electron and the nucleus, the more
                _____ in the electron.
            c. changes in potential energy of electrons can only occur in steps of
                _____ _____- an electron's potential energy is
                determined by its energy level.
        3. electron shell- electrons are found in shells that have an average distance from
            the nucleus and an average energy level.
            a. first shell is closest to the nucleus and has the lowest potential energy.
                The further the shell, the more potential energy of the electrons in the
                shell.
            b. An electron can escape a shell by absorbing or losing energy
                i. absorbing energy= moving to a shell further from the nucleus
                ii. losing energy= moving to a shell closer to the nucleus
V. Electron Distribution and Chemical Properties
    A. The chemical behavior of an atom is determined by the distribution of
        _____ in the atom's electron shells.
        1. As you cross a period, the number of _____ and
            _____ in an element increase.
    B. _____: outer electrons. Found in the valence shell.
        1. the chemical behavior of an atom depends on the number of electrons in the
            valence shell.
            a. an atom with a complete valence shell are unreactive.
            b. atoms without complete valence shells are reactive.

Complete Questions 1-3 from page 24 in the space below

1.

2.

3

VI. Covalent Bonds:

_____

A. _____: two or more atoms held together by covalent bonds
   a. example: H2, O2
B. _____: sharing of one pair of electrons
C. _____: sharing of two pairs of electrons
D. _____: the bonding capacity of an atom (usually equals the number of electrons needed to complete the outermost shell of the atom)
E. _____: the attraction of an atom for electrons.
   a. fluorine is the most electronegative atom. Why?

   _____
   _____
   _____
   _____

F. _____: two atoms with the same electronegativity are bound together and the electrons are shared equally.
   a. Examples:
G. _____: when an atom is bonded to a more electronegative atom, the electrons will be closer to the more electronegative atom giving it a slightly negative charge while the less electronegative atom will have a slightly positive charge.
   a. Example:
VII. _____: one atom strips electrons from its partner (NaCl). This causes one ion to have a positive charge and the other to have a negative charge. The attraction of the opposite charges holds the molecule together.
   A. ion: a charged atom
      a. cation:

      _____

      b. anion:

      _____

   B. ionic compounds (salts): compounds formed by ionic bonds
      a. most drugs are manufactured as salts because they are stable when dry but dissociate when in water.
VIII. Weak Chemical Bonds
   A. _____: the noncovalent attraction between a hydrogen and an electronegative atom.
      a. Ex: water
      b. In the space below, draw a picture of the hydrogen bonding between two molecules of water. Include charges on the different atoms.

B. _____: ever-changing regions of
positive and negative charge that enable all atoms and molecules to stick to one
another.
     a. How are Van der Waals interactions important to proteins?

       _____

_____

_____

___

IX. Molecular Shape and Function
   A. What shape does water take? _____
   B. What is the basic shape taken by a molecule with 1 Carbon atom?

   _____

   C. Why is shape important?

     _____

_____

_____

Complete questions 1-3 on page 28 in the space below.

1.)

2.)

3.)

X. Chemical Reactions Make and Break Chemical Bonds
    A. _____ : the making and breaking of chemical
        bonds leading to changes in the composition of matter.
        a. _____ - starting materials of a reaction
        b. _____ - ending materials of a reaction
        c. _____ - reactions cannot create
        nor destroy matter but can only rearrange it.
    B. _____ : the point at which the
        reactions offset one another exactly. It is dynamic, meaning the reactions are constantly
        occurring but with no net effect on the concentrations of reactants and products.
XI. Properties of Water
    A. _____ : the unequal sharing of electrons in a molecule. In water,
        electrons are more attracted to Oxygen, so Oxygen has a slight negative charge while
        Hydrogen will have a slight positive charge.
    B. _____ : when water molecules bind to each other
        a. _____ : a measure of how difficult it is to break the
        surface of a liquid.
    C. _____ : when water binds to something that is not water.
    D. _____ : water absorbs heat from warm
        air and releases heat into cooler air.
        a. _____ : the energy of motion. The faster a molecule
        moves, the greater its kinetic energy.
        b. _____ : the kinetic energy associated with the random
        movement of atoms or molecules.
          i. _____ : the average kinetic energy of the molecules
    E. _____ : the amount of heat that must be
        absorbed or lost for 1 gram of that substance to change its temperature by 1 degree
        Celsius.
        a. Why does water have such a high specific heat?

        b. Why is the high specific heat of water important to life on earth?-

    F. Evaporative Cooling

a. _____: the quantity of heat a liquid must absorb for 1 gram to be converted from liquid to gas.
   i. why is this characteristic of water important?

b. _____: when the molecules with the most kinetic energy escape in a gaseous form causing the liquid to cool.
   i. why is humidity uncomfortable?

G. Floating of Ice
   a. What happens to water when it solidifies?

      i. Why is this important?

H. Water as a Solvent
   a. _____: a liquid that is a completely homogenous mixture of two or more substances.
      i. _____: the dissolving agent of a solution
      ii. _____: substance that is dissolved
      iii. _____: one in which the water is the solvent
      iv. _____: the sphere of water molecules around each dissolved ion
I. Hydrophilic and Hydrophobic Substances
   a. _____: substances with an affinity for water
      i. examples of hydrophilic molecules: salt, sugar
   b. _____: substances that repel water
      i. examples of hydrophobic molecules: oils, waxes
J. Solute Concentrations in Aqueous Solutions
   a. What is the advantage of measuring in mols?

   b. What is Molarity?

XII. Acids and Bases
   A. _____: a single proton with a charge 1+. Often binds to another water molecule to create a hydronium ion (H3O+)
   B. _____: charge of 1-.
   C. _____: a substance that increases the hydrogen ion concentration of a solution.
      a. examples: HCl
   D. _____: a substance that reduces the hydrogen ion concentration of a solution.
      a. examples: ammonia
      b. two ways that bases reduce H+ concentration
         i. _____
         ii. _____
   E. pH scale
      a. based on hydrogen ion concentration
         i. pH declines as hydrogen ion concentration increases
            1. pH below 7= _____
            2. pH above 7= _____
            3. pH of 7= _____
XIII. Buffers
   A. buffer: _____

   ___ _____

   ___
         a. example: carbonic acid in the blood
   B. acidification
      a. how does the level of Carbon Dioxide affect the ocean?

Page 37: Complete #s 1, 2, 3, 4

Graphing on Excel

Directions:.
1. Contact me at mbauman@mckasd.net and request an electronic copy of this assignment. The email subject should be *AP Summer Graphing Assignment.* Please include your name in the body of the email.
2. Save this file as a WORD document
2. Use Excel—any version you have to graph data... (or another spreadsheet style application)
3. Copy and paste the graphs AFTER each data set.
4. Answer the questions AFTER each graph.
5. Save Frequently!
6. **Bring Hard Copy on the 1st day of class**

Example of a graph well done based on the following data:

Time (hr)	Average Length of Root Tips in Solution with Al Ions (mm)	Average Length of Root Tips in Solution without Al Ions (mm)
0	2.0	2.0
1	2.1	2.2
2	2.2	2.4
3	2.4	2.8
4	2.6	2.9
5	2.7	3.2
6	2.8	3.7
7	2.8	3.9

Data is 'continuous'; use a line graph

XY (Scatter) graph style chosen for line graphs; used for comparing values of continuous data

Title: clear and accurate

Length of Root Tip Based on Al Ion Solution
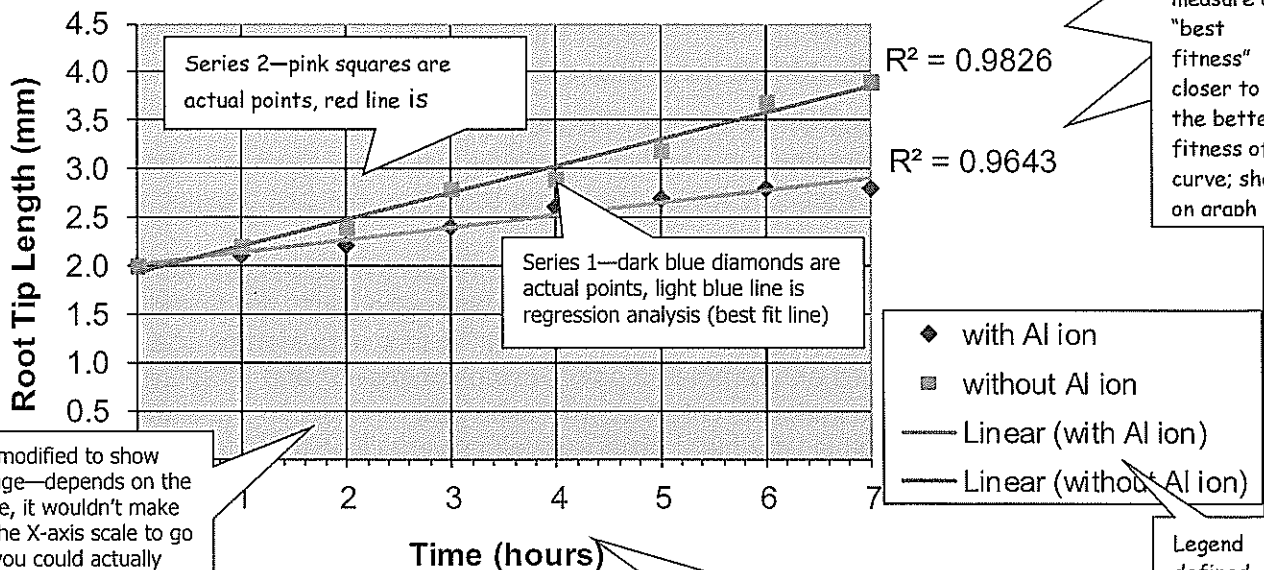
R-squared value is a measure of "best fitness" closer to 1.0, the better fitness of curve; show on graph

$R^2 = 0.9826$

$R^2 = 0.9643$

Series 2—pink squares are actual points, red line is

Series 1—dark blue diamonds are actual points, light blue line is regression analysis (best fit line)

Root Tip Length (mm)
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0.5

Time (hours)
2 3 4 5 6 7

◆ with Al ion
▨ without Al ion
— Linear (with Al ion)
— Linear (without Al ion)

Axis is modified to show correct range—depends on the data (here, it wouldn't make sense for the X-axis scale to go to 10; you could actually modify the Y-axis just to show from 2.0 to 4.0)

Both axes need to be labeled accordingly—units included

Legend defined clearly labeled

USING EXCEL TIPS

There are many ways to make graphs using Excel. Here are a few pointers that you can use for both the newer Excel and the older versions which are on many computers. It is important that your graphs are accurately presented in your lab reports. You want to have both a written description and graphical description of your results. Your graph should be able to tell the story of your results on its own...

USING OLDER EXCEL (up to 2003)

Making a Graph

1. Compose your data in a formatted table in Excel.
2. Insert → Chart (or use the Chart Wizard Icon)
3. For continuous data, you need to use line graphs, choose the XY (Scatter) type. Bar graphs follow similar but not identical procedures listed below.
4. Click on the "Series" tab.
5. Click "Add".
6. In the "Name:" box, put the correct label for this line/series.
7. In the "X Values:" box, click the right most section and then choose the cells that you want for the X-axis.
8. In the "Y Values:" box, click the right most section and then choose the cells that you want for the Y-axis.
9. Repeat steps 5 → 8 for each line/series you want to include. (You should see the points being plotted in the preview pane of the Chart Wizard—without a line)
10. Click "Next>".
11. Under the tab "Titles", put the title for the graph as well as the headings for each axis.
12. Under the tab "Axes", make sure both values boxes are checked.
13. Under the tabs Gridlines", "Legend", "and "Data Labels", decide which looks best.
14. Click "Next>".
15. Choose where you want to place the graph.

Formatting a Graph

16. Now that you have your graph, you can make it look presentable for your data.
17. Right-clicking on the title, axis labels, or legend gives you formatting options for all.
18. Right-clicking on the axis numbers (or anywhere on the axis) lets you format the appearance (font, color, how many decimals) of the numbers as well as scale shown (min/max values, major/minor divisions, linear or logarithmic, for each axis. You have to do this for both axes!
19. Right clicking on any of the points of one line and clicking on "Format Data Series" lets you modify the color/shape of the points, whether or not to connect the points, etc. (remember, if you have more than one line, you might need to adjust these more than once).

Using a Best-Fit line (Regression Analysis/Trendline)

20. Right clicking on any of the points of a line and clicking "Add Trendline" gives you the best fitting curve for the points. This is done mathematically for you based on the data—not just drawing a line through the points by eyeballing the data.
21. Under the "Type" tab, choose linear or logarithmic (for the respective series you want this for). Under the "Options" tab, you can forecast the best fit line forward or backward (units are based on axis scale) for extrapolation purposes. You can also click on the boxes for "Display equation on chart" (for determining slope as well as the exact values of interpolated points using **y=mx+b**) and "Display R-squared value on chart" (for seeing how well the variables correlate with each other—closer to 1.0 shows a high degree of correlation; the 'goodness of fit' is very high; observed values very close to expected).
22. Right-clicking on the trendline itself lets you change the label shown in the key, the color and or width of the line, etc.

USING Recent versions of EXCEL

Making a Graph

1. Compose your data in a formatted table in Excel.
2. Under the Insert tab, select "Scatter" from the list of charts. Choose the one that is just points (markers). Bar graphs follow similar but not identical procedures listed below.
3. A new set of tabs open up. It should be highlighted at the top of the Excel window. You can get these tabs anytime you click on the graph itself. Under the tab Chart Tools → Design, chose "Select Data".
4. Click "Add", under the Legend Entries (Series) menu.
5. In the "Series name:" box, put the correct label for this line/series.
6. In the "Series X Values:" box, click the right most section and then choose the cells that you want for the X-axis.
7. In the "Series Y Values:" box, click the right most section and then choose the cells that you want for the Y-axis.
8. Repeat steps 5 → 8 for each line/series you want to include (you should see the points being plotted in the preview pane of the Chart Wizard—with a line). Select "Ok" when you are done.
9. You should now see the graph in your Excel window. To remove the old-fashioned 'connect the dots' line, right-click on the actual graphed line. Select "Change Chart Type" and choose the type that just shows the points.
10. Under the tab Chart Tools → Layout, choose "Chart Title" and enter the title you want for the graph.
11. Under the tab Chart Tools → Layout, choose "Axis Titles", then select either "Primary Horizontal Axis Title" (for the X-axis) or the "Primary Vertical Axis Title" (for the Y-axis) and enter the labels you want for each.
12. You can alter the appearance of where the Legend shows or Data Labels with the drop down menus.

Formatting a Graph

13. Now that you have your graph, you can make it look presentable for your data.
14. Right-clicking on the title, axis labels, or legend gives you formatting options for all.
15. Right-clicking on the axis numbers, then selecting "Format Axis..." lets you format the appearance (font, color, how many decimals) of the numbers as well as scale shown (min/max values, major/minor divisions, linear or logarithmic, for each axis. You have to do this for both axes!
16. Right clicking on any of the points of one line and clicking on "Format Data Series..." lets you modify the color/shape of the points, whether or not to connect the points, etc. (remember, if you have more than one line, you might need to adjust these more than once).

Using a Best-Fit line (Regression Analysis/Trendline)

17. Right clicking on any of the points of a line and clicking "Add Trendline" gives you the best fitting curve for the points. This is done mathematically for you based on the data—not just drawing a line through the points by eyeballing the data. A window called "Trendline Options" will open up for trendline selection and formatting.
18. Under the "Trendline Options" subcategory, choose linear or logarithmic (for the respective series you want this for). You can also forecast the best fit line forward or backward (units are based on axis scale) for extrapolation purposes. You can also click on the boxes at the bottom of the window for "Display equation on chart" (for determining slope as well as the exact values of interpolated points using $y=mx+b$) and "Display R-squared value on chart" (for seeing how well the variables correlate with each other—closer to 1.0 shows a high degree of correlation; the 'goodness of fit' is very high; observed values very close to expected).
19. The other three selections in the "Format Trendline" window ("Line Color", "Line Style", and "Shadow") are for formatting the appearance of the trendline.

1. Baby chickens, like all baby birds, require a constant source of food. As chicks grow, more energy is required for daily activities, and their food requirements increase. The following data table reports the average food eaten by a group of 10 chickens over a 5-day period. Prepare a graph of the data points along with a best-fit curve (regression analysis trendline).

Baby Chicken Food Consumption

Day	Average Food Consumed (g)
1	1.0
2	3.2
3	6.5
4	10.6
5	15.4

Questions

1. Identify the independent and dependent variables.
2. How much grain will the chicks eat on day 6?
3. On day 7?
4. Both questions 2 and 3 have you *extrapolating* data from the set of points using a trendline. What is a danger of doing this?

Type answers for Problem Set 1 here:

PASTE GRAPH HERE

4

2. Elodea, a water plant commonly found in aquariums, gives off bubbles of oxygen when placed in bright light. Students in a biology class noted that if a light were placed at different distances from the plant in an aquarium, the rate of bubble production varied. The following data table shows the average results from several trials. Prepare a graph from the data. Create two trendlines—one linear and one logarithmic.

Elodea Bubble Production

Distance from Light (cm)	Bubble Production Rate (bubbles/min)
10	40
20	20
30	10
40	*
50	3

*They forgot to record data at this distance!

Questions

1. Identify the independent and dependent variables.
2. Use the R^2 values to decide which trendline best fits the relationship that exists. Which did you choose and why?
3. Estimate the O_2 production at 25 cm.
4. At 40 cm?
5. Questions 2 and 3 have you *interpolating* the data from the set of points. Can you do this if using a bar graph?

Type answers for Problem Set 2 here:

PASTE GRAPH HERE

3. The data below summarizes the results of a scientific experiment on the effects of a growth hormone (gibberellic acid) on plant height. A 0.1 molar solution was used in all experiments. Graph the data below—include a trendline for the given data.

Gibberellic Acid and Plant Height

Gibberellic Acid (0.1 M) (mL)	Plant Height at 1 Week (cm)
20	8.5
30	23.8
40	45.2
50	15.7
60	91.3

Questions

1. Identify the independent and dependent variables.
2. Explain why the plant height at 50 mL is not consistent with the rest of the data. What evidence can you use from the regression analysis to make this point?
3. Plot a second series that does not include the plant height at 50 mL of gibberellic acid and make a second trendline. How does this new analysis differ from the previous one?

Type answers for Problem Set 3 here:

PASTE GRAPH HERE

4. A team of scientists wanted to test the effects of temperature on the germination rate of pinto beans. They placed three sets of 100 pinto bean seeds in temperature-controlled chambers: Chamber A was set at 15° C, chamber B at 20°C, and chamber C at 25°C. Their results are shown in the table below. Plot the data including trendlines for each.

Germination Rates of Pinto Beans

Day	% Germination (15° C)	% Germination (20° C)	% Germination (25° C)
0	0	0	0
2	2	10	10
4	10	30	50
6	20	40	80
8	20	60	90
10	35	70	90

Questions

1. Identify the independent and dependent variables.
2. Summarize the experimental results.

Type answers for Problem Set 4 here:

PASTE GRAPH HERE

5. A number of Colonie High freshmen were working on their Making Connections lab and they collected data from over 100 students regarding their pulse rate at rest. The results are shown in the table below:

Resting Pulse Range (beats/min)	Number of Students
≤50	8
51-60	18
61-70	41
71-80	52
81-90	20
≥90	11

Use a bar graph for this set of data! Be careful to format it properly.

1. Summarize the significance of the 'curve' (pattern) shown by the graph.
2. Why would a line graph be inappropriate for this set of data?

Type answers for Problem Set 5 here:

PASTE GRAPH HERE

Reading and Taking Notes
on Scholarly Journal Articles

- Set aside enough time in your schedule to read material thoroughly and repeatedly, until you understand what the author is studying, arguing, or discussing.
- There are no short-cuts! You could learn to increase your speed while reading, but it is more important to learn how to comprehend what you read.
- Suspend any judgment or opinion about the reading until you have verified you really understand it.
- How often do we read and say to ourselves 'I have no clue what this author is talking about'? Don't give up, read it again!

Reading with a Purpose

- What is your goal or objective in the reading assignment? How you read should be determined by what you read.

[pleasure reading requires no particular skill level; to learn a new subject requires critical reading skills; reading a biology textbook requires different reflection than reading a history textbook; and reading a journal article requires critical analysis]

- Can I summarize the meaning of this text in my own words?
- What is clear to me and what do I need clarified?
- Can I connect the core ideas to other core ideas I do understand?

What is the system of logic?

- When you can effectively move back and forth between what you are reading and what you are thinking, you bring what you think to bear upon what you read and what you read to bear upon what you think.   (Elder & Paul, 2008)
- One reason reading is a passive activity for many students is because they have learned to read without understanding what good reading involves. One important way to understand what we read is to follow the logic behind the author's intent.

How to Understand the Author

- Authors of journal articles always have an argument; they are trying to convince you of something
- Authors can be both good and bad:
  - Good authors present you with new, research-based information
  - Bad authors can be biased and only present one side of the story
- You are an author too! Your thoughts and judgments about journal articles are worthwhile, so don't just take what other authors say on blind faith – ask questions!

How to Approach the Article

- When you read journal articles, think about how you are going to write a paper based on what you read.
- Keep in mind your own research question
- Focus on the information in the article that is relevant to your research question (you may be able to skim over other parts)
- Question everything you read - not everything is 100% true or correct
- Think critically about what you read and try to build your own argument based on it

Reading Strategy
The SQ3R Method

- **Survey**, skim, and scan entire reading assignment. Observe titles, subtitles, charts, diagrams, figures, tables. Preview the conclusion and summary and then the abstract/introduction. Think of this step as a "preview" to a movie you are about to watch.
- **Question** the authors' purpose and tone. Develop and write out questions about each section of the reading. You'll want to find the answers as you engage in the reading. Use these questions to guide your reading and your note-taking process.
- **Read** the assignment as thoroughly as possible. Read one section at a time, reflect on what you read, and don't get too bogged down with details. Search for the main ideas and supporting details. Keep reading!
- **Recite** and recall the information by summarizing and paraphrasing. Did you find the answers to the questions you wrote down earlier?
- **Review** the reading again and over time.

Reading the Article

- (Survey) Look at the structure of the article (most scientific articles follow the same specific format)
  - Abstract (summary of the whole article)
  - Introduction (why the author did the research)
  - Methodology (how the author did the research)
  - Results (what happened)
  - Discussion (what the results mean)
  - Conclusion (what the author learned)
  - References (whose research the author read)
- Read the abstract and conclusion first (these have the main points)
- If you find anything in the abstract or conclusion that is important for your paper, search for the information
- If you need more information, then read through whole sections (usually discussion or results section)
- "Close read" by deciding what parts of the reading are worthy of deeper study. This requires investigating early perceptions and scrutinizing possible significances.

Annotation
{the act of annotating, making notes, commenting upon}

- There are a few major ways to take notes (mapping, outlining, 2-column, word-for-word), but this is a personal style choice. Try different ways, but use the one that fits you best, and engages you in the topic.
- Pay attention to what each section is about. The Abstract, Discussion, and Conclusion sections usually have the most important information.
- Take notes while you are reading (that way you don't have to go back and re-read it when you write your paper)
- Write summarizing notes for main points in the margin, or on a separate piece of paper
- Highlight only very important quotes or terms

Sample Article Annotated

Memory works on 2 levels

①

focus/attention (what you need to know now) 7-9 items

②

what you know/ can recall (part of you)

HOW DOES MEMORY WORK?
Human memory works on two different levels: short term memory and long term memory.

Short term memory
This includes what you focus on in the moment, what holds your attention. Most people can only hold about 7 items of information in short term memory at any given moment, although some can hold up to nine.
Look at example A below. Then look away and try to hold it in your short term memory.
A = 6593028
Most likely, you can hold it as long as you choose. Now follow the same procedure with example B.
B = 573927450621
It's much more difficult, if not impossible, for most people.
Short term memory is exactly what the name says: short term. To learn information so you can retain and recall it, you must transfer it from short term to long term memory.

Long term memory
This includes all the information that you know and can recall. In many ways, it becomes a part of you. Once information becomes a part of your long term memory, you'll have access to it for a long time.

FROM SHORT TERM TO LONG TERM
How do you move information into long term memory? Two of the ways are: *rote learning* and *learning through understanding*.

continued

mechanical memorizing ex: alphabet

understanding ex: main ideas & details of a lecture

often combined ex: dates & concepts

Rote learning means learning through repetition, mechanically, with little understanding. For example, as a child you probably memorized the alphabet and the multiplication tables by rote.
Learning through understanding involves learning and remembering by understanding the relationships among ideas and information. Rather than using *rote memory*, you use *logical* memory when you learn through understanding. For example, you use logical memory when you remember main ideas and supporting details from a lecture not because you repeat the ideas in your mind, but rather, because you understand them.
Both types of learning and memory are useful and often are used together. For example, in history, you need to relate facts (like dates) which you memorized by rote to your understanding of historical concepts (like the Civil War) *4*

THE KEYS TO REMEMBERING
You can learn to remember more effectively if you learn and use the four keys described below. Each one helps you to enter information into your long term memory.

1. **Choose to remember.** Be interested. Pay attention. Want to learn and know. What you want is an important part of learning. People learn more effectively and remember more when they are interested and want to learn.
How can you choose to remember? One way is to take a few moments to choose to learn before you read or listen to a lecture. Sit calmly, take a few deep breaths, and tell yourself with your inner voice: "I choose to remember what I learn today." Repeat this a few times, and then begin.

2. **Visualize or picture in your mind what you wish to remember.** For many people, a mental picture or visualization is clearer and easier to remember than words. For each major concept that you want to remember, create a mental picture and then look at it carefully for a few seconds. Once you've seen it clearly, you'll probably be able to recall it.
If you are not a visual learner, you may find that you need to improve the quality of your mental pictures or images by practicing. Look at a picture, object, or photograph, then close your eyes and try to see it in your mind's eye. Practice this for a few moments each day.

connect new information to old (like filing)

③

Relate the ideas and information you wish to remember to each other and to ideas and information you already know. When you relate information to other information, you create a chain of memories which lead to one another. When you label an information chain or group of ideas, you create a kind of "file" that makes it easy to locate and remember the information.

You can help yourself to relate information by using mental pictures, visual organizers, or by outlining.

④

Repeat what you wish to learn until you *overlearn* it. Say it in your own words. Even though you've already learned something, go over it one more time. Research shows that the time you spend on *overlearning* and putting ideas into your own words will pay off by making recall easier and more complete.

If you are having difficulty annotating paragraphs, try annotating something visual for practice.
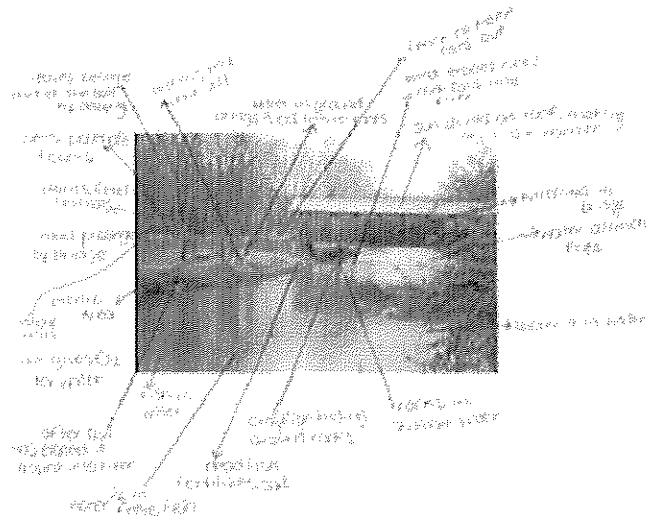
Photograph of Earth System Science

http://serc.carleton.edu/eslabs/climate/2a.html

Nonmedical Vaccine Exemptions and Pertussis in California, 2010

WHAT'S KNOWN ON THIS SUBJECT: Previous studies have shown that nonmedical exemptions (NMEs) to immunization cluster geographically and contribute to outbreaks of vaccine-preventable diseases such as pertussis. The 2010 pertussis resurgence in California has been widely attributed to waning immunity from acellular pertussis vaccines.

WHAT THIS STUDY ADDS: This study provides evidence of spatial and temporal clustering of NMEs and clustering of pertussis cases and suggests that geographic areas with high NME rates were also associated with high rates of pertussis in California in 2010.

AUTHORS: Jessica E. Atwell, MPH,[a] Josh Van Otterloo, MSPH,[b] Jennifer Zipprich, PhD,[c] Kathleen Winter, MPH,[c] Kathleen Harriman, PhD, MPH, RN,[c] Daniel A. Salmon, PhD,[a] Neal A. Halsey, MD,[a] and Saad B. Omer, MBBS, MPH, PhD[b]

[a]Department of International Health, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland; [b]Emory University School of Public Health, Atlanta, Georgia; and [c]Immunization Branch, California Department of Public Health, Richmond, California

BACKGROUND: In 2010, 9120 cases of pertussis were reported in California, more than any year since 1947. Although this resurgence has been widely attributed to waning immunity of the acellular vaccine, the role of vaccine refusal has not been explored in the published literature. Many factors likely contributed to the outbreak, including the cyclical nature of pertussis, improved diagnosis, and waning immunity; however, it is important to understand if clustering of unvaccinated individuals also played a role.

METHODS: We analyzed nonmedical exemptions (NMEs) for children entering kindergarten from 2005 through 2010 and pertussis cases with onset in 2010 in California to determine if NMEs increased in that period, if children obtaining NMEs clustered spatially, if pertussis cases clustered spatially and temporally, and if there was statistically significant overlap between clusters of NMEs and cases.

RESULTS: Kulldorff's scan statistics identified 39 statistically significant clusters of high NME rates and 2 statistically significant clusters of pertussis cases in this time period. Census tracts within an exemptions cluster were 2.5 times more likely to be in a pertussis cluster (odds ratio = 2.47, 95% confidence interval: 2.22–2.75). More cases occurred within as compared with outside exemptions clusters (incident rate ratios = 1.20, 95% confidence interval: 1.10–1.30). The association remained significant after adjustment for demographic factors. NMEs clustered spatially and were associated with clusters of pertussis cases.

CONCLUSIONS: Our data suggest clustering of NMEs may have been 1 of several factors in the 2010 California pertussis resurgence. *Pediatrics* 2013;132:624–630

Before introduction of pertussis-containing vaccines in the 1940s, pertussis was a leading cause of childhood mortality in the United States.[1] In 1934, there were >265 000 cases nationally, compared with a nadir of 1010 cases in 1976.[1] Pertussis is a cyclical disease with peaks in incidence approximately every 2 to 5 years when the number of susceptible people increases sufficiently to sustain transmission[2,3]; however, a substantial resurgence of pertussis has occurred in recent years.[4] Significant increases in pertussis activity began in 2003 and continued through 2005 in various locations throughout the United States, including California and the Midwest.[4] Although ~5100 to 7800 cases had been seen nationally each year in the late 1990s and early 2000s, >25 000 cases were reported in the United States in both 2004 and 2005.[4] In 2010, California experienced an outbreak of 9120 cases of pertussis and 10 deaths, representing one-third of all cases seen in the country that year.[4–6] Although a statewide outbreak occurred in California in 2005 as well, the magnitude of cases seen in 2010 was unprecedented, with more cases reported in California in 2010 than in any year since 1947.[5]

This outbreak has largely been attributed to waning immunity of acellular pertussis vaccines and other explanations including large birth cohorts of susceptible infants, increased detection of cases, and the possibility of genetic changes in circulating strains have been widely discussed in recent months.[2,3,7–12] Importantly, however, the role that nonmedical exemptions (NMEs) and clustering of unvaccinated individuals may have played in this outbreak has not been investigated. NMEs to immunization have been on the rise in many states in recent years, including California.[13–17] Correlations between the ease of obtaining NMEs

and the rates of NMEs have been demonstrated.[13,14,18,19] From 2000 to 2010, California's NME rates more than tripled from 0.77% to 2.33%, with some schools reporting NME rates as high as 84% in 2010.[20] Despite recent increases in NMEs, most estimates of statewide immunization coverage remain high. In 2010, 90.7% of the 509 849 students enrolled in reporting kindergartens (including conditional entrants) received all required immunizations, yet statewide coverage estimates can obscure lower community-level immunization rates.

Given what other studies have shown about the geographic clustering of unvaccinated or undervaccinated individuals, increased risk among vaccine refusers, and geographic and temporal clustering of pertussis outbreaks,[21] it is possible that refusal may also play a role in this resurgence. Our aim is to understand if refusal, and specifically geographic clustering of persons with NMEs, were contributing factors to the 2010 resurgence of pertussis in California. To explore these relationships, we evaluated the spatial clustering of NMEs from the 2005–2006 school year through the 2009–2010 school year and the space-time clustering of pertussis cases in 2010.

METHODS

Data Sources and Study Population

Data on NMEs for kindergarten students, the number of children enrolled in kindergarten (public and private), and pertussis cases were obtained from publically available data reported by the California Department of Public Health (CDPH). NME data were available for all elementary schools in California with ≥10 students for the school years 2005–2006 to 2009–2010. Parents in California can obtain NMEs if all or some immunizations are contrary to

their beliefs, whether those beliefs are religious, philosophical, or related to other unspecified nonmedical reasons.[22] The process of obtaining an NME varies across states; California only requires a signed form from the parent, whereas in other states, the process is more difficult.[23] Although California refers to such nonmedical philosophical or religious exemptions as Personal Belief Exemptions, we use the term NME here to indicate all exemptions for nonmedical reasons.

Pertussis is a reportable disease in California, and our data set included all confirmed, probable, and suspect pertussis cases reported to CDPH with onset dates from January 1, 2010, through December 31, 2010. According to CDPH, the clinical case definition of confirmed and probable pertussis in 2010 was a cough illness lasting ≥2 weeks without other apparent cause (as reported by a health professional) and ≥1 of the following: paroxysms of coughing, inspiratory "whoop," or posttussive vomiting. CDPH also used a suspect case category defined as an acute cough illness of any duration with detection of Bordetella pertussis–specific nucleic acid by polymerase chain reaction or an acute cough illness of any duration with ≥1 of the following: paroxysms of coughing, inspiratory "whoop," or posttussive vomiting that is epidemiologically linked directly to a confirmed case.[24]

Data on age, gender, race/ethnicity, date of onset, and outcome were also included for each case. All school addresses were geocoded to their exact point location (latitude and longitude). To protect confidentiality, pertussis data were geocoded and aggregated to the census-tract level by CDPH staff before data were shared with the other investigators. School enrollment and number of NMEs were aggregated to the census tract level.

Temporal Trends in Exemption Rates and Cluster Identification

NME rates for each school year were calculated by dividing the number of children with NMEs by the total number of kindergarten children in each census tract. We used generalized estimating equations to compute incident rate ratios (IRRs) and evaluate temporal trends in exemption rates, treating each census tract as a repeated observation. Census-tract-level kindergarten enrollment numbers were used as denominators in models evaluating NME temporal trends.

Kulldorff spatial scan statistics were used to identify spatial and space-time clusters of events.[25] Because the investigators considered the buildup of susceptibles to be a long-term phenomenon, and we observed within-school stability of NME rates (despite a temporal trend), we chose a spatial Poisson model for identifying school exemption clusters. Clustering of pertussis cases was considered a relatively short-term occurrence, and a space-time Poisson model was used to identify clusters of monthly pertussis cases. A detailed description of this application of Kulldorff spatial scan statistics and additional notes on the methods used here can be found in the Supplemental Information.

Evaluation of Census Tract Demographic Variables, the Overlap of NME and Pertussis Case Clusters, and the Incidence of Pertussis Within Versus Outside NME Clusters

Simple and multivariate logistic regression models were used to compute odds ratios (ORs) comparing demographic characteristics of census tracts inside versus outside NME clusters and pertussis case clusters. The demographic variables (from 2005–2009 American Community Survey estimates) of proportion of racial and ethnic minorities

(proportion of the population identifying as not non-Hispanic white), average family size, population density, percent of the population with a college degree, median household income, and being within a metropolitan area (defined as Rural Urban Commuting Areas code, which characterizes census tracts according to their rural and urban status[26]) were chosen a priori based on epidemiologic plausibility or evidence in the literature of associations with individual-level vaccine refusal.[21,27] Logistic regression models were used to estimate the overlap between NME clusters and pertussis clusters. We estimated the overlap by calculating the ratio of the odds of a census tract within a NME cluster also being within a pertussis cluster compared with the odds of a census tract outside a NME cluster also being in a pertussis cluster.

We used repeated-measures negative binomial regression models to compare the likelihood of being a pertussis case inside versus outside census tracts belonging to a NME cluster. Census-tract-level population values were used as denominators in models evaluating population dynamics. In addition to simple regression models for overlap and incidence, we used multivariate regression models adjusting for proportion of racial and ethnic minorities, average family size, median age, percent of the population with a college degree, median household income, and being within a metropolitan area.

Analytical Tools and Statistical Significance

School addresses were geocoded using ArcGIS (ESRI, Redlands, CA). Pertussis cases were geocoded at CDPH by using the California Environmental Health Tracking Program's geocoding tool on a secure server. Geographic cluster analysis was performed by using

SatScan version 8.0 (Information Management Services Inc, Boston, MA). All regression and other statistical analyses were performed with SAS v9.3 (SAS Institute, Inc, Cary, NC). Results were considered significant at $\alpha = .05$.

Ethical Review

The Institutional Review Boards of CDPH, Johns Hopkins School of Public Health, and Emory Rollins School of Public Health deemed this project nonhuman subjects research. Non-CDPH staff members were not allowed access to disaggregated case data or personal identifying information.

RESULTS

Data on NME rates were obtained from 8360 schools during the 2005–2006 to 2009–2010 school years, producing 36 447 school years of NME rate data. One hundred percent of schools in the 2008–2009 and 2009–2010 school years were successfully geocoded. Of schools in the 2005–2006, 2006–2007, and 2007–2008 school years, 575 (7.80%), 386 (5.24%), and 326 (4.46%), respectively, could not be geocoded because of missing or incomplete addresses and were excluded from the analysis. In 2010, 9143 confirmed, probable, and suspect pertussis cases were reported. Of these, 622 (7.15%) cases could not be geocoded because of missing or incomplete addresses and were excluded from this analysis. Analyses comparing gender, age, ethnicity, race, and mortality between the entire data set and geocoded cases did not differ by >1% in any category; therefore, the subset of cases geocoded is likely to be representative of all cases.

The mean census-tract-level NME rate increased from 1.6% in the 2005–2006 school year to 2.4% in the 2009–2010 school year (yearly IRR = 1.11, 95% confidence interval [CI]: 1.10–1.12). During the study period, 39 statistically

significant clusters of high NME rates were identified (Tables 1 and 2, Fig 1), ranging from large geographic areas to single census tracts. Results from bivariate analysis with demographic variables are shown in Table 3.

Reported pertussis cases varied by month from <100 in January 2010 to a peak of >1000 in August 2010. Two statistically significant clusters of pertussis cases were identified spanning from May 2010 to October 2010 and from July 2010 to November 2010 (Tables 1 and 2, Fig 1). Significant demographic characteristics associated with pertussis clusters are shown in Table 3.

Census tracts within a NME cluster were more likely to be in a pertussis case cluster than census tracts outside of a NME cluster (OR = 2.47, 95% CI: 2.22–2.75). The association between the overlap remained significant after adjustment for proportion of racial/ethnic minorities, population density, average family size, proportion of the population with a college degree, metropolitan area designation, and median household income (OR = 1.73, 95% CI: 1.53–1.96).

The incidence of pertussis was higher within NME clusters than outside of NME clusters (IRR = 1.20, 95% CI: 1.10–1.30). The association remained significant after adjustment for demographic factors (IRR = 1.12, 95% CI: 1.02–1.23).

DISCUSSION

Our findings suggest that geographic areas with high rates of NMEs are associated with high rates of pertussis. The contribution of NMEs to the changing epidemiology of pertussis should be acknowledged and explored

TABLE 1 Personal Beliefs Exemption Spatial Clusters From 2005–2010

Exemptions Cluster	Cluster Centroid		Observed Exemptions	Expected Exemptions	Relative Risk	P	Description
	Latitude °N	Longitude °W					
1	40.866	124.079	10 020	4923.43	2.39	<.001	Northern California
2	33.540	119.454	4183	1673.52	2.68	<.001	Greater Santa Barbara area
3	33.254	117.323	5122	2371.48	2.34	<.001	Greater Escondido area
4	37.062	122.200	1178	185.43	6.52	<.001	Greater Santa Cruz area
5	33.612	117.89	882	351.27	2.55	<.001	Mission Viejo Area
6	33.116	116.290	133	9.35	14.27	<.001	Eastern San Diego County
7	33.878	117.588	22	0.0024	>100	<.001	Corona
8	34.112	118.400	589	257.36	2.31	<.001	Beverly Hills area
9	35.368	120.857	331	104.3	3.19	<.001	San Luis Obispo area
10	35.361	119.139	19	0.014	>100	<.001	West Bakersfield
11	35.394	119.013	73	10.79	6.78	<.001	North Bakersfield
12	34.301	116.949	131	36.9	3.56	<.001	Big Bear Lake area
13	35.112	118.570	91	24.55	3.71	<.001	Bear Valley Springs/Tehachapi
14	34.612	116.97	69	16.54	4.18	<.001	Victorville area
15	33.999	118.310	7	0.0084	>100	<.001	Vermont Harbor area
16	34.185	118.14	38	6.79	5.6	<.001	Altadena area
17	34.516	118.404	303	182.14	1.67	<.001	Canyon Country area
18	34.105	118.278	36	7.27	4.95	<.001	Los Feliz area
19	34.137	118.081	53	15.1	3.51	<.001	East Pasadena
20	34.689	118.174	6	0.024	>100	<.001	Lancaster
21	33.898	117.769	193	109.69	1.76	<.001	Northeast Orange County
22	34.340	118.288	4	0.0043	>100	<.001	Western Los Angeles
23	34.877	118.319	5	0.019	>100	<.001	Willow Springs area
24	34.015	117.030	4	0.0065	>100	<.001	Southeastern Yucaipa
25	33.760	118.104	45	14.14	3.18	<.001	Seal Beach area
26	34.129	118.158	32	8.07	3.97	<.001	South Arroyo area
27	33.965	118.378	18	2.96	6.09	<.001	Western Inglewood
28	34.164	118.338	36	11.58	3.11	<.001	Magnolia Park area
29	33.784	117.975	23	5.35	4.3	<.001	Northeast Garden Grove
30	34.638	118.223	77	37.95	2.03	.001	Quartz Hill area
31	33.708	117.958	3	0.0066	>100	.001	Fountain Valley area
32	34.151	117.590	110	62.71	1.76	.003	Northern Rancho Cucamonga
33	34.059	118.293	2	0.0006	>100	.003	Rampart Village area
34	33.984	116.905	2	0.0006	>100	.003	Northern Banning area
35	33.902	117.862	9	0.8	11.27	.006	North Placentia area
36	34.005	118.123	2	0.00091	>100	.01	South Montebello
37	35.544	117.278	89	48.97	1.82	.01	Northwest San Bernardino County
38	34.117	117.292	3	0.018	>100	.02	Central San Bernardino
39	33.860	117.315	3	0.019	>100	.02	Woodcrest Area

TABLE 2 Pertussis Case Spatial-Temporal Clusters in 2010 in California

Pertussis Cluster	Cluster Centroid		Start Date	End Date	Observed Cases	Expected Cases	Relative Risk	P	Description
	Latitude °N	Longitude °W							
1	36.201	121.153	May 2010	Oct 2010	3783	1835.53	2.91	<.001	Central California
2	33.231	117.097	July 2010	Nov 2010	980	390.52	2.71	<.001	San Diego County
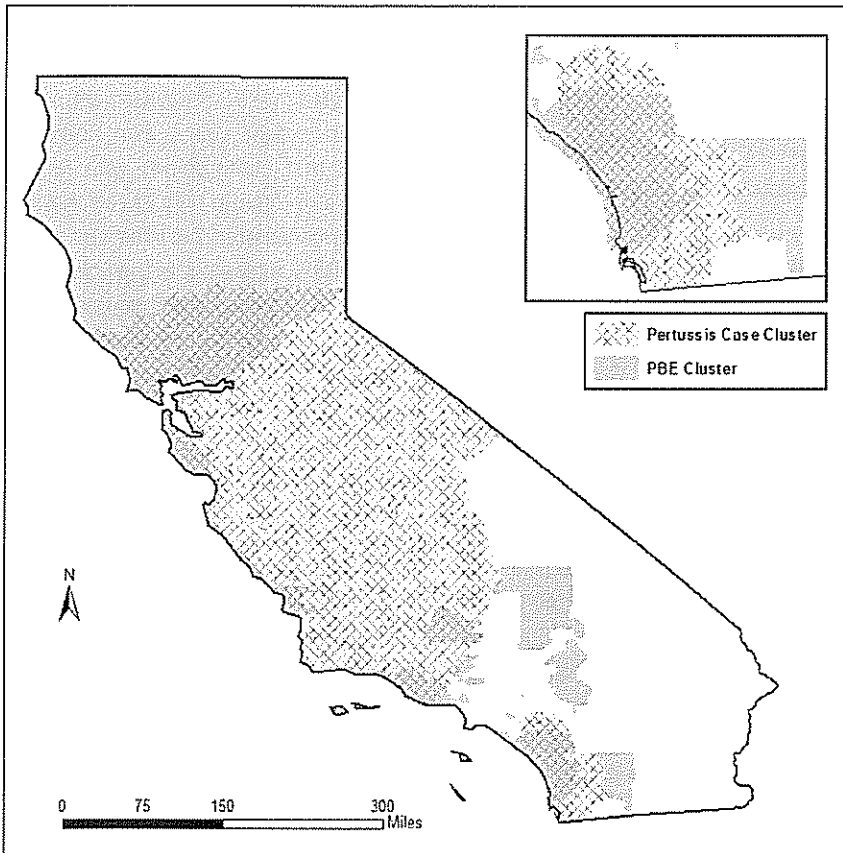
FIGURE 1
Relative locations of pertussis space-time clusters and personal beliefs exemption (PBE) clusters from 2005–2006 to 2009–2010. The inset in the top right corner shows the relative locations of pertussis space-time clusters and PBE spatial clusters in San Diego County.

in future studies along with other contributing factors, such as waning immunity of acellular vaccines.

In California, both NME and pertussis clusters were associated with factors characteristic of high socioeconomic status such as lower population density; lower average family size; lower percentage of racial or ethnic minorities; higher percentage of high school, college, or graduate school graduates; higher median household income; and lower percentage of families in poverty.

Although statewide immunization coverage in California is high among children entering kindergarten, in many communities within the state, coverage is far lower. Our findings are consistent with a previous study in which NMEs were associated with pertussis clusters.[21] Several studies have previously demonstrated the increased risk of vaccine-preventable diseases among those who refuse vaccines.[15,16,21,27–29] Other studies have shown increased community level-risk of vaccine-preventable diseases for persons living in areas with high NME rates.[21,28] With diseases like pertussis and measles, which have the highest known infectious disease reproduction numbers,[30] it is estimated that >95% of the population must be immune to prevent outbreaks and suppress sustained transmission.[30,31] Herd immunity must be maintained to reduce the risk of disease for those too young to be vaccinated or unable to receive vaccines.

This analysis is subject to several limitations. NME data from California do not contain specific data on which vaccine(s) or dose(s) were not received by a child with a NME, and it is possible that some children with a NME were completely vaccinated against pertussis. Future studies should attempt to analyze varying rates of vaccine avoidance for specific antigens to determine the magnitude of impact within populations with high NMEs. Furthermore, NME data from kindergarten entry are a 1-time measurement and only a proxy for community-level vaccination coverage and immunity. Immunization status of cases was not available for a large enough proportion of the pertussis cases to include this variable in our analysis. Also, underreporting of pertussis is known to occur, particularly in adults.[32,33] California implemented the "suspect" case definition to capture cases with positive polymerase chain reaction test results but for whom complete clinical information was not available. Analyses of subgroups by various combinations of case definition were not possible with this data set but should be incorporated into future analyses.

TABLE 3 Comparison of California Census Tracts Within Clusters Compared With Census Tracts Outside Clusters (Bivariate Logistic Regression Results)

Variable	Exemption Clusters	Pertussis Clusters
	OR (95% CI)	OR (95% CI)
Population density (100 person/square mile increase)	0.99 (0.99–0.99)	1.00 (0.99–1.00)
Outside of metro area (compared with inside)	2.01 (1.66–2.41)	1.27 (1.06–1.52)
Average family size (1 unit increase)	0.18 (0.16–0.20)	0.44 (0.45–0.53)
Percent nonwhite (1% increase)	0.96 (0.95–0.96)	0.98 (0.98–0.99)
Percent high school graduates (1% increase)	1.06 (1.06–1.07)	1.02 (1.02–1.03)
Percent college graduates (1% increase)	1.03 (1.03–1.03)	1.01 (1.01–1.02)
Percent graduate school graduates (1% increase)	1.05 (1.04–1.05)	1.03 (1.02–1.04)
Median household income ($10 000 increase)	1.12 (1.11–1.14)	1.10 (1.08–1.12)
Percent of families in poverty (1% increase)	0.95 (0.94–0.95)	0.97 (0.97–0.98)
Percent of families with children under age 5 in poverty (1% increase)	0.99 (0.99–0.99)	0.99 (0.99–1.00)

Schools with <10 students were not included in the data set provided by CDPH for this analysis because the CDPH expects that these schools are likely to be individual family home schools. Although the number of homeschooled children in the state is unknown, the US Department of Education estimates that ~1% of the school-age population nationally is homeschooled.[34] Exclusion of homeschooled children could affect the results of this analysis if homeschooled children are more or less likely to be immunized compared with children who are not homeschooled or if homeschooled children cluster geographically. Additional analysis of immunization coverage among homeschooled children should be explored.

We used census tracts as the unit of analysis to maintain compatibility with available demographic data and retain confidentiality of precise case location. It is possible that students did not attend schools within the census tract where they resided, but our clustering analysis identified geographically adjacent areas that most likely captured the residences of most children attending a given school. Additionally, size and location of clusters are influenced by underlying state characteristics such as geography, demographics, and population density. This complicates comparisons of such analyses from different states or geographic regions. Finally, small area problems could be an issue here, but this concern is not unique to analyses such as these.[35] Our

results are still significant despite the small number of exemptions in some clusters and would remain essentially the same if such clusters were removed from the analysis.

CONCLUSIONS

Other studies have shown evidence to support several factors that have likely contributed to the increase in pertussis cases in recent years. Our findings suggest that communities with large numbers of intentionally unvaccinated or undervaccinated persons can lead to pertussis outbreaks. In the presence of limited vaccine effectiveness and waning immunity, sustained community-level transmission can occur, putting those who are most susceptible to communicable diseases, such as young infants, at increased risk.

ACKNOWLEDGMENTS

REFERENCES

1. Centers for Disease Control and Prevention. In: Atkinson W, Hamborsky J, Wolfe S, eds. *Epidemiology and Prevention of Vaccine-Preventable Diseases*. 12th ed. Washington, DC: Public Health Foundation; 2012
2. Cherry JD. Why do pertussis vaccines fail? *Pediatrics*. 2012;129(5):968–970
3. Mattoo S, Cherry JD. Molecular pathogenesis, epidemiology, and clinical manifestations of respiratory infections due to *Bordetella pertussis* and other *Bordetella* subspecies. *Clin Microbiol Rev.* 2005;18(2):326–382
4. Centers for Disease Control and Prevention National Center for Immunization and Respiratory Diseases. Pertussis cases by year (1922–2012). 2013. Available at: www.cdc.gov/pertussis/surv-reporting/cases-by-year.html. Accessed August 11, 2013
5. Winter K, Harriman K, Zipprich J, et al. California pertussis epidemic, 2010. *Pediatrics*. 2012;161(6):1091–1096
6. Harriman K. Department of Health and Human Services Centers for Disease Control and Prevention Advisory Committee on Immunization Practices (ACIP) Summary Report. 2010. Available at: www.cdc.gov/vaccines/acip/meetings/downloads/min-archive/min-oct10.pdf. Accessed August 20, 2013

7. Cherry JD. Epidemic pertussis in 2012—the resurgence of a vaccine-preventable disease. *N Engl J Med.* 2012;367(9):785–787
8. Misegades LK, Winter K, Harriman K, et al. Association of childhood pertussis with receipt of 5 doses of pertussis vaccine by time since last vaccine dose, California, 2010. *JAMA.* 2012;308(20):2126–2132
9. Misegades LK, Martin SW, Messonnier NE, Clark TA. Estimating the effectiveness of acellular pertussis vaccines. *Clin Infect Dis.* 2012;55(10):1432–1433
10. Shapiro ED. Acellular vaccines and resurgence of pertussis. *JAMA.* 2013;308(20):2149–2150

11. Klein NP, Bartlett J, Rowhani-Rahbar A, Fireman B, Baxter R. Waning protection after fifth dose of acellular pertussis vaccine in children. *N Engl J Med.* 2012;367 (11):1012–1019

12. Witt MA, Katz PH, Witt DJ. Unexpectedly limited durability of immunity following acellular pertussis vaccination in pre-adolescents in a North American outbreak. *Clin Infect Dis.* 2012;54(12):1730–1735

13. Thompson JW, Tyson S, Card-Higginson P, et al. Impact of addition of philosophical exemptions on childhood immunization rates. *Am J Prev Med.* 2007;32(3):194–201

14. Omer SB, Pan WK, Halsey NA, et al. Nonmedical exemptions to school immunization requirements. *JAMA.* 2006;296(14):1757–1763

15. Salmon DA, Phillips L, Smith NJ, Chen RT, Page P. Health consequences of religious and philosophical exemptions from immunization laws. *JAMA.* 1999;281(1):47–54

16. Omer SB, Salmon DA, Orenstein WA, DeHart PM, Halsey N. Vaccine refusal, mandatory immunization, and the risks of vaccine-preventable diseases. *N Engl J Med.* 2009; 360(19):1981–1988

17. Salmon DA, Smith PJ, Navar AM, et al. Measuring immunization coverage among preschool children: past, present, and future opportunities. *Epidemiol Rev.* 2006;28: 27–40

18. Salmon DA, Omer SB, Moulton LH, et al. Exemptions to school immunization requirements: the role of school-level requirements, policies, and procedures. *Am J Public Health.* 2005;95(3):436–440

19. Safi H, Wheeler JG, Reeve GR, et al. Vaccine policy and Arkansas childhood immuniza-tion exemptions: a multi-year review. *Am J Prev Med.* 2012;42(6):602–605

20. Centers for Disease Control and Prevention National Center for Immunization and Respiratory Diseases. School vaccination coverage reports 2010–2011. Available at: www2.cdc.gov/nip/schoolsurv/rptgmenu.asp. Accessed August 20, 2013

21. Omer SB, Enger KS, Moulton LH, Halsey NA, Stokley S, Salmon DA. Geographic clustering of nonmedical exemptions to school immunization requirements and associations with geographic clustering of pertussis. *Am J Epidemiol.* 2008;168(12):1389–1396

22. The California Office of Administrative Law. Immunization against poliomyelitis, diphtheria, pertussis, tetanus, measles (rubeola), Haemophilus influenzae type B (hib) and mumps. California code of regulations. Title 17, Division 1, Subchapter 8

23. Johns Hopkins Bloomberg School of Public Health Institute for Vaccine Safety. Vaccine exemptions. 2012. Available at: www.vacci-nesafety.edu/cc-exem.htm. Accessed January 16, 2013

24. California Department of Public Health. Pertussis: CDPH case definition. 2010. Available at: www.cdph.ca.gov/programs/immunize/documents/CDPH_pertussis_case_definition_8_2010.pdf. Accessed January 16, 2013

25. Kulldorff M. A spatial scan statistic. *Comm Statist Theory Methods.* 1997;26(6):1481–1496

26. United States Department of Agriculture Economic Research Service. Rural-urban commuting area codes. Available at: www.ers.usda.gov/data.ruralurbancommunityareacodes. Accessed June 6, 2012

27. Hutchins SS, Baughman AL, Orr M, Haley C, Hadler S. Vaccination levels associated with lack of measles transmission among preschool-aged populations in the United States, 1989–1991. *J Infect Dis.* 2004;189 (suppl 1):S108–S115

28. Feikin DR, Lezotte DC, Hamman RF, Salmon DA, Chen RT, Hoffman RE. Individual and community risks of measles and pertussis associated with personal exemptions to immunization. *JAMA.* 2000;284(24):3145–3150

29. Berger BE, Omer SB. Could the United States experience rubella outbreaks as a result of vaccine refusal and disease importation? *Hum Vaccin.* 2010;6(12):1016–1020

30. Anderson RM, May RM. Immunization and herd immunity. *Lancet.* 1990;335:641–645

31. Fine P, Eames K, Heymann DL. "Herd immunity": a rough guide. *Clin Infect Dis.* 2011;52(7):911–916

32. Cornia PB, Hersh AL, Lipsky BA, Newman TB. Does this coughing adolescent or adult patient have pertussis? *JAMA.* 2010;304(8): 890–896

33. Cagney M, MacIntyre CR, McIntyre P, Torvaldsen S, Melot V. Cough symptoms in children aged 5–14 years in Sydney, Australia: non-specific cough or unrecognized pertussis? *Respirology.* 2005;10:359–364

34. Homeschool Association of California. General information about homeschooling. Available at: www.hsc.org/homeschoolinghelp/general-information.html. Accessed January 16, 2013

35. Moulton L, Foxman B, Wolfe R, Port F. Potential pitfalls in interpreting maps of stabilized rates. *Epidemiology.* 1994;5(3):297–301

Nonmedical Vaccine Exemptions and Pertussis in California, 2010

Jessica E. Atwell, Josh Van Otterloo, Jennifer Zipprich, Kathleen Winter, Kathleen Harriman, Daniel A. Salmon, Neal A. Halsey and Saad B. Omer

Updated Information & Services	including high resolution figures, can be found at: /content/early/2013/09/24/peds.2013-0878
Supplementary Material	Supplementary material can be found at: /content/suppl/2013/09/24/peds.2013-0878.DCSupplemental. html
Citations	This article has been cited by 23 HighWire-hosted articles: /content/early/2013/09/24/peds.2013-0878#related-urls
Permissions & Licensing	Information about reproducing this article in parts (figures, tables) or in its entirety can be found online at: /site/misc/Permissions.xhtml
Reprints	Information about ordering reprints can be found online: /site/misc/reprints.xhtml

American Academy of Pediatrics

DEDICATED TO THE HEALTH OF ALL CHILDREN

PEDIATRICS®

Nonmedical Vaccine Exemptions and Pertussis in California, 2010

Jessica E. Atwell, Josh Van Otterloo, Jennifer Zipprich, Kathleen Winter, Kathleen Harriman, Daniel A. Salmon, Neal A. Halsey and Saad B. Omer

The online version of this article, along with updated information and services, is located on the World Wide Web at:
/content/early/2013/09/24/peds.2013-0878

American Academy of Pediatrics
DEDICATED TO THE HEALTH OF ALL CHILDREN™

Contemporary Biology Article Assignment

The science of biology is a dynamic, ever changing field. Many scientists earn a living by doing research: they make observations, carry out experiments, try to figure out what their new information means, and use it to ask new questions about what we still don't know. As a result, people are making new discoveries all the time, adding to our knowledge, overturning old theories and tossing out 'facts' when new information shows them to be wrong. Information gathered by researchers is said by some people to be value-free. That is, by itself, it simply describes or characterizes biological phenomena, which is neither good nor bad, moral nor immoral. Yet, the results of biological research often have an impact on our daily lives, even if the original goal was 'pure' science or curiosity about the living world. The new (and old) information can be used to make important decisions that have far-reaching effects—whether it is better to open up a forest to economic development, for example, or to continue protecting it to keep species from extinction. Scientific discoveries are also used to develop new products and technologies which themselves can lead to unforeseen problems, such as the rise of antibiotic-resistant bacteria, or insecticide-resistant agricultural pests. It is not so much the finding of scientific research but the ways in which those findings are used that create social, political, and moral dilemmas Another and perhaps more pressing aspect of contemporary biology is our potential as humans to affect the conditions on our planet. With the great rise in human population size, we are producing global changes that are already affecting the existence of other species and will almost certainly affect our own ability to survive. Awareness and understanding of the biological principles at work here are critical, for our growing impact on the Earth will require us to make decisions about the fate of the global bio-system within our lifetimes.

As a well-educated student of biology, you should be able to catch the excitement of new research developments and anticipate how new findings in biology can affect your life—perhaps influencing a medical decision that you have to make, the food you eat, or the air you breathe. To these ends, this exercise requires you to read the news, find resources on contemporary research, and talk and write about what you learn. The main point of this exercise is to increase your awareness of biological science as a vital and changing discipline. It will also help you to develop skills for thinking and talking about what you read. You will find one contemporary article dealing with the biological discipline. Make sure it is from a respectable source, you can check with me if you are unsure about the source or content

YOUR ARTICLE ASSIGHNMENT SHOULD BE TYPED, AND CONTAIN THE FOLLOWING:

1. SUMMARY:

An explanation of what the news story is about and why it is a 'newsworthy' topic. Why do people need to know this? What did the researchers want to find out and what did they discover? How did they make their discovery? How many people were involved? Was it necessary to devise new equipment, or develop a new technique? What is the future of this research or findings? What did you learn from this article?

Remember this must be presented in your own words!!!

2. SOCIAL IMPLICATIONS:

Was the article you read about 'value free' research, or are there important social, political, or economic aspects? For example, if it is about a new medicine or diagnostic test, how much does it cost? Who will (or should) have access to it?

Who will decide these things? Try to imagine how this new information might affect people you know.

3. QUALITY:

Comment on how well you think the subject was presented and why you liked or didn't like the article, or the information it contained. Be opinionated. Did the article seem objective or biased? Did the author rely on just one source of information, or several? How reliable or authoritative were the reporter's sources? Who else might the reporter have interviewed? What else would you have wanted to know?

4. A COPY OF THE ARTICLE:

If you have bought your own copy of the newspaper or magazine, please cut out the article and hand it in (or hand in the entire magazine.) If you read the article in a library, please hand in a copy of the article and cover of the magazine or newspaper.

The articles may or may not be returned. The copy should include:

a. Name of the newspaper or magazine or other source

b. Date of publication

c. Page numbers

d. Author's name if it appears on the article; news source it is from one of the wire services (AP, Reuters, N.Y. Times, etc.)You may also find articles on the internet. You should be able to find the above information for internet articles as well (page numbers being the exception)

5.TIMELINESS:

Your article must be no more than 6 months old from the date you hand it in

6.SOURCES:

It is important for you to be able to read and evaluate high quality news reporting. Much science journalism is sensationalistic and not accurate enough to justify your

time. Appropriate sources may include (but are not limited to):Newspapers: New York Times (especially Tuesday's 'Science Times'), Oregonian, Boston Globe, Washington Post, Los Angeles Times,...the major papers...

Magazines: Discover, Time, Newsweek, Natural History, Science News, The Scientist, Audubon Magazine, National Geographic, Scientific American, Bio Science, news sections of the weekly professional journals Nature and Science Web Sites: You MAY NOT use web sites for this exercise unless they are VALID sites (i.e. those from the above listed sources) If you have questions about this, please ask me before you decide on an article to present.

- o Your paper must be between 1-½ and 3 pages long.
- o Carefully edit your work using the conventions of Chicago-Turabain (see attached ppt.)
- o Cite all direct quotes and paraphrased information in footnotes.
- o Be sure to include a bibliography (even if it only includes your article)

General Turabian Guidelines
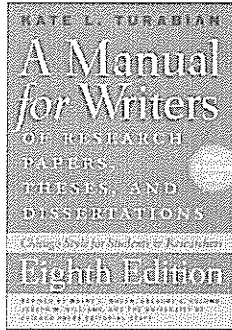
- This slide show will provide you with the a guide to paper formatting procedures for this class.

- We will be using Chicago- Turabian in this class. It is commonly used in natural and social sciences.

General Guidelines

- Format
  - 1 inch margins / 12 pt. Times New Roman font
  - Double Spaced (block quotes are single spaced)
  - Page Numbers
    - No page number on title page
    - Bottom right corner of each page

Turabian Pagination

Turabian Pagination

Turabian Pagination

Block Quotes

- 5 or more lines
- Single spaced
- Indented
- No quotation marks
- Footnote at end

General Turabian Guidelines

- Your paper should have three major sections.
  1. Title Page
  2. Main Body
  3. Bibliography

- Title Page
  - Two formats: Class Paper & Dissertation
  - NO Page Number on title page
  - Note: Your professor may have unique format requirements.

**Turabian Sample Title Page
Class Paper**
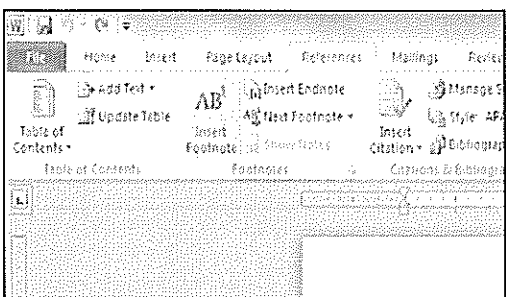
Turabian Sample Title Page Dissertation

General Turabian Guidelines

- Main Body
  - NO strict format for headings and subheadings
  - Most commonly uses footnotes
    - First citation includes full bibliographical information
    - Short forms used thereafter
    - Consecutive citations use Ibid.

- Footnotes
  - Refers to the original source (quote or paraphrase)
  - Further Explanation of the text
  - Reference to further information

Inserting Footnotes

General Turabian Guidelines

- Footnotes, cont.
  - First Reference
    - Cite all information
    - First name first
    - Follow style format

  - Further References
    - Author's last name (comma)
    - Short version of the title (comma)
    - Page number (period)

General Turabian Guidelines

- Footnotes, cont.
  - Consecutive citing of the same source
    - Ibid. (comma)
    - Page number (if different page)
    - Avoid using if referring to a note on a different page of your text.
  - Format
    - Use 10 or 12 point font
    - Footnote is single spaced
    - First line is indented
    - Space between each footnote
    - Each footnote ends with a period

Turabian Footnotes

- Book (single author or editor)

  1. Malcolm Gladwell, ed., *The Tipping Point: How Little Things Can Make a Big Difference* (Boston: Little, Brown, 2000), 64–65.

- Book (two or three authors)

  1. Peter Morey and Amina Yaqin, *Framing Muslims: Stereotyping and Representation after 9/11* (Cambridge, MA: Harvard University Press, 2011), 52.

- Book (four or more authors)

  1. Jay M. Bernstein et al., *Art and Aesthetics after Adorno* (Berkeley: University of California Press, 2010), 276.

Turabian Footnotes

- Book (author plus editor or translator)

  1. Jane Austen, *Persuasion: An Annotated Edition*, ed. Robert Morrison (Cambridge, MA: Belknap Press of Harvard University Press, 2011), 311–12.

- Book (edition number)

  1. John Van Maanen, *Talkes of the Filed: On Writing Ethnograpy*, 2nd ed. (Chicago: University of Chicago Proess, 2011), 84.

- Book (single chapter in an edited book)

  1. Ángeles Ramírez, "Muslim Women in the Spanish Press: The Persistence of Subaltern Images," in *Muslim Women in War and Crisis: Representation and Reality*, ed. Faegheh Shirazi (Austin: University of Texas Press, 2010), 231.

Turabian Footnotes

- Book (electronic)

  1. Isabel Wilkerson, *The Warmth of Other Suns: The Epic Story of America's Great Migration* (New York: Vintage, 2010), 183–84, Kindle.

  2. Philip B. Kurland and Ralph Lerner, eds., *The Founders' Constitution* (Chicago: University of Chicago Press, 1987), chap. 10, doc. 19, accessed October 15, 2011, http://press-pubs.uchicago.edu/founders/.

  3. Joseph P. Quinlan, *The Last Economic Superpower: The Retreat of Globalization, the End of American Dominance, and What We Can Do about It* (New York: McGraw-Hill, 2010), 211, accessed December 8, 2012, ProQuest Ebrary.

Turabian Footnotes

- Journal Article (print)

  1. Alexandra Bogren, "Gender and Alcohol: The Swedish Press Debate," *Journal of Gender Studies* 20, no. 2 (June 2011): 156.

- Journal Article (online)

  1. Campbell Brown, "Consequentialize This," *Ethics* 121, no. 4 (July 2011): 752, accessed December 1, 2012, http://dx.doi.org/10.1086/660696.

  2. Anastacia Kurylo, "Linsanity: The Construction of (Asian) Identity in an Online New York Knicks Basketball Forum," *China Media Research* 8, no. 4 (October 2012): 16, accessed March 9, 2013, Academic OneFile.

Turabian Footnotes

- Website

  1. Susannah Brooks, "Longtime Library Director Reflects on a Career at the Crossroads," University of Wisconsin-Madison News, September 1, 2011, accessed May 14, 2012, http://www.news.wisc.edu/19704.

  2. "Toy Safety," McDonald's Canada, accessed November 30, 2011, http://www.mcdonalds.ca/en/community/toysafety.aspx.

- Biblical References
  - Only included in footnotes
  - Use an abbreviated form of the book
  - List which version in the first citation

General Turabian Guidelines

- Bibliography
  - "Bibliography" centered at the top of the page
  - Uses the same information as initial footnotes, yet with minute differences.
  - Alphabetical order by last name
    - Only the first author's name is reversed
  - Hanging indent
  - Multiple works by the same author
    - Author's name on first
    - A 3-em dash replaces name thereafter (———)

Turabian Bibliography

- Rules of Thumb
  - Reverse the first name only.
  - Change commas to periods between items.
  - Remove parentheses
  - Remove specific page numbers.