

Glossary

A

absolute magnitude: the brightness of a star as it would be if it were a standard distance from Earth

aircraft: a vehicle that travels through the air, usually no higher than 20 km above ground

alchemist: an experimenter—part philosopher, part scientist, part magician; some alchemists believed that metal could be turned into gold

alkali metals: elements that occupy the far left column (first group) of the periodic table

alloy: a metal made by combining two or more different metals or metals and nonmetals

ampere: the SI unit used to measure electric current; symbol: A

anaphase: the phase of mitosis during which the chromosomes split and single strands of genetic information move to opposite ends of the cell

anode: a positive plate that produces electrons in a fuel cell

anther: part of the stamen, the male structure, in the flower of a plant; holds pollen grains

apparent magnitude: the brightness of a star as it appears to a person on Earth

asexual reproduction: any of several forms of reproduction that results in offspring that are genetically identical to the parent

asteroid: a small rocky object; from the Greek work *astron*, meaning “starlike”

asteroid belt: a ring around the Sun made up of thousands of asteroids

astronomical unit: a distance measure (a.u.) equal to the average distance between Earth and the Sun, used to compare large distances in the solar system

astronomy: the study of what is beyond Earth

atom: a particle in an element; from the Greek word *atomos*, meaning “indivisible”

atomic mass: the average mass of an atom of an element

atomic model: a theory proposed by John Dalton in 1808 to explain why elements differ from each other and from non-elements

atomic number: the number of protons in an atom

atomic radius: the average distance from the nucleus to the “outer edge” of a spherical atom

axis: an imaginary straight line joining the North Pole and the South Pole

B

benign: the term used to describe a cancerous tumour that remains in a confined area, causing little damage to the organism

Big Bang theory: a model of the beginning of the universe

binary fission: the form of asexual reproduction in which the organism splits directly into two equal-sized offspring, each with the parent’s genetic material

black hole: the high-density core left when a star about 30 times the mass of the Sun dies

Bohr diagram: a diagram, representing the electronic structure of an element, that comprises electrons in a series of concentric circles (energy levels or orbits) drawn around the central nucleus, containing the symbol of the element

Bohr-Rutherford diagram: a diagram, summarizing the numbers and positions of all three subatomic particles in an atom, that comprises electrons in a series of concentric circles (energy levels or orbits) drawn around a central nucleus, containing the numbers of protons and neutrons in the element

bond: a concept used in models that represents the forces that hold atoms together

branch circuit: a separate circuit through which current passes to each load in a parallel circuit

brittle: the physical property of a substance that shatters easily

budding: the form of asexual reproduction in which the offspring begins as a small outgrowth of the parent and eventually breaks off, becoming an organism on its own

C

cancer: the term for a group of diseases associated with uncontrolled, unregulated cell division

carcinogen: a substance or energy that causes a mutation in the genes that regulate cell division

cathode: a negative plate in a fuel cell

cell cycle: the sequence of events in a cell from one division to another

cell membrane: a covering around a cell that controls the movement of materials into and out of the cell

cell wall: the non-living outermost covering of a plant cell

centriole: a small protein structure in animal cells, critical to cell division

ceramic: a material manufactured by heating minerals and rocks

CFCs: chlorofluorocarbons; compound made of carbon, chlorine, and fluorine atoms, developed by scientists in the 1930s

charge: a negative or positive quantity of electricity that builds up on an object

charging by contact: transferring an electric charge from one substance to another by touching

charging by friction: transferring an electric charge from one substance to another by a rubbing action

charging by induction: transferring an electric charge from one substance to another without direct contact

chemical change: the alteration of a substance into one or more different substances with different properties

chemical formula: the combination of symbols that represents a particular compound

chemical group: the set of elements that appears in the same column in the periodic table

chemical property: the characteristic behaviour that occurs when one substance interacts with another to become a new substance

chemical symbol: an abbreviation for the name of an element

chemical test: a test that produces a distinctive chemical reaction to identify an unknown substance

chloroplast: the organelle in a plant cell that contains chlorophyll

chromosome: a threadlike structure that contains genetic information

cilia: tiny small hairs on an animal cell

circuit breaker: a safety switch that controls the amount of current that flows in a circuit

circuit diagram: a drawing that uses a special set of symbols to represent the electrical components and wiring in an electric circuit

cloning: the technical process by which identical offspring are formed from a single cell or tissue

combining capacity: the ability of an element to combine with other elements

combustible: the chemical property of a substance that allows

it to burn when exposed to flame and oxygen

combustion: the chemical reaction that occurs when a substance reacts rapidly with oxygen and releases energy

comet: a chunk of ice and dust that travels in a very long orbit around the Sun

composite: a material formed by combining two other materials

compound: a pure substance that contains two or more different elements in a fixed proportion

conception: the process of fertilization in which the head of the sperm cell penetrates the cell membrane of the egg

conjugation: the form of sexual reproduction in which two cells come together and exchange genetic information

connector: a conducting wire that provides a controlled path for electric current to flow to each part of the circuit

constellation: a group of stars that forms shapes or patterns

corpus luteum: a tissue inside the ovary that secretes hormones essential for pregnancy

corrosion: a slow chemical change that occurs when a metal reacts with oxygen to form oxide

cosmology: the study of the origin and changes of the universe

crossbreeding: the process of taking pollen from one plant and using it to fertilize the eggs of another

crystal: a solid mineral in which a regular pattern of three-dimensional shapes is visible

cytokinesis: the process in cell division in which the cytoplasm and its contents separate into equal parts

cytoplasm: the area of a cell where nutrients are absorbed, transported, and processed

D

decay: splitting apart of unstable nuclei to produce radioactive particles

density: the mass per unit volume of a substance, usually expressed in kilograms per cubic metre or grams per cubic centimetre

deoxyribonucleic acid: the genetic chemical found in all living things

discharge: to neutralize or remove all electric charges

discharge at a point: removing an electric charge by repelling electrons off the tip of a conductor that is pointed at the end

distribution panel: a metal box where all circuit breakers (or fuses) are connected to each of the separate circuits

DNA: *See* deoxyribonucleic acid

ductile: the physical property of a solid that allows it to be pulled into wires

E

Earth-centred universe: a belief that the stars were attached to a large ball that revolved around Earth once every day

efficiency: a comparison between the amount of useful energy produced (output energy) and the original amount of energy used (input energy)

egg: the female sex cell; a package designed to feed and protect a developing embryo

electric charge: a negative or positive quantity of electricity that builds up on an object

electric circuit: a controlled path through which electric current passes

electric current: a measure of the rate at which electric charges flow; symbol: I

electric potential: the electrical energy that an electron possesses

electrical conductor: a substance in which electrons can move freely from one atom to another

electrical energy: the energy released into an electrical load by moving electrons

electrical insulator: a substance in which electrons cannot move freely from one atom to another

electrical load: anything that converts electrical energy into the form of energy required

electrical power: the rate at which electrical energy is used

electrodes: metal plates, usually zinc and copper, that are placed in liquid or gel in a voltaic cell

electrolysis: the use of electricity to cause chemical changes in solutions

electrolyte: the liquid in a voltaic cell that conducts an electric current

electromagnetic spectrum: the broad band of energies that comprises radio waves, microwaves, infrared rays, visible light, ultraviolet rays, X rays, and gamma rays

electron: a negatively charged particle with a relative mass of about 1/2000 of the mass of a proton or a neutron

electrostatic series: a continuum of substances listed in order of increasing tendency to gain electrons

electrostatics: the study of static electric charge

element: a pure substance that cannot be broken down into simpler substances

embryo: the stage in development when a fertilized egg has divided to form a mass of at least 64 cells

endometrium: the thick lining of the uterus

endoplasmic reticulum: a series of "canals" that carry materials throughout a cell

energy: the ability to do work

energy level: the circular path or orbit around the nucleus associated with individual electrons

energy meter: a meter that measures the total amount of electrical energy used in a building

excited state: the condition of an electron when it is energized sufficiently to jump to a higher orbit

external fertilization: a process in which the male sperm cells are united with the female egg cells outside the female's body

F

fertilizer: a chemical substance added to the soil to increase plant growth

flagellum: a whiplike tail on the outside of the cell membrane that helps the cell move

flame test: an experimental technique using a flame to determine the identity of a metal

flammable: the chemical property of a substance that allows it to burn when exposed to flame and oxygen

follicle: a group of cells, including a reproductive cell, inside the ovary of the female

fossil fuel: coal, oil, natural gas, and gasoline formed from the long-buried remains of organisms

fragmentation: the form of asexual reproduction in which a new organism is formed from a part that breaks off from the parent

free fall: a continuous falling effect of a spacecraft created by the combination of the gravitational pull of Earth and the forward speed of the spacecraft

fuel cell: a cell that produces electricity without combustion, using hydrogen and oxygen

fuse: a piece of material that will melt (fuse) when heated to a high temperature by the current flowing through it

G

galaxy: a huge collection of gas, dust, and hundreds of millions of stars and planets

gas giant: planet with an atmosphere that consists mainly of the low-density gases hydrogen and helium

gene: a unit of the genetic information that determines a specific characteristic of an individual

geosynchronous orbit: the orbit of a satellite around Earth that takes 24 h, allowing it to remain in the same location above Earth's surface

GFCI: *See* ground fault circuit interrupter

Global Positioning System: the 24 satellites used for search and rescue operations that travel in 12-h orbits, 20 000 km above Earth's surface

Golgi apparatus: an organelle that stores proteins and packages them for release inside or outside the cell

gravity: the force that pulls objects toward each other

ground: connect to Earth

ground fault circuit interrupter: a special kind of combination outlet socket and circuit breaker that responds to very small changes in current; (GFCI)

ground state: the low-energy state that is the normal orbit of an electron

ground terminal: a third round hole underneath the other two holes in an outlet socket, which is connected to the ground terminal inside the distribution panel

grounding pin: the third pin, containing the grounding wire, in the three-pin plug of an appliance that grounds the appliance to the circuit breaker

group: a column of the periodic table

H

halogens: reactive nonmetals that occur in different states and occupy the seventeenth column of the periodic table

hardness: the physical property of a solid that is the measure of its resistance to being scratched or dented

heavy metal: an element that is shiny, malleable, and conducts electricity, is generally solid at room temperature, and has very high density

hermaphrodite: any organism that creates both male and female sex cells

heterogeneous mixture: a substance in which the different components are identifiable and can be separated by physical means

hormone: any chemical that acts as a messenger between cells

hydrocarbon: a compound containing hydrogen and carbon; found in fossil fuels

I

induced charge separation: a slight shift in position of electrons that produces opposite charges on the two sides of a particle

inner planet: one of four small planets close to the Sun, with a density roughly the same as the density of rock; also known as a terrestrial planet

internal fertilization: a process in which the male sperm is united with the female egg cell inside the female's body

International Space Station (ISS): a space station that involves the co-operation of space agencies from Brazil, Canada, Europe, Japan, Russia, and the United States

input energy: the amount of energy used to make electricity

interphase: the phase of mitosis during which the cell grows and prepares for cell division by duplicating its genetic information

ion: an atom that has become charged by gaining or losing one or more electrons

isotope: any of two or more forms of an element, each with the same number of protons but with different numbers of neutrons

J

joule: the SI unit for measuring energy; symbol: J

K

kilowatt hour: the unit for measuring energy; the number of kilowatts of electrical power used multiplied by the number of hours; symbol: kW·h

L

launcher: a device that carries a payload into space

lead-acid cell: a reusable energy source in which the chemical change is reversed by connecting the cell to a source of electrical energy until the cell is recharged and the electrodes return to their original state

light-year: the distance that light rays travel in one year (9.46×10^{12} km)

live wire: an insulated wire that carries electrical energy into a building

low Earth orbit: an orbit just above Earth's atmosphere

lysosome: a saclike organelle used to break down large compounds

M

main breaker switch: the central location in a building where the two live wires are each connected to the circuit breaker

malignant: the term used to describe a cancerous tumour that spawns cells that can break away and move to other areas of the body

malleable: the physical property that allows the shape of a solid to be changed

mass number: the sum of the protons and neutrons in the nucleus of an atom

matter: anything that takes up space and has mass

meiosis: the process that forms sex cells

Mendeleev's periodic law: a statement summarizing Dmitri Mendeleev's observations that elements arranged in order of increasing atomic mass reflect a pattern in which similar properties occur regularly

menstruation: the process in non-pregnant women during which the endometrium is shed from the uterus through the vagina

metal: a solid that is generally shiny and malleable and a good conductor of heat and electricity

metalloids: elements that possess both metallic and nonmetallic properties

metallurgy: the technology of separating metals from their ores

metaphase: the phase of mitosis in which the chromosomes line up in the middle of the cell

meteor: a bright streak of light across the sky caused by a meteoroid

meteorite: a meteoroid that reaches the ground

meteoroid: a lump of rock or metal trapped by Earth's gravity and pulled down through Earth's atmosphere

microgravity: *See free fall*

mineral: a naturally occurring compound, sometimes containing metal combined with oxygen, sulfur, or other elements

mitochondrion: an oval-shaped organelle that provides cells with energy

mitosis: the process by which nuclear material is divided during cell division

mixture: a substance that contains two different pure substances or types of particles

model: a way to represent a thing or process

modern periodic law: a law stating that elements arranged in order of increasing atomic number reflect a pattern in which similar properties occur regularly

molecule: the combination of two or more atoms

mutation: a change in the genetic code

N

nebula: a huge cloud of dust and gases in outer space; the beginning and ending of a star

negative charge: an excess of electrons

negative terminal: the plate in a voltaic cell where electrons collect

neutral wire: a wire that leads from the main electrical supply outside to the inside of a building where it is attached with a special wire to the plumbing system or to a metal stake driven into the ground

neutralize: to discharge or remove all electric charges

neutron: a neutral particle located in the nucleus, with a relative mass of 1

neutron star: an extremely dense star composed of neutrons; results when a star about 10 times the mass of the Sun dies

noble gases: inert gases, found on the far right column of the periodic table, that almost never form chemical compounds with other elements

nonluminous: not making or emitting its own light; reflecting light from other light sources

nonmetal: one of a class of elements that are not good conductors of heat or electricity

nonrenewable energy resources: sources of fuel that cannot be replaced in a reasonable amount of time

nuclear fusion: a process during which substances fuse to form new substances, releasing huge amounts of heat, light, and other forms of energy

nuclear model: Ernest Rutherford's model of an atom describing a dense, positive nucleus around which negative electrons appear to occupy a large amount of space

nucleolus: a spherical structure, within the nucleus of some cells, associated with the production of proteins

nucleus: 1. the central core of an atom, which contains two kinds of particles: the positively charged proton and the uncharged neutron; 2. the main organelle of the cell, which directs the cell's activities

nutrient: a chemical compound necessary for growth

O

observatory: a large building with an open dome through which a telescope provides a view of planets, stars, and other objects in the universe

ohm: the SI unit for electric resistance; symbol: Ω

ohmic resistor: a type of electrical load that does not change electrical resistance with temperature

open circuit: a circuit this is not operating and through which no current is flowing

orbit: 1. a circular path around the nucleus associated with individual electrons; 2. a circular or elliptical path followed by one object as it revolves around a much larger object

orbital period: the period of time required for an orbiting object to complete one revolution of the central object

ore: rock containing a valuable mineral

organelle: a specialized structure inside plant and animal cells

outer planet: a planet in the solar system beyond the four inner planets; one of the four gas giants or Pluto

outer space: everything outside of Earth's atmosphere

output energy: the amount of energy produced

ovary: an organ or structure designed to contain female sex cells; the primary reproductive organ of the female mammal

oviduct: the part of the female reproductive system where fertilization of the egg cell takes place

ovulation: the process during which the ovary wall bursts and the egg cell is released into the oviduct

P

parallel circuit: an electric circuit in which each electrical load is connected to the energy source by its own separate path or branch circuit

parturition: the process of human birth

payload: a satellite, piloted spacecraft, or cargo launched into space

period: a horizontal row of elements in the periodic table

periodic table: an organized arrangement of elements that explains and predicts physical and chemical properties

periodic trend: a gradual change in the properties of elements across a row in the periodic table

photoelectric cell: a cell that converts light energy directly into electrical energy

photosynthesis: a chemical process during which plants combine carbon dioxide from the air, water, and energy from the Sun to produce sugars and oxygen gas

physical change: a change in the state or form of a substance that does not change the original substance

physical property: a characteristic or description of a substance that can be used to identify it

pistil: the female reproductive structure in the flower of a plant, composed of the stigma, style, and ovary

placenta: an organ in a pregnant woman formed by the blood vessels from the mother and the embryo growing side-by-side

planet: a large piece of matter, generally spherical, that revolves around a star

planetary system: a group of objects that includes at least one planet in orbit around a star

polarized plug: a plug with two different-sized prongs, one narrow connected to the 120-V conductor through a terminal in a lamp or appliance and one wider connected to the neutral wire in a distribution panel

pollen: the male sex cells of a flower

pollination: the process by which pollen is moved from the anther to the egg cells to fertilize those cells

polymer: a material made of long molecules composed of repeating subunits

positive charge: the charge on a proton; a deficiency of electrons

positive terminal: the plate in a voltaic cell where positive charges collect

potential difference: the loss of electric potential produced by electrical resistance as a current flows through a conductor

precipitate: a solid, insoluble material that forms in a liquid solution

primary cell: a disposable energy source in which the chemical reactions use up the materials in the cell as electrons flow from it

products: the substances resulting from a chemical reaction

prophase: the phase of mitosis in which the individual chromosomes become visible

proton: a positively charged particle located in the nucleus, with a relative mass of 1

pulsar: a type of neutron star that emits pulses of very high-energy radio waves

pure substance: a substance that contains only one kind of particle

Q

quasar: an object that looks like a faint star but emits up to 100 times more energy than our entire galaxy; from the expression “quasi-stellar radio source,” which means a starlike object that emits radio waves

R

radar: a device that emits bursts of radio waves and picks up their reflections to detect the location of objects and determine how far away they are

radio telescope: a device that receives radio waves from space

radioactive: the state of an unstable element in which nuclei may break apart, ejecting very high-energy particles

radioisotope: an atom with an unstable nucleus

reactants: the substances participating in a chemical reaction

red giant: a star, near the end of its life, that becomes larger and redder as it runs out of hydrogen fuel

red shift: a movement toward the red end of the spectrum

red supergiant: a star with a mass 10 times or more larger than the Sun's near the end of its life, that becomes larger and redder as it runs out of hydrogen fuel

reflecting telescope: an optical device that uses a concave mirror to gather light and make distant objects appear larger

refracting telescope: an optical device that uses lenses to gather and focus light and make distant objects appear larger

regeneration: the ability to regrow a tissue, an organ, or a part of the body

remote sensing: using imaging devices to make observations from a distance, such as from a satellite in low Earth orbit

renewable energy resources: sources of fuel that constantly replenish themselves

reproductive cells: cells that produce sex cells through the process of meiosis

resistance: the ability to impede the flow of electrons in conductors

resistor: an electrical device designed to impede the flow of electrons in conductors

revolution: the movement of one object travelling around another

ribosome: an organelle involved in building proteins essential for cell growth and reproduction

rotation: the spinning of an object around its axis

S

satellite: an object that travels in orbit around another object

secondary cell: a reusable energy source in which one chemical process discharges the cell and another recharges it to its original state

selective breeding: a method of reproduction that results in several generations of offspring all having the same desired characteristics

seminiferous tubules: tiny, twisting tubes inside the testis that produce sperm cells

series circuit: an electric circuit in which the electrical loads are wired to one another in a single path

sexual reproduction: reproduction in which two sex cells unite to form a zygote

solar system: the Sun and all the objects that travel around it, including the nine known planets and the moons of those planets

solubility: the ability of a substance to dissolve in a solvent

solution: a mixture made up of liquids, solids, or gases

somatic cells: cells that reproduce only by normal cell division

space probe: an unpiloted spacecraft that is sent to moons, planets, comets, the Sun, and other parts of the solar system to relay information back to Earth

spacecraft: a vehicle designed to travel in the near vacuum of space

spectroscope: a device that splits light energy into patterns of colour

spectrum: the band of colours produced when light is split into its component frequencies

sperm: the male sex cell

spinoff: an extra benefit from technology originally developed for another purpose

spore: a reproductive body encased within a protective shell

spore formation: the form of asexual reproduction in which the organism undergoes cell division to produce smaller, identical cells, called spores, that are usually housed within the parent cell

stamen: the male reproductive structure in the flower of a plant, composed of the anther and the filament

standard atomic notation: an internationally recognized system used to identify chemical substances

static electricity: a charge on a substance that stays in the same place

star: a large collection of matter that emits huge amounts of energy

star cluster: a group of stars that are relatively close and travel together

structural diagram: a drawing to explain molecules in which atoms are represented by chemical symbols and bonds are shown as straight lines connecting the symbols

subatomic particles: the protons, neutrons, and electrons that make up atoms

Sun: the star around which Earth and eight other planets revolve

Sun-centred solar system: a model reflecting the observation that Earth and other planets travel around the Sun

sunspot: a dark patch on the Sun's photosphere

superconductors: ceramics that conduct electricity with no resistance at low temperatures

supernova: a huge explosion that occurs at the end of a massive star's life

sustainability: the pursuit of economic prosperity, social justice, and protection of the natural environment, while simultaneously securing good health and enhancing well-being for all people and for future generations

synthetic: a material that is invented and produced by people

T

telophase: a phase of mitosis during which the two halves of the cell reorganize to form daughter cells

terrestrial planet: one of four small planets close to the Sun, with a density roughly the same as the density of rock; from the Latin *terra* for “earth”; also known as an inner planet

testis: an organ that produces sperm cells; the primary reproductive organ of the male mammal

thrust: the force that causes an object to move

triangulation: a method of measuring the distance to an object by measuring the angles between the baseline and the object and then drawing a scale diagram to calculate the distance to the object

trimester: one of three stages in human pregnancy

tumour: a mass of cancer cells formed by abnormal rapid cell division

U

umbilical cord: the cordlike structure that connects the embryo with the placenta

universe: everything that exists, including all matter and energy everywhere

uterus: the organ in the female reproductive system where the embryo is nourished as it grows

V

vacuole: an organelle filled with water, sugar, minerals, and proteins

vegetative reproduction: the form of asexual reproduction in which a section of a plant grows to form a new plant

viscosity: the physical property of a liquid that limits its ability to flow

visible spectrum: a small part of the electromagnetic spectrum that can be seen as a pattern of colours

volt: the SI unit used to measure electric potential; symbol V

voltage: electric potential

voltage drop: a measure of the energy each electron gives up as it moves through a circuit; commonly used for potential difference

voltaic cell: the primary wet cell, developed by Alessandro Volta, consisting of two plates made of different metals (electrodes) placed in a liquid (electrolyte) that conducts an electric current

W

watt: the SI unit for electrical power; symbol: W

watt hour: a unit for measuring energy; the number of watts of electrical power used multiplied by the number of hours; symbol: W·h

weight: the force of gravity acting on an object

white dwarf: a small star created by the remaining material when a red giant dies

word equation: a concise way to indicate a chemical reaction between substances

Z

zodiac constellation: a constellation named after an animal; from the Greek word *zodion* for “animal sign”

zygote: a fertilized egg cell; the product of sexual reproduction

Index

- A**
- absolute magnitude, 459–460
 - acid
 - hazardous substance, 20, 32
 - reaction with, 19
 - aerobots, 424
 - aerospace engineer, 507
 - aging
 - and cell division, 170–171
 - in space, 509
 - air, gases in, 60–61
 - air pollution and combustion, 39
 - aircraft, 488
 - aircraft mechanic, 284
 - alchemists, 83
 - alkali metals, 111
 - alkyd paints, 22–23
 - alloys, 19, 72, 73, 117–118
 - Alouette 1* satellite, 492
 - Alpha Centauri, 444, 445
 - alpha particles, 85, 97
 - amateur astronomer, 429
 - ammeter, using, 546
 - amniocentesis, 224
 - amniotic egg, 234
 - ampere, 314
 - anaphase, 153
 - ancient ideas on the universe, 438
 - angles
 - estimating distances, 437
 - locating objects, 408–409
 - Anik* satellite, 495
 - animal cells
 - division. *see* cell division
 - hormones, 164–165
 - movement, 143
 - structures, 142
 - anode, 343
 - anthers, 208, 210
 - aphids, 200, 205
 - apparent magnitude, 459–460
 - argon, 60, 110
 - Aristotle, 82, 144
 - “artificial intelligence” in space, 433
 - asexual reproduction, 159
 - aphids, 200, 205
 - cloning. *see* cloning
 - methods, 160–161, 190–193, 202
 - asteroids, 431
 - astrolabe, 408–409, 442
 - astronomical unit, 420
 - astronomy, 400, 410
 - atomic mass, and periodic table, 104, 105, 108
 - atomic model, 128
 - of Dalton, 84
 - of Democritus, 82
 - Faraday, Nagaoka, Thomson, 84
 - electrical model, 273
 - “planetary” model, 90–93
 - Rutherford’s nuclear model, 85, 87, 90
 - atomic number, 88
 - and periodic table, 108
 - atomic radius, 108
 - atoms, 46
 - different kinds (elements). *see* elements
 - ions (“charged atoms”), 89
 - isotopes and radioisotopes, 96–97
 - subatomic particles, 87–89
 - auroras, 453
 - automobile
 - electric cars, 342
 - fuel cells, 331, 343
 - auxins, 164
 - averages, 561
 - axis of Earth, 404
- B**
- bacteria, reproduction, 159, 202, 203
 - bar graphs, 554, 558
 - base units and prefixes, 548–549
 - batteries
 - cells in parallel, 309, 310, 311
 - cells in series, 308, 310–311
 - costs and benefits, 312–313, 330
 - discharging, 332–333
 - energy capacity, 334–335
 - recycling, 313
 - types, 296
 - bean seed, 237
 - Becquerel, Henri, 96
 - benign tumours, 182
 - beta particles, 96–97
 - Big Bang theory, 478–479
 - binary fission, 159, 160, 194, 202
 - binary stars, 459
 - birth, 254–255
 - black holes, 471
 - Bohr diagrams, 92
 - Bohr, Niels, 91, 92
 - Bohr-Rutherford model, 92–93, 273
 - boiling point, 17
 - bonds linking atoms in a molecule, 62
 - bone growth in humans, 169
 - Boyle, Robert, 83
 - branch circuit, 325
 - breast feeding, 255
 - Briggs, Robert, 195
 - brine shrimp, 231
 - brittleness, 17
 - Brown, Robert, 140
 - budding, 160, 194
 - burning splint test for hydrogen, 54
- C**
- calendar of ancient astronomers, 410
 - cancer
 - cell division, 180–181
 - and lifestyle, 182–183
 - treating, 184
 - car radios, 293
 - carbon dioxide, 61
 - testing for, 55
 - carbon monoxide, 61
 - carcinogens, 180
 - Career Profile
 - aerospace engineer, 507
 - aircraft mechanic, 284
 - amateur astronomer, 429
 - biochemist, 86
 - colour technician, 31
 - electrical engineer, 355
 - electrician, 304
 - engineer in business, 379
 - fertility specialist, 219
 - genetics scientist, 179
 - law and science, 158
 - registered nurse, 247
 - science journalist, 125, 451
 - science teacher, 69
 - space artist, 474
 - cathode, 343
 - Cat’s Eyes Nebula, 466
 - Cavendish, Henry, 83
 - cell division
 - and aging, 170–171
 - cancer, 180–181
 - cell cycle, 150
 - and chromosomes, 150, 151, 202
 - cytokinesis, 151
 - determining the rate of, 156–157
 - development of organism, 240, 241
 - DNA, 174, 176–178
 - functions, 148–149

- growth in humans, 165, 168–169
 - and hormones, 164–165
 - inhibiting, 184–185
 - measuring plant growth, 166–167
 - meiosis, 206–207
 - mitosis, 151, 152–153
 - observing, 154–155
 - population growth rates, 162–163
 - questions still unanswered, 149
 - replication, 177
 - reproduction of organism, 149, 159–161
 - reproductive cells, 207, 217
 - somatic cells, 206–207
 - cell membrane, 142, 143
 - cell phones, 293
 - cell replacement, 139
 - cell theory
 - complete, 147
 - early version, 140
 - cell wall (of plant cells), 143
 - cells
 - animal. *see* animal cells
 - division. *see* cell division
 - plant. *see* plant cells
 - cells, electric
 - in batteries. *see* batteries
 - building a wet cell, 297, 305
 - electrochemical cells, 306–307
 - energy capacities, 336
 - in parallel, 309, 310, 311
 - primary, 306–307
 - secondary, 307
 - in series, 308, 310–213
 - centrioles, 142
 - ceramics, 118, 119
 - cervix, 216
 - Chadwick, James, 87
 - charges, electric, and atomic model, 84
 - charging by contact, 276–277, 278–279
 - charging by friction, 274–275
 - charging by induction, 285–289
 - chemical changes, 13, 29
 - combustion, 38–39
 - corrosion, 34–37
 - new substances, 26–27
 - observing, 30, 32–33
 - word equations, 52
 - chemical fertilizers, 66, 67, 68
 - chemical formulas, 59
 - chemical groups, 110–116, 124
 - chemical properties
 - combustibility, 18
 - defined, 18
 - reaction with acid, 19
 - chemical reactions and electricity, 303
 - chemical symbols, 58–59
 - chemistry, 69, 86
 - chemistry teacher, 69
 - chemotherapy, 184
 - chicken egg, 240
 - Chinese astronomers, 410
 - chlorine, 111, 112
 - chlorofluorocarbons (CFCs), 120–121
 - chloroplasts, 143
 - chromosomes, 142, 143
 - and cell division, 150, 151, 202
 - composed of DNA, 176
 - genetic screening, 201
 - homologous, 206, 207, 226
 - X and Y, 204
 - cilia, 143
 - circle (or pie) graphs, 554, 559
 - circuit breakers, 363, 364, 365–366
 - circuits, electric
 - branch circuit, 325
 - combinations of series and parallel, 327
 - constructing and drawing, 544–545
 - diagrams and symbols, 301
 - four basic parts, 300–301
 - multiple loads, 324–327
 - observations and analysis, 298–299
 - parallel circuits, 309, 310, 311, 325–327
 - series circuits, 308, 310–311, 324–325
 - short circuit, 318
 - cloning, 194–197, 258
 - frogs, 195–196
 - from grafting, 193
 - from plant cuttings, 192–193
 - mammals, 196–197
 - a plant from a single cell, 195
 - a potato, 175, 190
 - closed circuit, 301
 - clothes dryer, 292
 - cobalt chloride test for water vapour, 55
 - colonies on space objects, 440
 - colour technician, 31
 - combining capacity, 64–65
 - combustibility, 18
 - combustion, 38–39
 - and air pollution, 39
 - and fossil fuels, 38
 - Comet Hyakutake, 432
 - comets, 432–433
 - composites, 118–119
 - compound light microscope, 140
 - compounds, 46, 47
 - breaking compounds into elements, 52–53
 - investigating properties, 114–116
 - natural and synthetic, 102
 - and periodic table, 103
 - testing for elements and compounds, 54–55
 - computers
 - for graphing, 559
 - on-line searching, 531
 - use in astronomy, 482–483
 - using effectively, 570
 - concept mapping, 572–573
 - conception in humans, 242–243
 - conclusions, reaching, 562
 - conductors, 280, 281, 292, 293
 - conjugation, 203
 - connectors, 301
 - conserving energy
 - alternative approaches, 381
 - devices. *see* electrical appliances and devices
 - constellations, 400–401, 405
 - seasonal, 406–407
 - year-round, 406
 - contact, charging by, 276–279
 - controlled experiments, 526–527
 - conversion
 - of energy, 351, 353
 - of physical quantities, 548–549
 - Copernicus, Nicolaus, 438
 - corn seed, 236–237
 - corona discharge, 282
 - corpus luteum, 217, 218, 221
 - correlational studies, 528–529
 - corrosion
 - definition and examples, 34
 - preventing, 35, 36–37
 - cosmology, 478
 - critical thinking, 532–533
 - crossbreeding, 212
 - crystals, 17
 - CSA (Canadian Standards Association), 365
 - Curie, Marie, 96
 - current, electric, 84, 300, 314–315, 334
 - current vs. static electricity, 314
 - electric potential, 302–303
 - Ohm's law, 317
 - cuttings, 191, 192–193
 - cytokinesis, 151
 - cytokinins, 164
 - cytoplasm, 142, 143, 151
 - cytoplasmic transfer, 244
- D**
- Dalton, John, 84, 104
 - data tables, creating, 552
 - decay, radioactive, 96
 - Deep Space 1*, 433
 - Democritus, 82

- density
 defined, 18, 24
 identifying substances using, 24–25
- designing experiments, 536
- development of organisms, 232–35
 brine shrimp, 231
 eggs. *see* eggs
 embryo. *see* embryo development
 human conception and pregnancy, 242–243
 marsupials, 235
 placentals, 235
 spores, 232–233
- diploid chromosome number (2n), 204, 207
- discharge
 of cells or batteries, 307
 of electrically charged objects, 282–283
- distribution panel, 364
- DNA (deoxyribonucleic acid), 174, 176–178
 identification by, 178
 mutations, 180
 and organ transplants, 188–189
 replication, 177
- Down syndrome, 222
- drawings in science, 550–551
- dry cells, 306
- duckbill platypus, 234
- ductility, 17
- DuFay, Charles, 272
- dwarfism, 165
- E**
- Earth
 ideal medium for life, 425
 revolution, 404
 rotation, 404
- Earth-centred universe, 438
- earth-orbit satellites, 492–493
- Eckert, John, 361
- eclipse, solar, 436
- efficiency of energy conversions, 351, 353, 370
- egg case, 234
- egg donations, 246
- eggs
 of different animals, 234
 and embryo development, 240–241
 in flowers, 208, 210
- Egyptian astronomers, 411
- elastomers, 118
- electric cars, 342
- electric charges, 270–271
 discharging charged objects, 282–283
 law of electric charges, 272–273
- electric circuits. *see* circuits, electric
- electric current. *see* current, electric
- electric load, 300–301
- electric meter, 364
 calculating energy consumption, 374–375
 reading, 372
- electric potential (voltage), 302–303
- electrical appliances and devices
 describing, 368–369
 efficiency, 370–371
 energy consumption, 372–375
 energy-efficient lightbulbs, 376–377
 safety, 362–363
 standby mode, 377–378
 tips for saving energy, 377, 378, 380
- electrical conductors, 280, 281, 292, 293
- electrical energy
 alternative sources, 382
 defined, 334
 devices. *see* electrical appliances and devices
 energy transformations, 344–345
 environmental concerns, 341
 large-scale sources, 350–353
 measuring, 334–336
 safety features, 362–367
 small-scale generation methods, 346–349
 sources, 340, 356–357
 transmission, 353, 370
 use in the home, 372–375
- electrical insulators, 280–281, 292, 293
- electrical loads
 multiple loads, 324–327
 ohmic resistors, 317, 320
 in a parallel circuit, 322
 resistance of, 316, 317
 in a series circuit, 323
- electrical power
 calculating, 339
 generating stations, 350–352
 power ratings of appliances, 338
- electrical resistance, 316–317, 318, 319
- electricity
 batteries. *see* batteries
 cells. *see* cells, electric
 charges of, 84
 chemical reactions, 303
 circuits. *see* circuits, electric
 current, 84
 current ratings, 314
 dangers and safety features, 297
 electric potential (voltage), 302–303
 electric shock, 314–315
 ions, 84, 89
 sources. *see* electrical energy
 static. *see* static electricity
 use. *see* electrical energy
- electrochemical cells. *see* cells, electric
- electrolysis, 52
- electrolyte, 306
- electromagnetic spectrum, 449
- electron microscope, 141
- electrons, 84, 85, 87, 88
 arrangement in ions, 93
 Bohr’s “planetary” model, 91–93
 electric charges, 273
 electric potential, 303
 energy levels, 91–92, 94
 excited state, 91, 94
 and fireworks, 98
 ground state, 91, 94
- electroscopes
 metal-leaf, 288–289
 pith-ball, 276
- electrostatic, defined, 272
- elements, 43, 46
 Boyle’s definition, 83
 breaking compounds into elements, 52–53
 classifying, 48–49
 and compounds, 46, 47
 four-element model of Empedocles, 82
 groups in the periodic table, 110–116, 124
 periodic table, 103–105, 108–109
 periodic trends, 122–123
 testing for, 54–55, 94–95
- embryo, 216, 217, 232
- embryo development
 different species compared, 248–249
 in frogs, 241
 in humans, 243, 250–251
- embryo transfer, 246
- Empedocles, 82
- endometrium, 216, 217, 218, 220
- endoplasmic reticulum, 142, 143
- “Energuide” label, 371, 380
- energy, defined, 334
 energy levels (electrons), 91–92, 94
 energy transformations, 344–345
- engineer in business, 379
- ENIAC (Electronic Numerical Integrator and Computer), 361
- epididymis, 214
- estrogen, 218, 220, 221
- ethical guidelines for science, 86
- Europa, 431
- excited state (electrons), 91, 94
- expanding universe, 475, 476–477

external fertilization, 204
extrapolation of graphs, 555
extraterrestrial life, 440, 482

F

fabric softener, 292
Faraday, Michael, 84
fertility drugs, 244
fertility specialist, 219
fertilizers, 66–68
 chemical, 66, 67, 68
 organic, 66, 67, 68
Fetal Alcohol Syndrome (FAS),
 252–253
fetus, 249, 250–251
fireworks, 79, 98–99
 changes in electron levels, 98
First Nations legends, 410
flagellum, 143
flame test, 94–95
flammable substances. *see*
 combustibility
flow phase of menstrual cycle, 220
flower structures, 210–211
fluorescent bulbs, 376, 377
fluorine, 111, 112
follicle stimulating hormone (FSH),
 215, 217, 218
follicles, 216, 218, 220
follicular phase of menstrual cycle, 220
food package, 232
food production, increasing, 212–213
formulas in science, 561
fossil fuels, 38, 39
fossil-fuel generating stations, 350, 356
fragmentation, 161, 186
Franklin, Benjamin, 272
free fall, 500–501, 504–505
friction, charging by, 274–275
frog egg, 241
frogs, cloning, 195–196
fruit, 208, 233
fuel cells, 331, 343
fuses, 362, 366

G

galaxies, 439, 461–462, 463
 movement, 476–477
galaxy superclusters, 462
Galileo, 430, 438–439
gamete intrafallopian transfer, 245
gamma radiation, 96, 97
Ganymede, 440
gas giants, 426, 472–473
generating stations, 350–352
genes, 142, 177, 202, 203, 206
genetic disorders, 222–223

genetic screening, 201, 224–225, 226
geosynchronous orbit, 494–495
germinating seeds, 237, 238–239
giant stars, 469, 470
gigantism, 165
Gilbert, William, 274
glasses, 118
Global Positioning System (GPS), 495
glowing splint test for oxygen, 54
Golgi apparatus, 142
grafting, 193, 213
graphs
 constructing, 556–559
 extrapolating from, 555
 reading, 554–555
 types, 553–554
 using computers for graphing, 559
gravity, 461, 468
 artificial, 502, 511
 and free fall, 500, 501
Greek astronomers, 410
ground fault circuit interrupter
 (GFCI), 362, 367
ground state (electrons), 91, 94
ground terminal, 366
grounding, 282
grounding pin, 367
growth
 a function of cell division, 148
 of human body and organs, 168–169
growth hormone (GH), 165
 and aging, 171

H

Halley's comet, 433
halogens, 111–112
haploid chromosome number (*n*), 204,
 207
hardness, 17
hazardous substances. *see* safety
heavy metals, 50–51
helium, 110
hermaphrodites, 203
heterogeneous mixtures, 45
Hillier, James, 141
homologous chromosomes, 206, 207
Hooke, Robert, 140
hormones
 animal cells, 165
 in the birthing process, 254
 and cell division, 164–165
 estrogen, 218, 220, 221
 growth. *see* growth hormone
 and lactation, 254–255
 plant cells, 164
 progesterone, 218, 221
 testosterone, 215

Hubble Space Telescope, 448, 472, 482,
 483
 Hubble Deep Field, 480, 481
human sexual reproduction
 fertility specialist, 219
 genetic screening, 201, 224–225, 226
 internal fertilization, 204
 menstrual cycle, 220–221
 nondisjunction disorders, 222–223
 sex cell development in females,
 216–218
 sex cell development in males,
 214–215
hydrocarbons, 38, 39
hydroelectric generating stations, 351
hydrogen, 112–113
 testing for, 54
Hyperion, 431
hypothesizing, 535

I

in vitro fertilization, 245
indirect evidence, 467
induced charge separation, 285
induction, charging by, 285–289
Infrared Astronomical Satellite (IRAS),
 450, 472
inner (terrestrial) planets, 424, 473
input energy, 370
insulators, 280–281, 292–293
internal fertilization, 204, 215
International Space Station (ISS), 489, 498
 Canada's contributions, 498, 499
 effect of gravity on, 500
 illustration, 486–487
 living on, 501–503
interphase, 150, 152, 153
intrauterine insemination, 245
Io, 431
iodine, 111, 112
ions, 84, 89, 273
 electron arrangements in, 93
isotopes
 defined, 96
 radioisotopes, 96, 97
issues, exploring, 566

J

joule (J), 334, 372
Jupiter, 426

K

karyotypes, 224, 226–227
kilowatt hour, 334, 335, 372–373
King, Thomas, 195
Klinefelter syndrome, 223

L

laboratory equipment, 537
 Lagoon Nebula, 466
 latex paints, 22
 launcher, 490
 Lavoisier, Antoine, 83
 law of electric charges, 272–273
 law and science, 158
 lead-acid cell, 348
 leaf cuttings, 191
 Leeuwenhoek, Anton van, 140
 light
 and expanding universe, 476–477
 spectrum, 90, 92, 94
 light bulbs, energy-efficient, 376–377
 light pollution, 416–417
 light sources, 296
 light-year, 444–445, 446
 lightning, 290–291
 lightning rods, 291
 limewater test for carbon dioxide, 55
 live wires, 364–365
 low Earth orbit, 492
 luteal phase of menstrual cycle, 221
 luteinizing hormone (LH), 215, 217, 218
 lysosome, 142

M

main breaker switch, 364–365
 malignant tumours, 182
 malleability, 17
 mammals, cloning, 196–197
 Mars, 425, 440
 travel to, 511
 marsupials, 235
 mass number, 88
 materials science, 117, 119
 mathematics in science, 560–561
 matter
 changes of state, 13
 chemical changes. *see* chemical changes
 changes
 defined, 12
 identifying substances, 20–21, 24–25
 properties. *see* chemical properties;
 physical properties
 Mauchly, John, 361
 measurement
 base units and prefixes, 548–549
 conversions, 548–549
 problems, 549
 standards, 548
 meiosis
 compared with mitosis, 207
 dynamic model of, 207
 nondisjunction, 222–223

 stages (I and II), 206–207
 melting point, 17
 Mendeleev, Dmitri, 103, 104–105, 106–107, 108
 Mendeleev's periodic law, 105
 menopause, 220
 menstrual cycle, 220–221
 menstruation, 217, 218, 220
 Mercury, 424
 metal-leaf electroscope, 288–289
 metalloids, 113
 metallurgy, 72
 metals, 19, 117–118
 alloys, 71, 73
 combining capacities, 65
 corrosion, 34–37
 heavy metals, 50–51
 in history, 71
 minerals, 70
 mining, 71, 72, 74–75
 physical and chemical properties, 50
 putting metals to work, 50–51
 metaphase, 153
 meteor, 432
 meteor showers, 433
 meteorite, 432
 meteroid, 431–432
 microorganisms
 experiments on origin, 145–147
 microscopes, 140–141
 using, 538–541
 Milky Way Galaxy, 439, 461
 minerals, 70
 mining, 71, 72, 74–75
 minor bodies, 433, 473
Mir space station, 489, 498, 500
 mitochondrion, 142
 mitosis
 compared with meiosis, 207
 defined, 151
 dynamic model of, 153
 phases, 152–153
 mixtures, 44–45
 models
 of the atom, 78, 85
 developing models of matter, 82–85
 making a logical model, 80–81
 of matter, 78, 80. *see also* particle theory
 of molecules, 62–63
 scientific, 42
 of the universe, 475
 modern periodic law, 108
 molecules, 46–47
 models of, 62–63
 monoculture, 213
 Montreal Protocol, 120–121

moons, 401, 430–431
 Earth's Moon, 430
 mutations, 180
 mystery gases, identifying, 56–57

N

Nagaoka, H., 84
 nebulas, 466, 468
 Needham, John, 145, 146
 negative charge, 272
 negative ion, 273
 negative terminal, 306
 neon, 110
 Neptune, 427
 neutral wire, 364–365
 neutralizing charged objects, 282
 neutron stars, 470–471
 neutrons, 87, 88, 89, 273
 Next Generation Space Telescope, 450
 nickel-cadmium cell (NiCd), 348–349
 nitrogen, 60, 67
 noble gases, 110–111
 nondisjunction, 222
 nondisjunction disorders, 222–223
 diagnosing before birth, 224–225, 226
 nonluminous objects, 401
 nonrenewable energy resources, 340, 350–351
 nuclear fusion, 452
 nuclear generating stations, 350
 nuclear model of the atom, 79, 85, 87, 90
 nuclear power, 356–357
 nucleolus, 142
 nucleus, 85, 87, 273
 nucleus of cells, 140, 142, 143
 nutrients for plants
 from air and soil, 66
 from fertilizers, 66–68

O

observatories, 448
 Ohm, Georg, 317
 ohmic resistors, 317, 320
 Ohm's law, 317, 318, 320–321
 open circuit, 301
 orbital period, 418
 orbits
 of electrons around nucleus, 91–93
 of planets, 418
 ore, 70
 organ growth in humans, 169
 organ transplants, 188–189
 organelle, 142, 151
 organic fertilizers, 66, 68
 Orion, 406–407

- outer planets (gas giants), 426
 outer space, 488
 output energy, 370
 ovary
 in human females, 216, 217, 218
 in plants, 208, 210
 oviduct, 216, 217
 ovulation, 217, 220
 oxygen, 60–61, 120
 testing for, 54
 ozone, 60–61, 120
 effects of CFCs on ozone layer, 120, 121
- P**
- paint, safety questions, 22–23
 parallel circuit, 309, 310, 311
 characteristics, 326–327
 electrical loads in, 322
 with multiple loads, 326
 using Ohm’s law to analyze, 326
 paramecia, population growth rates, 162–163
 particle theory, 43, 44–47, 78
 parturition, 254
 Pasteur, Louis, 146–147
Pathfinder space probe, 425
 payload, 490
 PERCS checklist, 533
 periodic table
 and atomic mass, 104, 105, 108
 and atomic number, 108
 inventing, 106–107
 organization of elements, 103–105
 periodic trends, 122–123
 periods in the periodic table, 113
 phosphorus as plant nutrient, 67
 photoconductive material, 292
 photocopier, 292–293
 photoelectric cells, 347, 352
 photosynthesis, 66
 physical changes, 28
 observing, 32–33
 physical properties, 16–19, 22
 crystals, 17
 defined, 16
 density, 18, 24–25
 ductility, 17
 hardness, 17
 malleability, 17
 melting and boiling points, 17
 solubility, 17
 states of matter, 16
 viscosity, 17, 18
 pistil, 208, 210
 pith-ball electroscope, 276
 placenta, 235
 placental, 235
 planaria, regeneration in, 186
 planetarium
 in the classroom, 405
 model, 514
 “planetary” model of the atom, 90–93
 planetary systems, 472–473
 planets, 418–419
 a closer look, 424–428
 compared to stars, 402
 moons, 401, 430–431
 origin, 472–473
 properties of each, 418
 space probes to, 422, 430, 433
 speed of, 423
 travel around the sun, 405
 plant cells
 cell division, 154–157, 159–161
 hormones, 164
 measuring plant growth, 166–167
 plant reproduction. *see* asexual reproduction; sexual reproduction
 structures, 143
 plasmids, 203
 Pluto, 428
 point-and-line graphs, 553, 556–557
 Polaris (the North Star), 404
 polarized plugs, 366–367
 pollen, 201, 208, 210
 pollination, 208
 pollution and dust control, 286
 polymers, 118
 polyploidy, 207
 population growth rates, 162–163
 positive charge, 272
 positive ion, 273
 positive terminal, 306
 potassium as plant nutrient, 67
 potatoes, 175, 190
 potential difference, 316, 317
 power ratings of appliances, 338
 Prebus, Albert, 141
 precipitate, 55
 pregnancy, 217, 243
 presentations, 567
 Priestley, Joseph, 83
 primary cell, 306–307, 348
 products, 38
 progesterone, 218, 221
 projects in science, 567
 prophase, 152
 protons, 84, 85, 87, 88, 89, 273
 pulsars, 471
 pure substances, 43, 44
- Q**
- quaking aspen, 139
 qualitative observations, 547
 quantitative observations, 548–549
 quasars, 462
 questions for testing, 534–535
- R**
- radar, 496
 RADARSAT satellite system, 493, 496
 radio telescope, 449–450
 radioactivity, 96–97
 radioisotopes, 96, 97
 reactants, 38
 recharging electric cells
 primary cells, 306–307
 secondary cells, 307
 recording data, 547
 recycling of batteries, 313
 red giants, 470
 red shift, 477
 red supergiants, 470
 Redi, Francesco, 144, 145
 reflecting on ideas, 563
 reflecting telescope, 448
 refracting telescope, 448
 regeneration, 174
 complex animals and humans, 187
 sponges and planaria, 186
 registration plate on electrical device, 338
 remote sensing, 492–493
 satellite images, 493
 and weather forecasting, 492, 493
 renewable energy resources, 331, 340, 351–354
 replication, 177
 reports, 564–565
 reproduction
 asexual. *see* asexual reproduction
 and cell division, 149, 159–161
 population growth rates, 162–163
 sexual. *see* sexual reproduction
 reproductive cells, 207, 217
 reproductive technology, 244–246
 issues for society, 258–259
 research skills, 530–531
 resistance, electrical, 316–317
 resistors, 317
 revolution of Earth, 404
 ribosome, 142
 rocket engine, 490
 root division, 191
 rotation
 of Earth, 404
 of Sun, 454–455
 rows on the periodic table, 113

- runners for new plants, 139, 191
rusting, 34
Rutherford, Ernest, 85, 87
- S**
- safety
discharged batteries, 337
electric shock, 314–315
finding a safer paint, 22–23
heavy metals, 50–51
household chemicals, 29
in the laboratory, 522, 523–525
lightning, 290
recharging cells or batteries, 306–307
rules, 15
symbols, 14, 522
- salt, table salt, 111–112
- satellites
astronomical, 450
earth-orbit, 492–493
geosynchronous orbit, 494–495
Global Positioning System (GPS), 495
images from, 493
moons of planets. *see* moons
space junk, 495
telecommunications satellites, 494
tracking, 497
- Saturn, 427
- Saunders, Sir Charles, 212
- scale ratio, 551
- scanning electron microscope, 141
- schematic circuit diagrams, 301
- Schleiden, Matthias, 140
- Schwann, Theodor, 140
- science journalist, 125, 451
- scientific drawing, 550–551
- scientific notation, 444, 560
- sea turtle, 231
- search engines, using, 531
- seasonal constellations, 406–407
- seasonal star map
building, 412
using, 413, 414–415
- secondary cell, 307, 348
- seeds, 208, 233
examination of, 236–237
germinating, 237, 238–239
- selective breeding, 212
- selenium, 292–293
- self-sufficiency in energy, 382–383
- semiferous tubules, 214
- series circuit, 308, 310–311
characteristics, 325
electrical loads in, 323
with multiple loads, 324–325
using Ohm’s law to analyze, 324
- sexual reproduction, 159, 204
aphids, 200, 205
conjugation, 203
external fertilization, 204
hermaphrodites, 203
humans. *see* human sexual reproduction
internal fertilization, 204
meiosis. *see* meiosis
- significant figures, 560
- silicon, 113
- simple microscope, 140
- slope of a straight line, 561
- smoking in pregnancy, 251
- sodium, 111
- solar eclipse, 436
- solar energy, 452
- solar flares, 453
- solar system
formation, 472–473
modelling, 420–421
moons. *see* moons
ownership of resources, 440–441
planets. *see* planets
- solubility, 17
- solution, 45
- solvent, 22
- somatic cells, 206–207
- space artist, 474
- space colony, 514–515
- space junk, 495
- space medicine, 508–509
- space probes
observing the Sun, 452
to minor bodies, 433
to planets, 422, 430, 440
type of unpiloted spacecraft, 489
- space shuttle, 489
- space stations
ISS. see International Space Station (ISS)
Mir, 489, 498, 500
- space travel
effects on the human body, 508–509
experiments in space, 510
future of, 511
- space-age communicator, 451
- spacecraft, 488–489
- Spallanzani, Lazzaro, 146
- spectroscopy, 458–459
- spectrum, 90, 92, 94
of a moving object, 476–477
- perm, 214, 215, 230
- spinoffs from the space industry, 506
- spiny anteater, 234
- spiral galaxies, 461
- sponges, regeneration, 186
- spontaneous generation theory, 144–147
- spores, 232–33
formation, 161
- spray-painting system, 287
- spreadsheets, 552
- stamens, 208, 210
- standard atomic notation, 88–89
- standards
Canadian Standards Association, 365
measurement, 548
- star clusters, 463
- star maps, using, 542–543
- stars
black holes, 471
brightness, 456–457, 459–460
characteristics, 458–459
compared to planets, 402
giant stars, 470
life cycle, 466, 468–471, 478
neutron stars, 470–471
pulsars, 471
red giants, 470
red supergiants, 470
supernovas, 470
white dwarfs, 470
- states of matter, 16
- static electricity, 78, 84, 268, 269
charging by contact, 276–277, 278–279
charging by friction, 274–275
charging by induction, 285–289
compared with current electricity, 314
conductors, 281, 292, 293
defined, 272
discharging charged objects, 282–283
effects, 269, 270
electric charges, 270–273
electrical nature of matter, 273
insulators, 280–281, 292–293
lightning, 290–291
and winter, 281, 283
- static wicks, 283
- stem cells, 187
- stem cuttings, 191, 192
- Stewart, Frederick, 195
- Stonehenge, 411
- structural diagrams, 62
- study habits, 568–569
- subatomic particles, 87–89
- sulfur dioxide, 72
- Sun
eclipse. *see* solar eclipse
effects on Earth, 453

- energy production, 452
 - observing, 454–455
 - and planets, 418
 - rotation, 454–455
 - structure, 453
 - Sun-centred solar system, 439
 - sunlight
 - plant's response to, 165
 - ultraviolet (UV) radiation, 120
 - sunrise and sunset, 403
 - sunspots, 453, 454, 455
 - supernovas, 470
 - survival of offspring, 232–235
 - suspended animation, 232
 - sustainability, 341
 - switches, 301
 - ceiling fan, 360, 361
 - synthetic materials, 102
- T**
- tapeworm, 234
 - tarnishing of silver, 34
 - telecommunications satellites, 494
 - telescopes, 438, 448–450
 - telophase, 153
 - terrestrial planets, 424, 473
 - testing for elements and compounds, 54–55
 - testis, 214
 - testosterone, 215
 - Thales (Greek philosopher), 274
 - theme park (issue), 384–385
 - Thomson, J.J., 84
 - thrust, 490
 - tissue repair, 148
 - toxicity of electric cells, 312, 313
 - transmission electron microscope, 141
 - transplant farms, 188–189
 - transplanting organs in humans, 188–189
 - triangulation, 442–443, 444
 - Trifid Nebula, 468
 - trimesters (stages of human pregnancy), 250–251
 - tumours, 182
 - Turner syndrome, 222–223
 - twins. *see* identical twins
- U**
- ultraviolet (UV) radiation, 120
 - universe, 400
 - expanding, 475, 476–477
 - models, 475, 476
 - origin, 478–479
 - size, 446–447
 - uranium, radioactivity, 96
 - Uranus, 427
 - uterus, 216, 217
- V**
- vacuole, 143
 - vagina, 216
 - variables, 534–535
 - vegetative reproduction, 161, 190–191
 - Venus, 424
 - viscosity, 17, 18
 - visible spectrum, 458–459, 476–477
 - volt, 303
 - Volta, Alessandro, 306
 - voltage, 302
 - voltage drop, 317, 334
 - voltaic cell, 306
 - voltmeter, using, 546
 - Voyager 2*, 422, 426, 427
- W**
- wall outlets, 366
 - water rocket, 491
 - water vapour, cobalt chloride test for, 55
 - watt (W), 339
 - watt hour, 334, 335
 - weather forecasts by remote sensing, 492, 493
 - weight, 501, 502, 504
 - wet cell, building, 305
 - white dwarfs, 470
 - Wilmot, Ian, 197
 - word equations, 38, 52
 - working together, 571
- Y**
- year-round constellations, 406
- Z**
- zodiac constellations, 405, 406–407
 - zygote, 159, 202, 217, 230, 249
 - development, 232, 234

Credits

Photo Credits

Table of Contents: p. 4 CORBIS/Graham Neden/Edoscene; p. 7 Visuals Unlimited/Science VU.

Matter: Unit Opener © Phil Norton; **Unit Overview:** p. 10 top Corel, bottom CORBIS/Paul A. Souders;

Chapter 1: p. 12 top CORBIS/Michael Neveux, bottom Canapress/Fabrice Coffrini; p. 13 top PhotoDisc, inset Jeremy Jones; p. 16 middle Image Network, bottom left J. A. Wilkinson/VALAN PHOTOS, bottom centre PhotoDisc, bottom right Al Handen/Image Bank; p. 17 top to bottom CORBIS/Wolfgang Kahler, G. Kahrner/VALAN PHOTOS, Visuals Unlimited/Bill Beatty, Image Network, Visuals Unlimited/Mark A. Schneider, CORBIS/Henry Diltz, Visuals Unlimited/Mark Skalney; p. 18 top PhotoDisc, middle CORBIS/Kit Kittle; p. 19 top Visuals Unlimited/Glenn Oliver, bottom PhotoDisc; p. 28 CORBIS/Michael Yamashita; p. 29 left p. A. Wilkinson/VALAN PHOTOS, right Kennon Cooke/VALAN PHOTOS; p. 31 top CORBIS/Jules T. Allen, bottom PhotoEdit/D. Young-Wolff; p. 34 top Peggy Rhodes, bottom inset CORBIS/Gianni Dagli Orti; p. 35 top Greg Kinch, bottom CORBIS/Galen Rowell; p. 36 Mazda; p. 38 top CORBIS, middle CORBIS/Doug Wilson, bottom Visuals Unlimited/p. Holden.

Chapter 2: p. 42 top Canapress/Denis Seguin, bottom Scott Camazine/Oxford Scientific Films; p. 43 Canapress; p. 45 CORBIS/Philadelphia Museum of Art; p. 47 Richard Megna/Fundamental Photographs; p. 50 top and middle Visuals Unlimited/Richard Treptow, bottom V. Wilkinson/VALAN PHOTOS; p. 51 Visuals Unlimited/L. S. Stepanowicz; p. 58 Jerry Mason/Science Photo Library; p. 62 top CORBIS/Digital Art, middle and bottom right Dave Starrett, bottom left Jean Bruneau/VALAN PHOTOS; p. 66 top Ariel Skelley/First Light, bottom Guy Lebel/VALAN PHOTOS; p. 67 A. B. Joyce/VALAN PHOTOS; p. 68 Visuals Unlimited/R. E. Muck; p. 69 top courtesy of Glenn Martin, bottom Visuals Unlimited/W. A. Banaszewski; p. 70 top to bottom John Cancalosi/VALAN PHOTOS, Visuals Unlimited/Bob Newman, Visuals Unlimited/A. J. Copely, CORBIS/José Manuel Sanchis Calvete, Visuals Unlimited/Ken Lucas, CORBIS/James L. Amos, Visuals Unlimited/Dane S. Johnson; p. 71 Shashinka Photo; p. 72 top courtesy of INCO Ltd., bottom CORBIS/Paul A. Souders; p. 73 Simon Fraser/Northumbria Circuits/Science Photo Library.

Chapter 3: p. 78 Peggy Rhodes; p. 79 David M. Glass/Image Network; p. 80 Peggy Rhodes; p. 82 CORBIS/Ted Spiegel; p. 83 CORBIS/Bettmann; p. 84 NASA; p. 86 top courtesy of Shree Mulay, bottom Photo Edit/Amy Etra; p. 90 top Scott Camazine/Oxford

Scientific Films, bottom CORBIS/Lester V. Bergman; p. 94 Imperial College, Dept. of Physics/Science Photo Library; p. 95 Visuals Unlimited/Rich Treptow; p. 97 top Visuals Unlimited/SIU, middle James King-Holmes/Science Photo Library, bottom Visuals Unlimited/Deneve Feigh Bunde; p. 98 Sun Syndicate;

Chapter 4: p. 102 CORBIS/Lynn Goldsmith; p. 103 Julia Lee; p. 104 top Visuals Unlimited/Rich Treptow, bottom Burndy Library; p. 110 left Visuals Unlimited/Garry Carter, centre CORBIS/Michael Neveux, right CORBIS/Gunter Marx; p. 111 top Richard Megna/Fundamental Photos, bottom Janet Mortimer/VALAN PHOTOS; p. 112 top Canapress/Bill Sandford, bottom CORBIS/Graham Neden/Edoscene, bottom inset CORBIS/Bettmann; p. 117 V. Whelan/J. A. Wilkinson/VALAN PHOTOS; p. 118 Corel; p. 119 top Science Photo Library/© David Parker/IMI/University of Birmingham High Technology Consortium, bottom Michael Keller/First Light; p. 125 courtesy of Colin Haskin; p. 129 PhotoDisc.

Reproduction: Unit Opener Dr. Jeremy Burgess/Science Photo Library; **Unit Overview:** p. 136 top CORBIS/Lester V. Bergman, bottom Scott Camazine/Oxford Scientific Films; p. 137 top PhotoDisc, bottom CORBIS/Peter Johnson;

Chapter 5: p. 138 top left CORBIS/David Spears, top right CORBIS/Lester V. Bergman, middle left Carolina Biological Supply Co., middle right CORBIS/Lester V. Bergman, bottom left David E. Meyers/Tony Stone Images, bottom right CORBIS/Galen Rowell; p. 139 Alex Bartel/Science Photo Library; p. 140 Sinclair Stammers/Science Photo Library, inset D. p. Wilson/Photo Researchers; p. 141 top right Geoff Thompkinson/Science Photo Library, inset Dr Ann Smith/Science Photo Library/Photo Researchers, bottom left Takeshi Takahara/Photo Researchers, inset Biophoto Assoc./Photo Researchers; p. 148 top CORBIS/Guy Stubbs, bottom CORBIS/Lester V. Bergman; p. 149 CORBIS/Phil Schermeister; p. 150 top CORBIS/David Spers, middle Visuals Unlimited/Science VU; pp. 154–5 Andrew Bajer, University of Oregon; p. 158 top left courtesy of Harriet Simard, bottom right Michael Gadowski/Science Photo Library; p. 160 top left A. B. Dowsett/Science Photo Library, middle CORBIS/Jeffrey L. Rotman, bottom John Cooke/Oxford Scientific Films; p. 161 top CNRI/Science Photo Library, bottom Harry Taylor/Oxford Scientific Films; p. 164 CORBIS/Gary Braasch; p. 165 CORBIS/Bettman; p. 167 Visuals Unlimited/Gerald and Buff Corsi; p. 170 CORBIS/Vince Streano.

Chapter 6: p. 174 middle CORBIS/Paul Seheult, Eye Ubiquitous, bottom CORBIS/Jeffrey L. Rotman; p. 175 top Archive Photos/Stephen Vaughn/Fotos International, bottom Dave Starrett; p. 179 courtesy of Lap-Chi Tsui; p. 181 Dr. Brian Eyden/Science Photo Library; p. 187 CORBIS/Jeffrey L. Rotman; p. 188 CORBIS, inset CORBIS/Lester V. Bergman; p. 191 G. A. Maclean/Oxford Scientific Films; p. 194 top Visuals Unlimited/A. M. Siegelman, bottom left Carolina Biological Supply Co., bottom right Runk/Schoenberger from Grant Heilman/Miller Comstock.

Chapter 7: p. 200 top Visuals Unlimited/D. Kline, bottom S. Lowry, University of Ulster/Tony Stone Images; p. 201 A. Ramey/PhotoEdit; p. 212 middle PhotoDisc, inset courtesy of Central Experimental Farm, Ottawa, bottom CORBIS/Owen Franken; p. 213 George Holten/Photo Researchers; p. 219 courtesy of Genesis Fertility Centre, Vancouver, B.C.; p. 222 courtesy of Ontario Special Olympics; p. 224 A. Tsiaras/Photo Researchers.

Chapter 8: p. 230 top Professor p. Motta, Department of Anatomy, University "a Sapienza" Rome/Science Photo Library, middle Visuals Unlimited/John D. Cunningham, bottom left John Brown/Oxford Scientific Films, bottom upper right Martyn Chillmaid/Oxford Scientific Films, bottom lower right Kathie Atkinson/Oxford Scientific Films; p. 231 top CORBIS/Lynda Richardson, bottom left CORBIS/Lester V. Bergman, bottom right CORBIS/Douglas p. Wilson/Frank Lane Picture Agency; p. 232 middle Visuals Unlimited/George B. Chapman, bottom Visuals Unlimited/Arthur M. Stegelman; p. 233 middle left J. A. L. Cooke/Oxford Scientific Films, middle centre G. I. Bernard/Oxford Scientific Films, middle right Biophoto Assoc./Photo Researchers, bottom left J. A. Wilkinson/VALAN PHOTOS, bottom right Visuals Unlimited/ N. Pecnik; p. 234 top Harold Taylor/Oxford Scientific Films, bottom left Visuals Unlimited/Tom Ulrich, bottom right John Cancalosi/VALAN PHOTOS; p. 235 top Visuals Unlimited/John D. Cunningham, bottom Martyn Colbeck/Oxford Scientific Films; p. 238 PhotoDisc; p. 240 Dave Starrett; p. 242 Lennart Nilsson, *A Child is Born*, © 1966, 1977 Dell Publishing Company Inc.; p. 243 Andy Walker, Midland Fertility Services/Science Photo Library; p. 247 top courtesy of Madeleine Boscoe, bottom Canapress/Tom Hanson; p. 250 Joseph R. Siebert/Custom Medical Stock Photo; p. 251 middle Derek Bromhall/Oxford Scientific Films, bottom A. Barter/Custom Medical Stock © 1996 all rights reserved; p. 252 Lennart Nilsson, *A Child is Born*, © 1966, 1977 Dell Publishing Company Inc.; p. 254 CORBIS/Tim Page; p. 258–9 Canapress/Paul Clements.

Electricity: Unit Opener CORBIS/Kevin R. Morris; **Unit Overview:** top CORBIS/Roger Ressemeyer, bottom PhotoDisc; p. 267 PhotoDisc;

Chapter 9: p. 268 top CORBIS/Roger Ressemeyer; bottom Dave Starrett; p. 269 CORBIS/William James Warren; p. 271 Jeremy Jones; p. 276 courtesy of Boreal; p. 278 First Light/Stock Market Ted Horowitz; p. 280 CORBIS/Richard Hamilton Smith; p. 282 CORBIS/Steve Raymer; p. 283 Brian Losito/Air Canada; p. 284 top courtesy of W.C.S. Aviation; bottom Brian Losito/Air Canada; p. 287 Frank Scott/Spectrum Stock; p. 288 Dave Starrett; p. 290 CORBIS/Michael Neveux; p. 293 Image Network;

Chapter 10: p. 296 top CORBIS/Doug Wilson; bottom Val Wilkinson/VALAN PHOTOS; p. 297 Dick Hemingway; p. 300 Dave Starrett; p. 302 J.A. Wilkinson/VALAN PHOTOS; p. 304 top Randy Homenick; bottom courtesy of DaimlerChrysler; p. 306 J.A. Wilkinson/VALAN PHOTOS; p. 310 top left J.A. Wilkinson/VALAN PHOTOS; top right J.A. Wilkinson/VALAN PHOTOS; p. 313 courtesy Rechargeable Battery Recycling Corporation; p. 316 top to bottom J.A. Wilkinson/VALAN PHOTOS, PhotoDisc, CORBIS/Owen Franken; p. 317 Visuals Unlimited/Jeff Greenberg; p. 318 courtesy of Boreal; p. 324 CORBIS/Mike Zens; p. 325 top VALAN PHOTOS/John Fowler; bottom courtesy of Boreal.

Chapter 11: p. 330 top Dave Starrett, bottom left courtesy of Innovative Technologies Inc. Visit their website at www.windupradio.com. Bottom right courtesy of Zap Power Systems. Visit their website at www.zapbikes.com or call 1-800-251-4555 for more information; p. 331 CORBIS/Jim Sugar Photography; p. 334 Dave Starrett; p. 336 J. A. Wilkinson/VALAN PHOTOS; p. 337 PhotoDisc; p. 338 John Fowler/VALAN PHOTOS, table data from *Staying Connected Winter '98* © Ontario Hydro; p. 340 PhotoDisc; p. 341 Comstock; p. 342 courtesy of Ballard Power Systems Inc.; p. 346 top PhotoDisc, middle John Fowler/VALAN PHOTOS, bottom left J. A. Wilkinson/VALAN PHOTOS, bottom right J. A. Wilkinson/VALAN PHOTOS; p. 347 top, VALAN PHOTOS, bottom PhotoDisc; p. 348 top, bottom left and bottom right, VALAN PHOTOS; p. 349 Jean Bruneau/VALAN PHOTOS; p. 352 top to bottom R. Moller/VALAN PHOTOS, Francis Lepine/VALAN PHOTOS, V. Wilkinson/VALAN PHOTOS, James R. Page/VALAN PHOTOS, Jeannie R. Kemp/VALAN PHOTOS; p. 354 CORBIS/Nik Wheeler; p. 355 top courtesy of Nortel Networks, bottom Comstock, inset PhotoDisc; p. 356 Canapress/AP/Bill Schaefer/Idaho State Journal; p. 357 Courtesy of Ontario Hydro.

Chapter 12: p. 360 top CORBIS/Roger Ressemeyer, bottom J. A. Wilkinson/VALAN PHOTOS; p. 361 left CORBIS/Bettman, right ©1999 Apple Computer, Inc. All rights reserved. Apple and the Apple logo and Power Macintosh are trademarks of Apple Computer, Inc., registered in the U.S. and other countries. iMac is a trademark of Apple Computer, Inc.; p. 364 top J. Eastcott/E. Momatiuk/VALAN PHOTOS; middle and bottom J.A. Wilkinson/VALAN PHOTOS; p. 366 top

Al Harvey/The Slide Farm; middle J.A.Wilkinson/VALAN PHOTOS, bottom Jeremy Jones; p. 371 courtesy of Natural Resources Canada; p. 373 table data from *Staying Connected* Winter '98 © Ontario Hydro; p. 377 Dave Starrett; p. 379 courtesy of Robert Williams; p. 380 top J.A.Wilkinson/VALAN PHOTOS, bottom V. Wilkinson/VALAN PHOTOS; p. 381 CORBIS/Richard Hamilton Smith; p. 382 left Visuals Unlimited/John Sohliden, right Corel; p. 384 © Lee Foster/ FPG International L.L.C.; p. 385 Kennon Cooke/VALAN PHOTOS.

Space: Unit Opener Pekka Parviainen/Science Photo Library; **Unit overview:** p. 396 top VALAN PHOTOS, bottom Visuals Unlimited/Science VU; p. 397 top Visuals Unlimited/Science VU, bottom NASA;

Chapter 13: p. 398 top and bottom Jack Zehrt/FPG International; p. 398–399 Visuals Unlimited/George East; p. 399 Terence Dickinson; p. 400 Ian Davis-Young/VALAN PHOTOS; p. 405 CORBIS/Roger Ressmeyer; p. 406 T.C. Middleton/Oxford Scientific Films; p. 410 John Cancalosi/VALAN PHOTOS; p. 411 Visuals Unlimited/Cheryl Hogue; p. 417 Corel; p. 422 NASA/JPL/Cal Tech; p. 424 left NASA/Hawaiian Astronomical Society, right Visuals Unlimited/Ishtar Terra; p. 425 left Oxford Scientific Films/NASA, right NASA; p. 426 Visuals Unlimited/Science VU; p. 427 top left NASA/JPL/Cal Tech, top right NASA, bottom Visuals Unlimited/Science VU; p. 428 NASA; p. 429 top courtesy Mary Lou Whitehorne, bottom Terence Dickinson; p. 430 Oxford Scientific Films/NASA; p. 431 top NASA, middle left Visuals Unlimited/Science VU, middle right NASA; p. 432 top NASA/D. Roddy LPI, bottom NASA/JPL; p. 433 NASA/JPL/Cal Tech.

Chapter 14: p. 436 top Visuals Unlimited/George East, bottom Pekka Parviainen/Science Photo Library; p. 437 Visuals Unlimited/Science VU; p. 440 J. Baum/Science Source/Photo Researchers; p. 445 Images BC/Image Network; p. 448 left David Nunuk/First Light, right Visuals Unlimited/Science VU; p. 449 top National Optical Observatory, bottom CORBIS/Stephanie Maze; p. 450 top Stan Osolinski/Oxford Scientific Films, bottom NASA/JPL/Cal Tech; p. 451 top Dave Starrett, bottom Jack Zehrt/FPG International; p. 452 CORBIS/John Wilkinson/Ecoscene; p. 454 Visuals Unlimited/Science VU; p. 456 CORBIS/Roger Ressmeyer; p. 458 Al Harvey/The Slide Farm; p. 459 Dept. of Physics, Imperial College/Science Photo Library; p. 461 top Dennis Di Cicco/Science Photo Library, bottom left NASA, bottom middle Dr. Jeanne Lorre/Science Photo Library, bottom right Pekka Parviainen/Science Photo Library; p. 462 top left Visuals Unlimited/Science VU, top right Karl Henize, bottom NASA; p. 463 Visuals Unlimited/Science VU.

Chapter 15: p. 466 top CORBIS, bottom NASA; p. 467 top CORBIS/Roger Ressmeyer; p. 468 NASA; p. 470 top and bottom, NASA; p. 474 top courtesy Ron Thorpe, bottom painting by Paul Fjeld courtesy Ron Thorpe; p. 479 Brad Whitmore (STSCI)/NASA; p. 480 NASA; p. 482 John Morse/University of Colorado/NASA; p. 483 NASA.

Chapter 16 pp. 486–487 NASA; p. 489 bottom NASA; p. 491 Dave Starrett; p. 493 top NASA; p. 496 courtesy Canada Centre for Remote Sensing; p. 499 Visuals Unlimited/Science VU; p. 500 NASA; p. 501 bottom NASA; p. 503 NASA; p. 506 bottom left CORBIS/Lindsay Hebbard, bottom right courtesy Fyrepel, A Division of Lakeland Industries, Inc.; p. 507 top courtesy Aryn Samji, bottom Elliott Coleshill; p. 508 Dave Starrett; p. 511 NASA; p. 514 top courtesy Learning Technologies Inc., bottom Ames Research Centre/NASA; p. 515 Dave Starrett.

Skills Handbook: opener and p. 523 CORBIS/Phil Schermeister; pp. 523–525, 534, 546, 560, 569 Dave Starrett, p. 547 Comstock.

Career Profile Writing Credits

Alison Armstrong (*Madeline Boscoe*, p. 247; *Colin Haskin*, p. 125; *Dr. Shree Mulay*, p. 86; *Harriet Simand*, p. 158; *Helder Sousa*, p. 31; *Dr. Albert Yuzpe*, p. 219); Jim Dawson (*Gary Masse*, p. 286; *Shelley Harding-Smith*, p. 306; *Robert Williams*, p. 379); Julia Lee (*Karen Cheung*, p. 355; *Anya Martin*, p. 69; *Lap-Chi Tsui*, p. 179); Ron Thorpe (*Paul Fjeld*, p. 474; *Aryn Samji*, p. 507; *Ivan Semeniuk*, p. 451; *Mary Lou Whitehorne*, p. 429).