GRADE 9 · PRE-AP FOUNDATIONS

AP Science Readiness Guide

What a 9th grader should know, practice, and be able to do to build toward AP Biology, AP Chemistry, AP Physics, and AP Environmental Science.

Nothing in life is to be feared, it is only to be understood.

— Attributed to Marie Curie, Nobel Prize winner in physics (1903) and chemistry (1911)

1 The Road to AP Science
2 The AP Science Exams at a Glance
3 Science Practices Toolkit
4 Measurement and Math Toolkit
5 Data and Graphs
6 Matter and Chemistry Foundations
7 Forces, Motion, and Energy
8 Life Science Foundations
9 Earth and Environment
10 Science Words and Command Terms
11 Mistakes and Misconceptions
12 Study Plan and Resources
13 End-of-Year Self-Check
14 Practice
15 Answer Key

How to use this guide: sections marked CORE are what most 9th-grade science classes cover (usually Biology or Physical Science). Sections marked GET AHEAD are Chemistry and Physics ideas usually taught in 10th–11th grade — learning them early pays off in AP.

Name: _____ Class / Period: _____

1 The Road to AP Science

AP science courses are college-level classes in biology, chemistry, physics, and environmental science. Most students take them in 11th or 12th grade, so 9th grade is where you build the skills every one of them uses.

Grade 9

Biology, Physical Science, or Earth Science · some schools offer AP Environmental Science or AP Physics 1 in 9th–10th grade

- Cells, macromolecules, and enzymes
- DNA, genetics, and evolution
- Ecology and human impact
- Lab design, graphs, and CER

Grade 10

Chemistry, often Honors

- Atomic structure and bonding
- The mole and stoichiometry
- Gases, solutions, acids, and bases
- Algebra in every lab

Grade 11

AP Biology, AP Chemistry, AP Physics 1, or AP Environmental Science

- College-level labs
- Data analysis and statistics
- Timed written explanations
- Your first AP exam in May

Grade 12

A second AP science, or AP Physics C alongside calculus

- A second AP course and exam
- Calculus-based physics (AP Physics C)
- Independent research or science fair
- Full practice exams

Schools sequence science differently: some teach physics first in 9th grade, and some open AP Environmental Science or AP Physics 1 to 9th or 10th graders. AP Physics C uses calculus, so students usually take it in 12th grade, alongside or after a calculus course.

What AP science actually tests

AP science exams do not just ask you to remember facts. Every AP science course is built on **science practices** — the skills scientists use to ask questions, test ideas, and make sense of data. Facts are the tools; reasoning with evidence is the goal.

Practice	What it means	Grade 9 version
Explaining concepts	Use science ideas to explain how and why something happens.	Explain how an enzyme's shape lets it speed up one reaction.
Questions and experiments	Ask a testable question and design a fair test to answer it.	Design a test with a control group and repeated trials.
Data and models	Build and read graphs, tables, diagrams, and models.	Graph data, add a best-fit line, and explain its slope.
Math and data analysis	Calculate, use units, find patterns, and judge how reliable data are.	Calculate rates and percent change to the right significant figures.
Argument from evidence	Make a claim and support it with data and scientific reasoning.	Write a CER paragraph that cites numbers and a science principle.

The habits that matter most in 9th grade

Ask "How do you know?"

For every fact you learn, ask what evidence supports it. AP rewards reasoning, not memorized sentences.

Units, every time

Write a unit after every number: **12 m/s**, not 12. A number without a unit is not an answer.

Draw it first

Sketch a force diagram, a particle model, or a food web before you solve. A picture shows what the question really asks.

Keep a science notebook

Record every lab and every correction. Most lost points come from the same few mistakes.

2 The AP Science Exams at a Glance

Each AP science exam is given in May and scored from 1 to 5. Many colleges award credit or placement for a 3 or higher. Knowing the formats now shows you which skills to build over the next two or three years.

Exam and section	Questions	Time	Share of score
AP Biology			
Section I — Multiple choice	60	1 hr 30 min	50%
Section II — Free response (2 long, 4 short)	6	1 hr 30 min	50%
AP Chemistry			
Section I — Multiple choice	60	1 hr 30 min	50%
Section II — Free response (3 long, 4 short)	7	1 hr 45 min	50%
AP Physics 1: Algebra-Based			
Section I — Multiple choice	40	1 hr 20 min	50%
Section II — Free response: mathematical routines; translation between representations; experimental design and analysis; qualitative/quantitative translation	4	1 hr 40 min	50%
AP Environmental Science			
Section I — Multiple choice	80	1 hr 30 min	60%
Section II — Free response: design an investigation; analyze an environmental problem and propose a solution; the same with calculations	3	1 hr 10 min	40%

Formats per the College Board's Course and Exam Descriptions. Details can change: check AP Central (apcentral.collegeboard.org) during the year you take the exam.

What the four exams have in common

- **Data everywhere.** Many questions start from a graph, a data table, a diagram, or a lab description.
- **Experiments.** Every exam asks you to plan, critique, or analyze an investigation. Each AP science course includes required lab work.
- **Math.** Calculators are allowed, and each exam provides reference sheets of formulas, equations, or tables — you still choose and use them.
- **Writing.** Free-response questions ask you to explain, justify, and calculate in your own words.

How the free-response questions are scored

Each free-response question is scored with a rubric (the scoring guidelines) that awards points for specific pieces of a correct answer. Higher scores go to answers that:

- **Answer every part** — (a), (b), (c)… each earns its own points.
- **Show the work** — equation, numbers with units, answer with units.
- **Use evidence** — specific numbers from the data or graph.
- **Explain the "why"** — connect the evidence to a science idea.
- **Use precise words** — "kinetic energy," not "movement power."
- **Label everything** — axes, units, and parts of diagrams.

> **The 9th-grade takeaway**
>
> You do not need all the AP content yet. You need to read data carefully, write units, and explain *why* with evidence. Practice those three things all year. Past free-response questions and their scoring guidelines are on AP Central — look at one this year.

3 Science Practices Toolkit

Experiments are how science knows what it knows. These tools show up on every AP science exam, in every course.

From question to hypothesis CORE

A **testable question** names what you will change and what you will measure: "Does ___ affect ___?"

- Testable: **Does the height of a ramp affect how far a toy car rolls?**
- Testable: **Does water temperature affect how fast sugar dissolves?**
- Not testable: ~~Which car looks coolest?~~ (an opinion — nothing to measure)

HYPOTHESIS PATTERN

If [I change the independent variable], **then** [the dependent variable will…], **because** [a science reason].

If the ramp is higher, then the car will roll farther, because it starts with more gravitational potential energy.

A hypothesis is a **testable prediction with a reason**, not a wild guess. Data can **support** or **refute** it; one experiment never "proves" it.

Variables and controls CORE

Example experiment: *Do bean seeds sprout sooner if they are soaked in water overnight before planting?*

Term	What it is	In the seed experiment
Independent variable (IV)	The **one** thing you change on purpose. It goes on the x-axis.	Soaked or not soaked
Dependent variable (DV)	What you measure; it "depends on" the IV. It goes on the y-axis.	Days until each seed sprouts
Controlled variables	Everything you keep the same so the test is fair.	Seed type, soil, pot, water, light, temperature
Control group	The group that gets no treatment (normal conditions), for comparison.	The seeds that were not soaked
Repeated trials	Running the test more than once and averaging the results.	Repeat the experiment three times
Sample size	How many subjects you test. Bigger samples make odd results matter less.	20 seeds in each group, not 1

Change only one thing. If you soak the seeds *and* move them to a warmer room, you cannot tell which change made them sprout sooner.

Claim, Evidence, Reasoning (CER) CORE

CER is how scientists — and AP free-response answers — make an argument. Use it whenever a question says *explain*, *justify*, or *support your claim*. The **claim** is one sentence that answers the question. The **evidence** is specific data — numbers, units, comparisons. The **reasoning** is the science idea that explains *why* the evidence supports the claim ("This happens because…").

Worked example: ramp height and rolling distance

Ramp height	Trial 1	Trial 2	Trial 3	Average
10 cm	60	64	62	**62**
20 cm	116	121	117	**118**
30 cm	178	185	180	**181**

Distance rolled, in centimeters. Same car, same floor, released from rest every time.

Claim: A higher ramp makes the toy car roll farther. **Evidence:** As the ramp height increased from 10 cm to 20 cm to 30 cm, the average distance increased from 62 cm to 118 cm to 181 cm — tripling the height roughly tripled the distance. **Reasoning:** A car at the top of a higher ramp has more gravitational potential energy. As it rolls down, that energy becomes kinetic energy, so the car leaves the ramp faster and friction takes longer to stop it.

Models CORE

A **model** is a simplified picture of something too big, too small, too fast, or too slow to study directly: a **physical** model (a globe, a ball-and-stick molecule), a **diagram** (a food web, a particle drawing), a **mathematical** model ($D = m/V$), or a **computer simulation** (a PhET sim, a weather forecast). Every model leaves something out — and AP questions often ask what.

Lab safety basics: safe scientists are good scientists

- Read the whole procedure before you start.
- Wear goggles whenever chemicals, heat, or glass are in use.
- Tie back long hair; no food or drink in the lab.
- Waft odors toward your nose — never sniff directly.
- Point heated test tubes away from everyone.
- Report every spill, break, cut, or burn right away.
- Know where the eyewash, fire blanket, and extinguisher are.
- Dispose of materials as told; wash your hands after.

4 Measurement and Math Toolkit

Science runs on measurement. Every AP science course uses metric units, scientific notation, and algebra, so make them automatic now.

SI units CORE

Scientists everywhere use the International System of Units (SI). Seven base units cover everything; all other units are built from them.

Base quantity	Unit	Symbol
Length	meter	m
Mass	kilogram	kg
Time	second	s
Temperature	kelvin (K = °C + 273)	K
Amount of substance	mole	mol
Electric current	ampere	A
Luminous intensity	candela	cd

Built from them	Unit	Means
Volume	L, mL, cm^3	1 mL = 1 cm^3
Density	g/cm^3, g/mL	mass ÷ volume
Speed, acceleration	m/s, m/s^2	per second
Force	newton (N)	1 N = 1 kg·m/s^2
Energy, work	joule (J)	1 J = 1 N·m
Power	watt (W)	1 W = 1 J/s
Frequency	hertz (Hz)	waves per second

In class you will mostly measure mass in grams (g) and temperature in degrees Celsius (°C).

Metric prefixes CORE

Prefix	Symbol	Factor	Example
kilo-	k	1,000 (10^3)	1 km = 1,000 m
hecto-	h	100 (10^2)	1 hm = 100 m
deka-	da	10 (10^1)	1 dam = 10 m
base unit (m, g, L, s) = 1			
deci-	d	0.1 (10^{-1})	10 dm = 1 m
centi-	c	0.01 (10^{-2})	100 cm = 1 m
milli-	m	0.001 (10^{-3})	1,000 mL = 1 L
micro-	μ	10^{-6}	a cell ≈ 10 μm
nano-	n	10^{-9}	10^9 nm = 1 m

Kilo to milli, each step is ×10: **K**ing **H**enry **D**ied **B**y **D**rinking **C**hocolate **M**ilk.

Converting units CORE

Use the **factor-label method**: multiply by a conversion factor — a fraction equal to 1 — with the unit you want on top and the unit you are cancelling on the bottom. Units cancel like numbers.

$$2.5\ \text{km} \times \frac{1{,}000\ \text{m}}{1\ \text{km}} = 2{,}500\ \text{m}$$

$$72\ \frac{\text{km}}{\text{h}} \times \frac{1{,}000\ \text{m}}{1\ \text{km}} \times \frac{1\ \text{h}}{3{,}600\ \text{s}} = 20\ \text{m/s}$$

Shortcut: a **smaller** unit means a **bigger** number (move the decimal right); a bigger unit means a smaller number. 350 mL = 0.35 L.

Scientific notation CORE

Write very large or very small numbers as $a \times 10^n$, where a is at least 1 and less than 10.

- Speed of light: 300,000,000 m/s = **3.0×10^8 m/s**
- Earth to Sun: 150,000,000 km = **1.5×10^8 km**
- Red blood cell: 0.000008 m = **8×10^{-6} m**

Big numbers get a positive exponent; numbers smaller than 1 get a negative one.

MULTIPLY: MULTIPLY, THEN ADD EXPONENTS

$$(3 \times 10^4)(2 \times 10^3) = 6 \times 10^7$$

DIVIDE: DIVIDE, THEN SUBTRACT EXPONENTS

$$(8 \times 10^6) \div (2 \times 10^2) = 4 \times 10^4$$

Averages, percent change, and percent error CORE

MEAN (AVERAGE)

$$\text{mean} = \frac{\text{sum of values}}{\text{number of values}}$$

Trials of 4.1 s, 3.8 s, and 4.3 s: mean = 12.2 ÷ 3 ≈ 4.1 s. Range = 4.3 − 3.8 = 0.5 s.

PERCENT CHANGE

$$\frac{\text{new} - \text{original}}{\text{original}} \times 100\%$$

Water warms from 20 °C to 26 °C: 6 ÷ 20 × 100% = a 30% increase. A negative answer means a decrease.

PERCENT ERROR

$$\frac{|\text{measured} - \text{accepted}|}{\text{accepted}} \times 100\%$$

You measure g = 9.5 m/s^2; the accepted value is 9.8 m/s^2: 0.3 ÷ 9.8 × 100% ≈ 3.1%.

Rearranging a formula CORE

To solve for a different variable, do the same operation to both sides. Learn one form of each formula and rearrange it for the others.

$D = m/V \rightarrow m = DV \rightarrow V = m/D$	A rock with D = 3.0 g/cm^3 and V = 12 cm^3 has m = 3.0 × 12 = 36 g.
$v = d/t \rightarrow d = vt \rightarrow t = d/v$	At 5 m/s, a 100 m run takes t = 100 ÷ 5 = 20 s.
$F = ma \rightarrow a = F/m \rightarrow m = F/a$	A 20 N net force on a 10 kg cart gives a = 20 ÷ 10 = 2 m/s^2.

Significant figures and precision CORE

Your answer can't be more precise than your measurements

Which digits count? Nonzero digits always count (245 → 3). Zeros between them count (1,005 → 4). Leading zeros never count (0.0042 → 2). Trailing zeros count only with a decimal point (2.50 → 3; 1,200 → 2).

Accuracy is how close you are to the true value; **precision** is how close repeated measurements are to each other.

Multiply or divide: keep the fewest significant figures. 4.56 cm × 1.4 cm = 6.384 → **6.4 cm^2**

Add or subtract: keep the fewest decimal places. 12.11 g + 3.2 g = 15.31 → **15.3 g**

High-school Chemistry, AP Chemistry, and AP Physics expect this on every calculation.

5 Data and Graphs

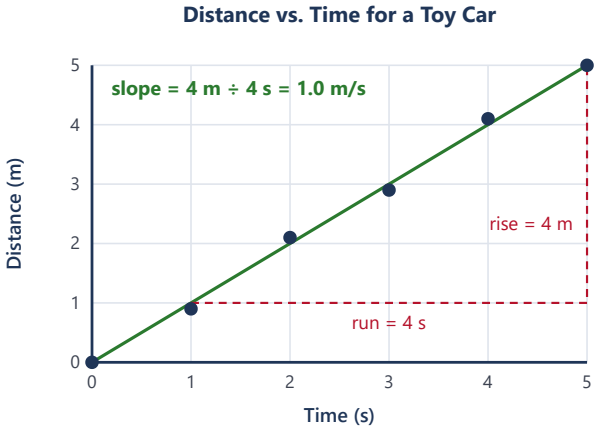
On AP science exams, most questions start with a graph, a data table, or a diagram. Reading data well is half the battle.

Which graph for which data? CORE

Graph	Use it when…	Example
Line graph	The independent variable is a number that changes continuously, often time.	Temperature of water every minute while it heats
Bar graph	You compare amounts across separate categories.	Average plant height with three different fertilizers
Scatter plot	You look for a relationship between two measured numbers; add a best-fit line.	Arm span vs. height for 30 students
Pie (circle) chart	You show parts of a whole that add up to 100%.	Air: 78% nitrogen, 21% oxygen, 1% argon and other gases
Histogram GET AHEAD	You show how data are spread across ranges.	Number of students in each height range

Parts of a good graph CORE

- A **title** that names both variables: "Distance vs. Time for a Toy Car."
- **Independent variable on the x-axis**, dependent variable on the y-axis. Remember DRY MIX: **D**ependent, **R**esponding, **Y**-axis; **M**anipulated, **I**ndependent, **X**-axis.
- **Axis labels with units**: "Time (s)."
- An **even scale** — equal steps — that uses most of the grid.
- Points plotted carefully, then a smooth **best-fit line or curve** — not connect-the-dots.
- A **key** when there is more than one data set.



The best-fit line passes near every point. Its slope, 1.0 m/s, is the car's speed.

Line of best fit and slope

A best-fit line shows the trend. It does not have to touch every point; about as many points should sit above it as below it. Its slope has units:

$$\text{slope} = \frac{\text{rise}}{\text{run}} = \frac{\text{change in } y}{\text{change in } x}$$

On a distance–time graph, slope = **speed**. On a velocity–time graph, slope = **acceleration**. On a mass–volume graph, slope = **density**.

Reading tables and describing trends CORE

Read the title and every column heading first — the units are there. Then use the pattern **"As [the IV] increases, [the DV] increases / decreases / stays the same"**, and add numbers and the shape: *As time increases from 0 to 5 s, the distance increases steadily from 0 m to 5.0 m — about 1 m every second.* A **positive** trend goes up to the right, a **negative** trend goes down, and a trend can be **linear** (straight) or **curve and level off**. Compare averages, not single trials, and look for **outliers** — values far from the rest. Check an outlier for a mistake, and never drop data without saying so and why.

Interpolate vs. extrapolate

Interpolating means estimating *between* your data points — fairly safe: at 2.5 s the car had gone about 2.5 m. **Extrapolating** means extending *beyond* your data — risky: at 30 s the car may have hit a wall or stopped.

Correlation is not causation

Ice cream sales and sunburns rise and fall together, but ice cream does not cause sunburns — hot, sunny weather causes both. Only a controlled experiment can show that one thing causes another.

Get ahead: variability and error bars

Repeated measurements never match exactly. The **range** (largest − smallest) is the simplest measure of spread; later you will use the **median** and the **standard deviation**. In AP Biology and AP Physics you will draw **error bars** to show the uncertainty around each average. When the error bars of two groups overlap a lot, the difference may be due to chance; when they are far apart, it is more likely to be real.

6 Matter and Chemistry Foundations

Everything around you is matter, and all matter is made of atoms. These ideas lead straight into Chemistry (usually 10th grade) and AP Chemistry.

Inside the atom CORE

Particle	Charge	Where it is	Mass
Proton	+1	In the nucleus	About 1 atomic mass unit (amu)
Neutron	0	In the nucleus	About 1 amu
Electron	−1	Outside the nucleus, in energy levels (the electron cloud)	About 1/1,836 amu — almost nothing

Atomic number = number of protons. It identifies the element.

Mass number = protons + neutrons.

Neutral atom: electrons = protons.

Sodium-23 (atomic number 11): 11 protons, 11 electrons, and 23 − 11 = 12 neutrons.

Isotopes and ions

Isotopes are atoms of the same element with different numbers of neutrons. Carbon-12 has 6 protons and 6 neutrons; carbon-14 has 6 protons and 8 neutrons. Carbon-14 is radioactive and is used to date once-living things.

Ions form when an atom gains or loses electrons: Na loses one to become Na^+; Cl gains one to become Cl^-.

The periodic table CORE

Elements are arranged in order of **atomic number**. Rows are periods; columns are groups (families), and elements in the same group have similar chemical properties.

Families to know: Group 1 alkali metals (very reactive, react with water) · Group 2 alkaline earth metals · Groups 3–12 transition metals · Group 17 halogens (very reactive nonmetals) · Group 18 noble gases (almost never react).

Region	Properties	Examples
Metals (left and center)	Shiny, conduct heat and electricity, can be hammered into sheets or drawn into wires; most are solid	Iron, copper, sodium (mercury is a liquid)
Nonmetals (upper right, plus hydrogen)	Dull, brittle as solids, poor conductors; many are gases	Oxygen, carbon, sulfur, chlorine
Metalloids (along the "staircase")	Some properties of each; semiconductors	Silicon, boron, germanium

Valence electrons and chemical bonds CORE

Valence electrons are the electrons in an atom's outermost energy level, and they decide how it bonds. For the main groups, groups 1 and 2 have 1 and 2 valence electrons; groups 13–18 have 3 to 8 (helium has 2). Atoms tend to gain, lose, or share electrons until their outer level is full — usually 8, the **octet rule**.

Bond	Forms between	What the electrons do	Examples
Ionic	A metal and a nonmetal	Transferred: the metal loses electrons, the nonmetal gains them, and the + and − ions attract	NaCl, MgO
Covalent	Two nonmetals	Shared in pairs	H_2O, CO_2, CH_4, O_2

In water, oxygen pulls the shared electrons harder than hydrogen does, so the molecule is **polar**: slightly negative at the oxygen end and slightly positive at the hydrogen ends. The attractions between neighboring water molecules are **hydrogen bonds**. They make water cling together, resist temperature change, dissolve many substances, and expand as it freezes — which is why ice floats.

Elements, compounds, and mixtures CORE

Type	What it is	Examples
Element	Only one kind of atom; cannot be broken down by chemical means	Gold (Au), carbon (C), oxygen gas (O_2)
Compound	Two or more elements chemically bonded in a fixed ratio, with new properties	Water (H_2O), carbon dioxide (CO_2), table salt (NaCl)
Mixture	Substances physically combined in any ratio; separated by physical means such as filtering, evaporating, or a magnet	**Homogeneous** (a solution): salt water, air. **Heterogeneous**: trail mix, sand in water

Physical and chemical changes CORE

Physical change: same substance

The form or state changes, but no new substance forms: melting, boiling, dissolving sugar, cutting paper. **Physical properties** — color, density, melting point, hardness — can be observed without changing the substance.

Chemical change: new substance

Atoms rearrange into new substances: burning, rusting, cooking an egg. Signs: gas bubbles, a color or temperature change, light, a precipitate (a new solid), or a new odor. **Chemical properties** describe how a substance reacts, such as flammability.

States of matter and particle motion CORE

State	Shape	Volume	Particles
Solid	Definite	Definite	Packed tightly; vibrate in place
Liquid	Takes the container's shape	Definite	Close together; slide past each other
Gas	Fills the container	Fills the container	Far apart; move fast in all directions

Temperature measures the average kinetic energy (motion) of the particles. Adding thermal energy speeds particles up and can change the state: **melting** (solid → liquid), **freezing** (liquid → solid), **evaporation / boiling** (liquid → gas), **condensation** (gas → liquid), **sublimation** (solid → gas, like dry ice), and **deposition** (gas → solid, like frost). Pure water freezes at 0 °C and boils at 100 °C at sea level.

Density CORE

$$D = \frac{m}{V} \quad (\text{g/cm}^3 \text{ or g/mL})$$

A stone of mass 52 g raises the water in a graduated cylinder from 20.0 mL to 40.0 mL. Its volume is 20.0 mL, so D = 52 ÷ 20.0 = **2.6 g/mL**. It sinks.

Water's density is **1.0 g/cm^3**. Anything less dense floats on it; anything more dense sinks. Ice (about 0.92 g/cm^3) floats.

Density is a **characteristic property**: a paper clip and a steel beam have the same density, no matter their size.

Conservation of mass and balancing equations CORE

In a chemical reaction, atoms are rearranged — never created or destroyed. In a closed system, the total mass of the **reactants** equals the total mass of the **products**. (If a gas escapes from an open container, the mass only *seems* to drop.)

A **subscript** counts atoms in one molecule: H_2O has 2 H and 1 O. A **coefficient** counts molecules: $3H_2O$ has 6 H and 3 O.

Never change a subscript

Balance with coefficients only. Changing H_2O to H_2O_2 turns water into hydrogen peroxide — a different substance.

WORKED EXAMPLE

$Na + Cl_2 \rightarrow NaCl$ Left: 1 Na, 2 Cl. Right: 1 Na, 1 Cl.

$Na + Cl_2 \rightarrow 2NaCl$ Cl balanced; now 2 Na on the right.

$2Na + Cl_2 \rightarrow 2NaCl$ Check: 2 Na and 2 Cl on each side. ✓

Get ahead: the mole and stoichiometry

A **mole** is 6.02×10^{23} particles — a chemist's "dozen." The mass of one mole (the **molar mass**) comes from the periodic table: $H_2O = 2(1.0) + 16.0 = 18.0$ g/mol. The coefficients in a balanced equation are mole ratios: in $2H_2 + O_2 \rightarrow 2H_2O$, 2 mol of H_2 react with 1 mol of O_2 to make 2 mol of H_2O. So 4.0 g of H_2 (2.0 mol) makes 2.0 mol of water, or 36 g. This is **stoichiometry**, the heart of Chemistry and AP Chemistry.

Acids, bases, and pH GET AHEAD



Approximate pH of common substances. Below 7 is acidic, 7 is neutral, and above 7 is basic.

Each step on the pH scale is a factor of 10

Acids (pH below 7) release hydrogen ions (H^+); **bases** (pH above 7) release hydroxide ions (OH^-). Test them with an indicator, never by taste or touch: acids turn blue litmus paper red, and bases turn red litmus blue. pH 3 is 10 times more acidic than pH 4 and 100 times more acidic than pH 5. Acid + base → salt + water: $HCl + NaOH \rightarrow NaCl + H_2O$.

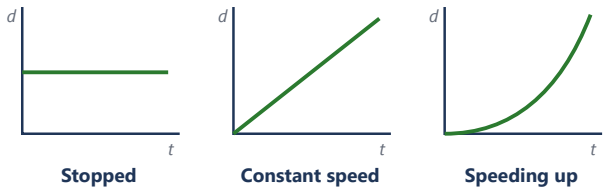
7 Forces, Motion, and Energy

Physics explains how and why things move. Everything here is the starting point for high-school Physics and AP Physics 1.

Speed, velocity, and acceleration CORE

Quantity	Formula	Units	Meaning
Speed	$v = \frac{d}{t}$ (distance ÷ time)	m/s	How fast. 300 m in 60 s is 5 m/s.
Velocity	speed + direction	m/s + direction	How fast and which way: 12 m/s north.
Acceleration	$a = \frac{v_f - v_i}{t}$	m/s^2	How fast velocity changes: speeding up, slowing down, *or* turning. A car going 0 → 20 m/s in 5 s: a = 20 ÷ 5 = 4 m/s^2.

Motion graphs CORE



Three distance–time graphs. Steeper slope = faster.

Distance–time graph: the slope is the speed. A flat line means stopped; a straight sloped line means constant speed; a curve that gets steeper means speeding up.

Velocity–time graph: the slope is the acceleration. A flat line means constant velocity (zero acceleration). GET AHEAD The area under the line is the distance traveled.

Newton's three laws CORE

Law	In plain words	Example
1st — inertia	An object at rest stays at rest, and an object in motion keeps moving at the same speed and direction, **unless an unbalanced (net) force acts on it**.	Passengers lurch forward when a bus stops suddenly.
2nd — *F* = *ma*	Net force = mass × acceleration. More net force → more acceleration; more mass → less acceleration.	An empty cart is easier to speed up than a full one.
3rd — pairs	When object A pushes on object B, B pushes back on A with an equal and opposite force. The two forces act on **different** objects, so they do not cancel.	A swimmer pushes water backward; the water pushes the swimmer forward.

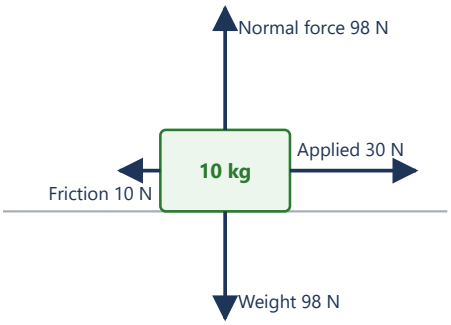
Balanced and unbalanced forces

Add the forces on an object, with direction, to get the net force. If the forces are **balanced** (net force = 0), the object's velocity does not change. If they are **unbalanced**, it accelerates in the direction of the net force.

A free-body diagram shows every force on one object as an arrow. AP Physics 1 uses them in almost every problem — start drawing them now.

$$\text{net force} = 30\ \text{N} - 10\ \text{N} = 20\ \text{N}$$

$$a = \frac{F}{m} = \frac{20\ \text{N}}{10\ \text{kg}} = 2\ \text{m/s}^2$$



A 10 kg box pulled across a floor. Up and down forces balance; sideways forces do not.

Mass, weight, friction, and gravity CORE

Mass is the amount of matter in an object, in kilograms. It is the same everywhere.

Weight is the force of gravity on that mass, in newtons:

$$W = mg, \quad g \approx 9.8\ \text{m/s}^2 \text{ on Earth}$$

A 50 kg student weighs 50 × 9.8 = 490 N on Earth, but only about 80 N on the Moon ($g \approx 1.6\ \text{m/s}^2$). Her mass is still 50 kg.

Friction is a force that opposes motion between surfaces that touch. Rougher surfaces and harder pressing mean more friction. **Air resistance** (drag) is friction with air. Friction turns kinetic energy into thermal energy — that is why rubbing your hands warms them.

Gravity pulls every mass toward every other mass. More mass means a stronger pull; more distance means a weaker one.

Energy and its conservation CORE

Energy	Formula	Example
Kinetic energy (motion)	$\text{KE} = \frac{1}{2}mv^2$	A 1,000 kg car at 10 m/s: KE = ½ × 1,000 × 10^2 = 50,000 J
Gravitational potential energy (height)	$\text{PE} = mgh$	A 2 kg book on a 1.5 m shelf: PE = 2 × 9.8 × 1.5 = 29.4 J
Other forms	Thermal, chemical (food, fuel, batteries), electrical, elastic (a stretched spring), radiant (light), sound, and nuclear	

Because speed is squared, **doubling the speed makes the kinetic energy four times as large** — a favorite AP question.

Conservation of energy

Energy cannot be created or destroyed; it only changes form or moves between objects. A roller coaster trades PE for KE on the way down and KE for PE on the way up. A 2 kg ball dropped from 5 m starts with PE = 2 × 9.8 × 5 = 98 J, so it has about 98 J of KE just before it lands (ignoring air resistance). When energy seems "lost," it has usually become thermal energy through friction or air resistance.

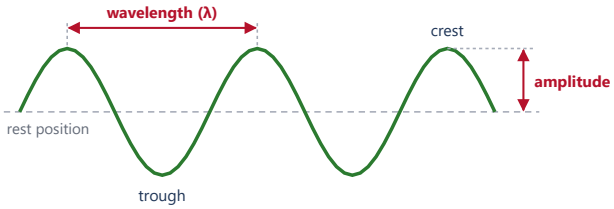
Work, power, and momentum GET AHEAD

Quantity	Formula	Units	Meaning and example
Work	$W = Fd$	joules (J)	Force × distance moved in the direction of the force. Pushing a box with 50 N for 4 m: 200 J.
Power	$P = \frac{W}{t}$	watts (W)	How fast work is done. 200 J in 10 s: 20 W.
Momentum	$p = mv$	kg·m/s	"Mass in motion." A 60 kg runner at 5 m/s: 300 kg·m/s. In a collision, total momentum is conserved when no outside force acts.

Waves CORE

A wave carries **energy** from place to place without carrying matter along with it.

- **Wavelength (λ)**: crest to crest, in meters.
- **Amplitude**: rest position to crest. More amplitude = more energy (louder, brighter).
- **Frequency (*f*)**: waves per second, in hertz (Hz).
- **Wave speed**: $v = f\lambda$. Sound at 340 m/s with f = 170 Hz has λ = 340 ÷ 170 = 2 m.



A transverse wave. For waves at the same speed, higher frequency means shorter wavelength.

Mechanical waves	Electromagnetic waves
Need a medium (solid, liquid, or gas); cannot cross empty space. Sound (about 343 m/s in air), water waves, earthquake waves.	Can travel through a vacuum, at 3.0×10^8 m/s. Light, radio waves, X-rays.
Transverse waves	**Longitudinal waves**
Particles vibrate at right angles to the wave's direction: light, a wave on a rope.	Particles vibrate back and forth along the wave's direction, in compressions and rarefactions: sound.

The electromagnetic spectrum, in order

Radio	Microwaves	Infrared	Visible light	Ultraviolet	X-rays	Gamma rays
Radio, TV	Cooking, phones	Heat, TV remotes	Red → violet (ROYGBIV)	Sunburn	Medical images	Radioactive decay

← longer wavelength, lower frequency, less energy — shorter wavelength, higher frequency, more energy →

Memory aid: **R**aging **M**artians **I**nvaded **V**enus **U**sing **X**-ray **G**uns.

8 Life Science Foundations

Most 9th graders take Biology, so this section goes deepest. These are the ideas AP Biology builds on — from molecules, to cells, to populations.

Cell theory and levels of organization CORE

1. All living things are made of one or more cells.
2. The cell is the basic unit of structure and function in living things.
3. All cells come from existing cells.

Life is organized in levels: **molecule → organelle → cell → tissue → organ → organ system → organism**. A heart muscle cell is part of cardiac muscle tissue, which makes up the heart, part of the circulatory system.

The molecules of life CORE

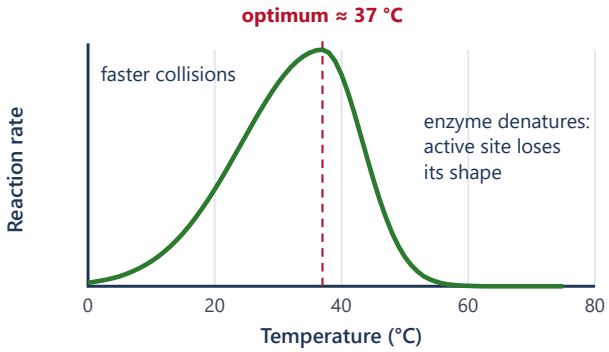
Living things are built mostly from four kinds of large carbon-based molecules (**macromolecules**). Most are polymers: long chains of small repeating units called **monomers**.

Macromolecule	Monomer (building block)	Main jobs	Examples
Carbohydrates	Simple sugars (monosaccharides) such as glucose	Quick energy, energy storage, structure	Glucose, starch, glycogen, cellulose
Lipids	Fatty acids and glycerol (not true polymers)	Long-term energy storage, cell membranes, insulation, some hormones	Fats, oils, phospholipids, cholesterol
Proteins	Amino acids (20 kinds)	Speed up reactions, build structures, carry substances, send signals	Enzymes, hemoglobin, keratin, insulin
Nucleic acids	Nucleotides	Store and carry genetic information	DNA, RNA

Enzymes CORE

Enzymes are proteins that speed up (catalyze) chemical reactions by lowering the energy needed to start them. Each enzyme has an **active site** shaped to fit one kind of molecule, its **substrate** — like a key in a lock. The enzyme is not used up, so it can work again and again.

Temperature and pH matter. Each enzyme works best at an **optimum**. Warming speeds collisions, but too much heat — or the wrong pH — changes the enzyme's shape. It is **denatured**: the active site no longer fits. Pepsin in your stomach works best near pH 2; amylase in saliva works best near pH 7.



A typical human enzyme: activity rises to an optimum near body temperature, then drops quickly.

Prokaryotic and eukaryotic cells CORE

Feature	Prokaryotic	Eukaryotic
Nucleus	No — DNA sits in the cytoplasm	Yes — DNA is inside a nucleus
Membrane-bound organelles	None	Many (mitochondria, ER, Golgi…)
Size	Very small (usually 1–5 µm)	Larger (usually 10–100 µm)
Shared by both	Cell membrane, cytoplasm, ribosomes, and DNA	
Examples	Bacteria and archaea	Animals, plants, fungi, and protists

Organelles and their jobs CORE

Organelle	Job	Found in
Nucleus	Holds the DNA; controls the cell's activities	Plant and animal
Cell membrane	Controls what enters and leaves (selectively permeable)	All cells
Cell wall	Rigid outer layer for support and protection	Plant (also fungi, bacteria)
Cytoplasm	Gel-like fluid where organelles sit and many reactions happen	All cells
Mitochondrion	Cellular respiration: releases energy from glucose as ATP	Plant and animal
Chloroplast	Photosynthesis: captures light energy to make glucose	Plant (and algae)
Ribosome	Builds proteins	All cells
Endoplasmic reticulum	Rough ER (with ribosomes) makes and moves proteins; smooth ER makes lipids	Plant and animal
Golgi apparatus	Modifies, sorts, and packages proteins for shipping	Plant and animal
Vacuole	Stores water, nutrients, and wastes	Plant (one large), animal (small)
Lysosome	Breaks down wastes and worn-out parts with enzymes	Mainly animal

Plant cells have three things animal cells lack: a **cell wall**, **chloroplasts**, and a **large central vacuole**.

Moving across the cell membrane CORE

The cell membrane is a double layer of phospholipids with proteins set into it. It is **selectively permeable**: small molecules such as O_2 and CO_2 slip through, while others need a protein channel or pump.

Process	Energy needed?	What moves, and which way	Example
Diffusion	No (passive)	Particles move from high to low concentration	O_2 entering a cell; CO_2 leaving
Facilitated diffusion	No (passive)	High to low, through a protein channel or carrier	Glucose entering many cells
Osmosis	No (passive)	Water crosses the membrane toward the side with more dissolved solute	Plant roots taking in water
Active transport	Yes (ATP)	Low to high concentration, pushed by a protein pump	The sodium–potassium pump in nerve cells

Predicting osmosis: compare the solution outside the cell with the inside

Solution outside the cell	Water moves	Animal cell	Plant cell
Hypertonic (more solute)	Out of the cell	Shrivels	Membrane pulls away from the wall
Hypotonic (less solute)	Into the cell	Swells and may burst	Firm (turgid); the wall stops it from bursting
Isotonic (equal)	No net movement	Normal	Limp (flaccid)

Photosynthesis and cellular respiration CORE

PHOTOSYNTHESIS · IN CHLOROPLASTS

carbon dioxide + water — light → glucose + oxygen

$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$

Plants, algae, and some bacteria store light energy as chemical energy in glucose.

CELLULAR RESPIRATION · IN MITOCHONDRIA

glucose + oxygen → carbon dioxide + water + energy

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O + ATP$

Nearly all living things — **plants included** — release the energy in glucose as ATP.

Notice that the products of one process are the reactants of the other. Together they cycle carbon and oxygen between living things and the air.

DNA, RNA, and proteins CORE

DNA is a double helix — a twisted ladder whose rungs are base pairs: **A pairs with T** and **C pairs with G**. A gene is a section of DNA with the instructions for one protein. Chromosomes are long, coiled DNA molecules; human body cells have 46 (23 pairs), one set from each parent.

DNA — transcription (in the nucleus) → mRNA — translation (at a ribosome) → protein → trait

RNA is single-stranded and uses **uracil (U)** in place of thymine, so A pairs with U. A ribosome reads the mRNA three bases at a time; each three-base codon codes for one amino acid. Example: the DNA bases **TAC** are transcribed into the mRNA codon **AUG**, the "start" codon for the amino acid methionine. A mutation is a change in the DNA sequence. It can change the protein (harmful or helpful) or have no effect, and it is the raw material of evolution.

Mitosis and meiosis CORE

Feature	Mitosis	Meiosis
Purpose	Growth, repair, and asexual reproduction	Making sex cells (gametes): eggs and sperm
Divisions	One	Two
Cells produced	2	4
Chromosome number	Same as the parent cell (46 in humans)	Half (23 in humans)
Genetically	Identical to the parent cell	All different — a source of variation

Mendelian genetics and Punnett squares CORE

Gregor Mendel discovered the basic rules of heredity with pea plants in the 1860s. Each organism has two copies (**alleles**) of each gene, one from each parent.

Genetics vocabulary			*B = black fur, b = white fur*
dominant	shows whenever present; capital letter (B)	**recessive**	shows only with two copies; lowercase (b)
genotype	the alleles an organism has: BB, Bb, or bb	**phenotype**	the trait you observe: black or white fur
homozygous	two identical alleles: BB or bb	**heterozygous**	two different alleles: Bb

How to fill a Punnett square

1. Write each parent's genotype: **Bb × bb**.
2. Put one parent's alleles across the top and the other's down the side.
3. Fill each box with one letter from its column and one from its row.
4. Count: each box is a 25% chance for every offspring.

A Punnett square gives **probabilities**, not guarantees: each offspring is a new “coin flip.”

	B	**b**
b	Bb	bb
b	Bb	bb

Genotypes: 2 Bb : 2 bb = 1 : 1.
Phenotypes: 50% black fur, 50% white fur.

Natural selection and evolution CORE

1. **Variation:** individuals in a population differ.
2. **Inheritance:** many differences are passed on in genes.
3. **Overproduction:** more offspring are born than can survive, so they compete.
4. **Selection:** those with traits that suit the environment survive and reproduce more.
5. **Time:** over many generations, helpful traits become more common — the population **evolves**.

Example: when antibiotics are used, the few bacteria that happen to resist them survive and multiply, so the population becomes resistant. Individuals do not evolve — populations do.

Evidence for evolution	What it shows
Fossil record	Life has changed over time; transitional forms
Homologous structures	Same bones in a human arm, bat wing, and whale flipper
DNA comparisons	Closely related species have more similar DNA
Embryology	Related species look alike early in development
Direct observation	Antibiotic resistance; finch beaks changing after droughts

Homeostasis CORE

Homeostasis is keeping internal conditions stable — body temperature near 37 °C, blood sugar, and water balance. The body uses **negative feedback**: a change triggers a response that reverses it. Too hot? You sweat, and evaporation cools your skin. Too cold? You shiver, and muscle activity releases heat. After a meal, the hormone insulin helps cells take in glucose, bringing blood sugar back down.

9 Earth and Environment

Environmental science connects biology, chemistry, physics, and Earth science to real problems. These ideas lead to AP Environmental Science.

Ecosystems and food webs CORE

An ecosystem is all the living (**biotic**) and nonliving (**abiotic** — sunlight, water, soil, temperature) things in an area, interacting. Levels: **organism → population → community → ecosystem → biome → biosphere**.

Role	What it does	Examples
Producer (autotroph)	Makes its own food by photosynthesis	Grass, trees, algae, phytoplankton
Primary consumer	Herbivore: eats producers	Rabbits, grasshoppers, zooplankton
Secondary and tertiary consumers	Carnivores and omnivores: eat other consumers	Frogs, snakes, hawks, people
Decomposer	Breaks down dead organisms and wastes, returning nutrients to the soil	Bacteria, fungi

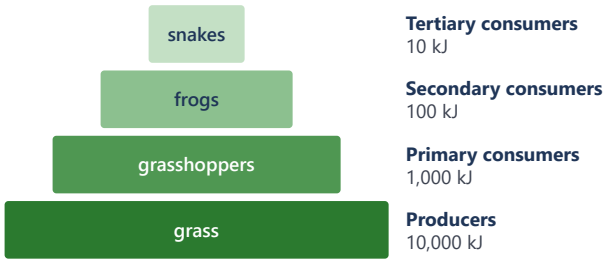
Arrows in a food chain point the way **energy flows** — from the eaten to the eater: **grass → rabbit → fox**. A **food web** is many connected food chains, so a change in one population ripples through the whole web.

Trophic levels and the 10% rule CORE

Only about **10%** of the energy at one trophic level is stored in the bodies of the next. The other 90% is mostly given off as **heat** during cellular respiration, used for moving and living, or never eaten or digested.

That is why food chains rarely have more than four or five levels, and why there are far fewer hawks than mice.

10,000 kJ → 1,000 kJ → 100 kJ → 10 kJ



An energy pyramid. Each level holds about one-tenth of the energy of the level below.

Cycles of matter CORE

Energy flows through an ecosystem in one direction — in as sunlight, out as heat. **Matter cycles**: the same atoms are used again and again.

Cycle	Key steps
Water	Evaporation from oceans and lakes and **transpiration** from plant leaves → condensation into clouds → precipitation → runoff and infiltration into groundwater → back to oceans and lakes. The Sun's energy drives it.
Carbon	Photosynthesis removes CO_2 from the air. Cellular respiration, decomposition, and burning fuels return it. Carbon is stored in living things, the ocean, fossil fuels, and rocks such as limestone.
Nitrogen	Air is about 78% nitrogen gas (N_2), but most living things cannot use it directly. **Nitrogen-fixing bacteria** (some live in the roots of beans and peas) and lightning change it into forms plants can absorb. Animals get nitrogen by eating; decomposers return it to the soil; other bacteria release N_2 to the air. Living things need nitrogen to build proteins and DNA.

Biodiversity and resources CORE

Biodiversity is the variety of life in an area — of genes, species, and ecosystems. Ecosystems with more biodiversity are usually more stable and recover better from disturbances such as drought or disease.

The biggest threats spell **HIPPCO**: **H**abitat loss, **I**nvasive species, **P**opulation growth, **P**ollution, **C**limate change, and **O**verharvesting.

Renewable	Nonrenewable
Replaced naturally within a human lifetime	Take millions of years to form, or are not replaced
Solar, wind, hydroelectric, geothermal, and biomass (if managed well)	Coal, oil, and natural gas (fossil fuels); uranium for nuclear power

Weather, climate, and the greenhouse effect CORE

Weather is the condition of the atmosphere at one place and time: today's temperature, rain, and wind. **Climate** is the average weather pattern of a region over a long time, usually 30 years or more. Climate is what you expect; weather is what you get.

Seasons come from the **23.5° tilt** of Earth's axis, which changes how directly sunlight strikes each hemisphere — not from Earth's distance to the Sun.

1. Sunlight passes through the atmosphere and warms Earth's surface.
2. The warm surface gives off infrared radiation (heat).
3. **Greenhouse gases** — water vapor, carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O) — absorb some of it and send part back toward the surface.
4. The lower atmosphere stays warmer. Without this natural effect, Earth would average about −18 °C instead of about 15 °C.

> **The enhanced greenhouse effect**
>
> Burning fossil fuels and clearing forests have raised the amount of CO_2 in the air from about 280 parts per million before the Industrial Revolution to more than 420 ppm today. The extra greenhouse gases trap more heat, warming Earth's climate and making the ocean more acidic.

Human impacts and solutions CORE

Impact	Effects	Solutions
Burning fossil fuels	Air pollution, climate change, ocean acidification	Renewable energy, efficiency, public transit
Deforestation, habitat loss	Lost biodiversity, more CO_2, soil erosion	Protected areas, replanting, sustainable forestry
Fertilizer runoff	Algae blooms that use up oxygen, creating “dead zones” in lakes and coasts	Careful fertilizer use; plants along stream banks
Plastic and chemical pollution	Harms wildlife; builds up in food webs	Reduce, reuse, recycle; better waste treatment
Overfishing, overhunting	Populations collapse	Catch limits, marine protected areas

Plate tectonics CORE

Earth has a thin rocky **crust**, a hot **mantle** of slowly flowing solid rock, a liquid **outer core**, and a solid **inner core** (both mostly iron and nickel). The rigid outer layer is broken into **plates** that move a few centimeters a year — about as fast as your fingernails grow — carried by slow convection in the mantle.

Boundary	Plates…	What forms	Example
Divergent	Move apart	New crust, mid-ocean ridges, rift valleys	Mid-Atlantic Ridge
Convergent	Collide	Mountains, deep-ocean trenches, volcanoes	Himalayas, Andes
Transform	Slide past each other	Earthquakes along faults	San Andreas Fault

Evidence: the continents fit like puzzle pieces, the same fossils and rock layers appear on continents now oceans apart, and seafloor rock is youngest near mid-ocean ridges.

10 Science Words and Command Terms

Science vocabulary is built from Greek and Latin parts. Learn the roots once and you can decode hundreds of terms. Then learn exactly what each AP command term asks you to do.

Greek and Latin roots CORE

Life and Earth	*root · meaning · example*	
bio-	life	biology, biome
eco-	home, environment	ecosystem
geo-	Earth	geology
hydro-	water	hydrosphere
photo-	light	photosynthesis
chloro-	green	chlorophyll
cyto-, -cyte	cell	cytoplasm
auto-	self	autotroph
-troph	nourishment	heterotroph
homo-	same	homozygous
hetero-	different	heterozygous
-vore	eater	herbivore

Matter and Energy	*root · meaning · example*	
therm-	heat	thermometer
endo-	inside, into	endothermic
exo-	outside, out of	exothermic
-synthesis	putting together	photosynthesis
-lysis	splitting	hydrolysis
hyper-	over, above	hyperthermia
hypo-	under, below	hypothermia
iso-	equal, same	isotope
kine-	motion	kinetic
micro- / macro-	small / large	microscope
mono- / poly-	one / many	polymer
-some	body	chromosome

Put them together: an **endothermic** reaction takes heat *in* (an instant cold pack feels cold); an **exothermic** reaction gives heat *out* (burning wood). A **heterotroph** gets its nourishment from *other* living things.

AP command terms CORE

The verb at the start of a free-response question tells you exactly what earns the point.

> **Underline the verb**
>
> Before you answer any question, underline its command term. “Identify” wants one line. “Explain” wants a *because*. “Calculate” wants work and units. Many lost points come from answering a different question than the one that was asked.

Term	What it requires	Grade 9 example
Identify	Name or point out a specific answer. No explanation needed.	Identify the independent variable in the ramp experiment.
Describe	Give the important features, or state the trend in data, with numbers.	Describe how the cocoa's temperature changes over 10 minutes.
Explain	Tell how or why, linking cause to effect with a science idea.	Explain why a red blood cell shrinks in salt water.
Calculate	Show the equation, substitute values with units, and give the answer with units.	Calculate the speed of a runner who covers 100 m in 12.5 s.
Justify	Support a claim or answer with evidence and reasoning.	Justify your claim that the fertilizer worked.
Predict	State what will happen in a new situation, usually with a reason.	Predict how an enzyme’s activity changes at 60 °C.
Make a claim	State a clear, specific answer to the question.	Make a claim about whether light color affects plant growth.
Represent / Draw	Make a graph, diagram, or model with labels and units.	Draw a free-body diagram of a book resting on a table.
Compare	Give similarities **and** differences, mentioning both things.	Compare mitosis and meiosis.

11 Mistakes and Misconceptions to Avoid

Students everywhere hold the same wrong ideas — and AP questions are written to catch them. Fix these now and they will never cost you points.

Not this	This	Why
~~My mass is smaller on the Moon.~~	**My weight is smaller on the Moon; my mass is the same.**	Mass is matter; weight is gravity's pull.
~~Heat and temperature are the same thing.~~	**Temperature measures particle motion; heat is energy that flows from hot to cold.**	A bathtub of warm water holds more thermal energy than a cup of hot tea.

Not this	This	Why
~~A theory is just a guess.~~	**A theory is a well-tested explanation backed by a lot of evidence.**	The guess is the hypothesis.
~~My data proved my hypothesis.~~	**My data support my hypothesis.**	New evidence could always change the conclusion.
~~Plants get their food from the soil.~~	**Plants make glucose from CO_2 and water by photosynthesis.**	Soil gives water and minerals; most of a plant's mass comes from the air.
~~Plants photosynthesize; animals respire.~~	**Plants do both photosynthesis and cellular respiration.**	All living cells need ATP.
~~Heavier objects fall faster.~~	**Without air resistance, all objects fall with the same acceleration.**	A feather falls slowly only because of air resistance.
~~A moving object needs a force to keep it moving.~~	**It keeps moving unless a net force (like friction) acts on it.**	Newton's first law.
~~The battery's energy got used up.~~	**The energy changed form: to light, sound, and thermal energy.**	Energy is conserved.
~~Sugar disappears when it dissolves.~~	**The sugar is still there, spread among the water particles.**	Mass is conserved; the water tastes sweet.
~~Summer happens when Earth is closest to the Sun.~~	**Seasons are caused by the tilt of Earth's axis.**	Earth is closest to the Sun in early January.
~~The ozone hole causes global warming.~~	**They are different problems.**	Ozone blocks UV light; greenhouse gases trap heat.
~~Giraffes stretched their necks, so their babies had long necks.~~	**Giraffes with longer necks survived and reproduced more.**	Populations evolve by natural selection; individuals don't.
~~Ice cream sales cause sunburns.~~	**They are correlated; hot, sunny weather causes both.**	Correlation is not causation.
~~I changed the ramp height and the car.~~	**I changed only the ramp height.**	One independent variable per test.
~~Enzymes get used up in a reaction.~~	**Enzymes are reused; the reaction does not change them.**	They are catalysts: they speed reactions up without being consumed.
~~In osmosis, salt moves into the cell.~~	**In osmosis, water moves across the membrane.**	Water moves toward the side with more dissolved solute.
~~The speed is 12.~~	**The speed is 12 m/s.**	A number without a unit is not a measurement.

12 Study Plan and Resources

Twenty minutes a day beats two hours on Sunday. Here is a routine that fits around homework and activities.

When	What to do	Time
Every day	Reread today's notes and fix anything unclear · learn five science words by their roots · do one quick unit conversion or calculation · notice one piece of science around you and ask "why?"	15–20 min
Every week	One practice set or simulation online · redraw one set of notes as a diagram or concept map · make or read one graph · write one CER paragraph about something from class · review your mistakes notebook	About 1 hr total
Every month	One mini-investigation at home with a timer, a ruler, or a kitchen scale · read one science news article and explain it to someone · check yourself against the list in section 13	30–45 min
Summer	One long project (a science-fair idea or a citizen-science project) · visit a science museum, nature center, or park · read a science book you choose · review sections 3–5	A little, often

Free and widely used resources

Learning and practice

- **Khan Academy** (khanacademy.org) — free videos and practice in biology, chemistry, and physics, and later the AP courses.
- **PhET Interactive Simulations** (phet.colorado.edu), from the University of Colorado Boulder — free simulations of forces, density, atoms, energy, waves, and more.
- **CK-12** (ck12.org) — free online textbooks and practice for every science subject.

Real science and the exam

- **HHMI BioInteractive** (biointeractive.org) — videos and real-data activities in biology and environmental science, used in many AP classrooms.
- **NASA Science** (science.nasa.gov) and **NASA Climate Kids** — Earth, climate, and space explained with real images and data.
- **AP Central** (apcentral.collegeboard.org) — the official course descriptions, past free-response questions, and scoring guidelines.

Be a scientist now, not just later

- Enter your school or regional science fair — pick a question you actually wonder about and test it fairly.
- Join a citizen-science project: photograph plants and animals for **iNaturalist**, count birds with the Cornell Lab's **eBird**, or classify real research images on **Zooniverse**.
- Keep a weather log for a month and graph it. Then compare it with your area's climate averages.
- Explain one thing you learned to a family member each week. If you can teach it, you know it.

13 End-of-Year Self-Check

Check off each statement when it is true for you. Anything unchecked in June is your summer goal.

Experiments and Data

- [ ] I can write a testable question and an *if… then… because…* hypothesis.
- [ ] I can identify the variables, control group, and sample size in an experiment.
- [ ] I can draw a graph with a title, labeled axes, units, and a best-fit line.
- [ ] I can describe a trend with numbers and write a CER paragraph.

Math in Science

- [ ] I can convert metric units and use scientific notation.
- [ ] I can rearrange a formula and solve two-step problems.
- [ ] I can calculate a mean, a rate, a percent change, and a percent error.
- [ ] I give answers with units and the right number of significant figures.

Matter

- [ ] I can find the protons, neutrons, and electrons in an atom or isotope.
- [ ] I can use valence electrons to predict ionic and covalent bonds.
- [ ] I can tell physical changes from chemical changes.
- [ ] I can calculate density and balance a chemical equation.

Forces and Energy

- [ ] I can calculate speed, acceleration, and net force.
- [ ] I can state Newton's three laws with an example of each.
- [ ] I can calculate kinetic and potential energy and explain energy conservation.
- [ ] I can label a wave and use $v = f\lambda$.

Life Science

- [ ] I can name the four macromolecules, their monomers, and their jobs.
- [ ] I can explain how enzymes work and how temperature and pH affect them.
- [ ] I can name the main organelles and predict which way water moves by osmosis.
- [ ] I can write the equations for photosynthesis and cellular respiration.
- [ ] I can explain transcription and translation, and compare mitosis and meiosis.
- [ ] I can complete a Punnett square and explain natural selection.

Earth and Environment

- [ ] I can trace energy through a food web and use the 10% rule.
- [ ] I can describe the water, carbon, and nitrogen cycles.
- [ ] I can explain the greenhouse effect and three human impacts.
- [ ] I can describe the three kinds of plate boundaries.

14 Practice

Answers and model responses are in section 15. Try everything first without looking. Show your work, and write units and the right number of significant figures.

A. Design an experiment

Jordan wants to know whether a liquid plant fertilizer helps bean plants grow taller. He plants 20 bean seeds of the same variety in identical pots with the same soil. Ten pots get 10 mL of fertilizer solution each week; the other ten get 10 mL of plain water each week. All 20 pots sit by the same window and get 50 mL of water every two days. After four weeks, he measures the height of every plant in centimeters.

1. Identify the independent variable. _____
2. Identify the dependent variable. _____
3. Name two controlled variables. _____ _____
4. Which plants are the control group? _____
5. Why did Jordan use ten plants in each group instead of one?

_____

6. Write a hypothesis in *if… then… because…* form.

_____

_____

B. Units, notation, and significant figures

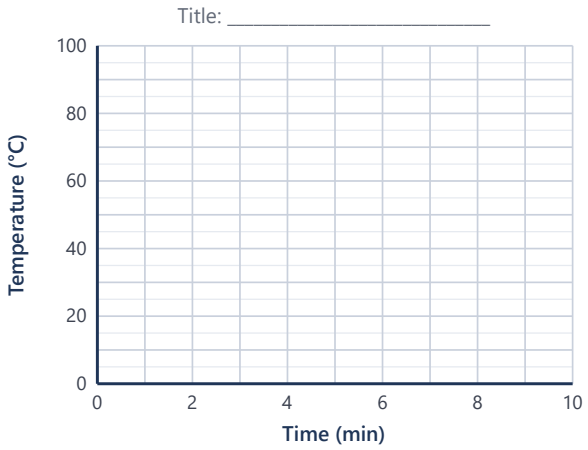
1. 2.5 km = _____ m
2. 450 mg = _____ g
3. 3.2 L = _____ mL
4. 75 cm = _____ m
5. 0.068 kg = _____ g
6. 1,500 mm = _____ m
7. 36 km/h = _____ m/s
8. How many significant figures are in 0.04050 g?

   _____
9. 6,200,000 = _____ (sci. notation)
10. 0.00045 = _____ (sci. notation)
11. 3.0×10^{8} = _____ (standard form)
12. 7.1×10^{-3} = _____ (standard form)
13. $(2 \times 10^{3})(4 \times 10^{5})$ = _____
14. $(9 \times 10^{8}) \div (3 \times 10^{2})$ = _____
15. 3.6 cm × 2.15 cm = _____ (correct sig. figs.)

C. Read and graph data

A student pours hot cocoa into a mug in a 22 °C room and records its temperature every 2 minutes.

Time (min)	0	2	4	6	8	10
Temperature (°C)	80	65	54	46	40	35



1. Plot the data on the grid, draw a smooth best-fit curve, and give the graph a title.
2. Which variable belongs on the x-axis? Why?

   _____
3. Describe the trend, using numbers.

   _____

   _____
4. Estimate the temperature at 5 minutes: _____ °C. Is that interpolation or extrapolation? _____
5. Calculate the average rate of cooling over the first 4 minutes, in °C per minute. _____
6. Predict the temperature after 60 minutes. Why can't you just extend the curve's steady drop?

   _____

   _____

D. Energy in a food chain

In an ocean food chain, **phytoplankton → zooplankton → small fish → tuna**. The phytoplankton store 50,000 kJ of energy.

Trophic level	Organism	Energy (kJ)
Producer	Phytoplankton	50,000
Primary consumer	Zooplankton	_____
Secondary consumer	Small fish	_____
Tertiary consumer	Tuna	_____

1. Use the 10% rule to fill in the table.
2. Where does most of the other 90% go at each step?

3. Explain why there are far fewer tuna than small fish.

4. What percent of the phytoplankton's energy reaches the tuna? _____

E. Calculations

For each one, write the formula, substitute the numbers with units, and give the answer with units. Numbers 3 and 4 take two steps.

1. A cyclist rides 450 m in 90 s. What is her speed?

2. A train slows from 30 m/s to 12 m/s in 6 s. What is its acceleration? What does the sign tell you?

3. An 81 g rock is lowered into a graduated cylinder, and the water rises from 50.0 mL to 80.0 mL. What is the rock's density? Will it float?

4. A 1,200 kg car speeds up from 5 m/s to 25 m/s in 4 s. What net force acts on it?

5. What does a 45 kg student weigh on Earth?

6. What is the kinetic energy of a 2 kg ball moving at 3 m/s? At 6 m/s?

7. What is the potential energy of a 50 kg diver on a 4 m platform?

8. A wave has a frequency of 4 Hz and a wavelength of 2.5 m. What is its speed?

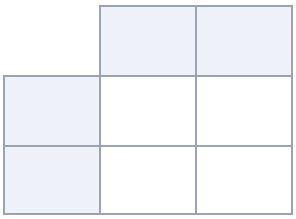
9. A pond's frog population falls from 80 to 60. What is the percent change?

10. A student measures water's density as 0.96 g/mL. The accepted value is 1.00 g/mL. What is the percent error?

F. Punnett squares

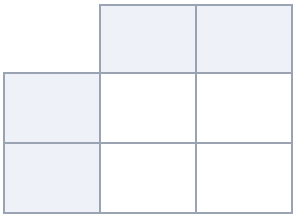
In pea plants, the allele for purple flowers (**P**) is dominant to the allele for white flowers (**p**).

Cross 1: two heterozygous plants, Pp × Pp.



1. Genotype ratio PP : Pp : pp = _____
2. Phenotype ratio purple : white = _____
3. Chance an offspring is white: _____

Cross 2: a homozygous purple plant × a white plant, PP × pp.



4. What percent of the offspring will have purple flowers? _____
5. What is their genotype? _____
6. If cross 1 produces 400 seeds, about how many will grow into white-flowered plants? _____

G. Atoms, bonds, and equations

1. Oxygen-16 (atomic number 8): protons _____ neutrons _____ electrons _____
2. Chlorine-35 (atomic number 17): protons _____ neutrons _____ electrons _____
3. How many valence electrons do oxygen (group 16) _____ and magnesium (group 2) _____ have?
4. Ionic or covalent? NaCl _____ CO_2 _____ MgO _____ CH_4 _____
5. In a closed container, 12 g of magnesium burns and combines with 8 g of oxygen. What mass of magnesium oxide forms? _____

Balance each equation by writing coefficients in the blanks (write 1 if none is needed). Number 10 is **GET AHEAD**.

6. ___ H_2 + ___ O_2 → ___ H_2O
7. ___ N_2 + ___ H_2 → ___ NH_3
8. ___ CH_4 + ___ O_2 → ___ CO_2 + ___ H_2O
9. ___ Mg + ___ HCl → ___ $MgCl_2$ + ___ H_2
10. ___ Fe + ___ O_2 → ___ Fe_2O_3

H. Cells: match and predict

Match each term with its description. Write the letter in the blank.

1. Enzyme _____
2. Amino acid _____
3. Mitochondrion _____
4. Ribosome _____
5. Lipids _____
6. Nucleic acids _____

a. The monomer that proteins are built from

b. Organelle that releases energy from glucose as ATP

c. Protein that speeds up a reaction without being used up

d. Molecules for long-term energy storage and cell membranes

e. Organelle that builds proteins

f. Molecules that store and carry genetic information

7. A red blood cell is placed in salt water that is much saltier than its cytoplasm. Which way does water move, and what happens to the cell?

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8. A plant cell is placed in distilled water. What happens to it, and why doesn't it burst?

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9. An enzyme from the human body works best at about 37 °C. Predict its activity at 60 °C, and explain why.

I. Claim, evidence, reasoning — mini AP free response

Here are Jordan's results from part A.

Group	Number of plants	Average height after 4 weeks	Range of heights
Fertilizer	10	24.6 cm	21–28 cm
Plain water (control)	10	18.2 cm	15–21 cm

Does the fertilizer help bean plants grow taller? Write a paragraph that makes a claim, supports it with evidence from the table (including how much taller, as a percent), and explains your reasoning with a science idea. Then name one way Jordan could make his conclusion stronger.

15 Answer Key

For the open-ended questions there are many correct answers; the models show one strong way to do it.

A. Design an experiment

1	**Fertilizer or no fertilizer**
2	**Plant height after 4 weeks (cm)**
3	**Any two: seed variety, pot, soil, window light, 50 mL of water every two days, 10 mL a week, time**
4	**The ten given plain water**
5	**One plant could be unusual** (a weak seed); a bigger sample makes the averages more reliable
6	e.g. **If bean plants get fertilizer, then they will grow taller, because fertilizer adds minerals plants need to grow.**

B. Units, notation, sig. figs.

1	**2,500 m**	9	**6.2×10^{6}**
2	**0.45 g**	10	**4.5×10^{-4}**
3	**3,200 mL**	11	**300,000,000**
4	**0.75 m**	12	**0.0071**
5	**68 g**	13	**8×10^{8}**
6	**1.5 m**	14	**3×10^{6}**
7	**10 m/s**	15	**7.7 cm^2**
8	**4**		

7: 36 × 1,000 ÷ 3,600. 8: the 4, the 0 between 4 and 5, the 5, and the final 0 count. 15: 3.6 × 2.15 = 7.74, rounded to 2 sig. figs.

C. Read and graph data

1	**Title such as "Temperature of Cocoa vs. Time"; a smooth curve that drops steeply, then flattens**
2	**Time** — it is the independent variable
3	**The temperature falls from 80 °C to 35 °C in 10 min — fast at first (15 °C in the first 2 min), then more slowly (5 °C in the last 2 min).**
4	**About 50 °C; interpolation**
5	**(80 − 54) °C ÷ 4 min = 6.5 °C/min**
6	**About 22 °C (room temperature). The cocoa cools only until it matches the room; a steady drop would go below 22 °C, which cannot happen.**

D. Energy in a food chain

1	**Zooplankton 5,000 kJ; small fish 500 kJ; tuna 50 kJ**
2	**Mostly given off as heat during cellular respiration** (used to move and stay alive)**, plus parts never eaten or digested**
3	**Each level up has only about a tenth of the energy, so it can support far fewer organisms.**
4	**50 ÷ 50,000 × 100% = 0.1%**

E. Calculations

1	**$v = d/t$ = 450 m ÷ 90 s = 5 m/s**
2	**a = (12 − 30) m/s ÷ 6 s = −3 m/s^2** (negative: it is slowing down)
3	**V = 80.0 − 50.0 = 30.0 mL; D = 81 g ÷ 30.0 mL = 2.7 g/mL; it sinks**
4	**a = (25 − 5) m/s ÷ 4 s = 5 m/s^2; F = 1,200 kg × 5 m/s^2 = 6,000 N**
5	**$W = mg$ = 45 kg × 9.8 m/s^2 = 441 N**
6	**KE = ½ × 2 kg × (3 m/s)^2 = 9 J; at 6 m/s, 36 J** (double the speed, 4 times the KE)
7	**PE = 50 kg × 9.8 m/s^2 × 4 m = 1,960 J**
8	**$v = f\lambda$ = 4 Hz × 2.5 m = 10 m/s**
9	**(60 − 80) ÷ 80 × 100% = −25%** (a 25% decrease)
10	**|0.96 − 1.00| ÷ 1.00 × 100% = 4%**

F. Punnett squares

	P	**p**
P	PP	Pp
p	Pp	pp

1	**1 : 2 : 1**
2	**3 : 1**
3	**25%** (1 box in 4)
4	**100%** (every box is Pp)
5	**Pp** (heterozygous)
6	**About 100** (25% of 400)

G. Atoms, bonds, and equations

1	**8 p, 8 n, 8 e**
2	**17 p, 18 n, 17 e** (35 − 17 = 18)
3	**Oxygen 6; magnesium 2**
4	**NaCl ionic; CO_2 covalent; MgO ionic; CH_4 covalent** (metal + nonmetal = ionic)
5	**20 g** (12 g + 8 g; mass is conserved)
6	**$2H_2 + O_2 \rightarrow 2H_2O$**
7	**$N_2 + 3H_2 \rightarrow 2NH_3$**
8	**$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$**
9	**$Mg + 2HCl \rightarrow MgCl_2 + H_2$**
10	**$4Fe + 3O_2 \rightarrow 2Fe_2O_3$**

H. Cells: match and predict

1	**c**
2	**a**
3	**b**
4	**e**
5	**d**
6	**f**
7	**Water moves out of the cell, toward the saltier (hypertonic) solution, so the cell shrivels.**
8	**Distilled water is hypotonic, so water moves in and the cell swells until it is firm (turgid). The rigid cell wall pushes back and keeps it from bursting.**
9	**Activity drops to nearly zero. At 60 °C the enzyme denatures: its shape, including the active site, changes, so the substrate no longer fits.**

I. Model CER paragraph

Claim: The fertilizer helped the bean plants grow taller. **Evidence:** After four weeks, the fertilized plants averaged 24.6 cm, while the control plants given plain water averaged 18.2 cm — a difference of 6.4 cm, so the fertilized plants were about 35% taller (6.4 ÷ 18.2 × 100%). Even the shortest fertilized plant (21 cm) was as tall as the tallest control plant (21 cm). **Reasoning:** Plants make their own sugar by photosynthesis, but they need minerals such as nitrogen and phosphorus from the soil to build proteins, nucleic acids, and new cells. The fertilizer supplied extra minerals, so the plants could grow more. Because the seeds, soil, light, and water were the same for both groups, the fertilizer is the most likely cause of the difference. **Making it stronger:** Jordan could repeat the experiment with more plants, or test several amounts of fertilizer to see how the height changes.

Why it works: the claim answers the question directly · the evidence uses specific numbers with units, a percent difference, and compares the two groups · the reasoning links the data to a science idea (minerals for building molecules) and to the fair-test design · it suggests a real improvement.

Keep asking why

Two or three years from now, an AP science exam will feel like the next step, not a leap. Keep measuring, keep graphing, and keep asking "How do you know?" — and remember Marie Curie: nothing in life is to be feared; it is only to be understood.