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I

Physics

The study of matter, motion, energy and the fundamental forces that govern the physical universe — from a falling apple to the light of distant stars.

01 Motion and Measurements

PHYSICS

Everything around us is in motion — planets orbit, blood flows, atoms vibrate. To describe and predict motion we must first agree on how to measure it, then study the forces that cause it.

Physical Quantities, Units and Measurement

A **physical quantity** is anything that can be measured; it has a **magnitude** (number) and a **unit**. Quantities are of two kinds: **scalars**, which have only magnitude (distance, speed, mass, time, energy), and **vectors**, which have both magnitude and direction (displacement, velocity, force, acceleration). The internationally agreed system of units is the **SI system**, built on seven base units.

Base Quantity	SI Unit	Symbol
Length	metre	m
Mass	kilogram	kg
Time	second	s
Electric current	ampere	A
Temperature	kelvin	K
Amount of substance	mole	mol
Luminous intensity	candela	cd

Derived units are combinations of base units — speed (m/s), force (newton = $kg \cdot m/s^2$), pressure (pascal = N/m^2), energy (joule), power (watt). To express very large or very small values we use **prefixes**: kilo (10^3), mega (10^6), giga (10^9), milli (10^{-3}), micro (10^{-6}), nano (10^{-9}).

Measuring instruments: a metre scale measures up to millimetres; a **vernier callipers** measures to 0.1 mm; a **screw gauge** (micrometer) measures to 0.01 mm. Every measurement carries some **error** — instrumental, personal (parallax) or random — which is why readings are repeated and averaged.

Measurement of Time

Before clocks, humans read time from natural cycles. A **sundial** used the Sun's shadow; **water clocks** and **sand clocks** measured fixed intervals; months and years came from the lunar cycle and Earth's revolution. The key advance was the **simple pendulum**: a bob on a thread swings with a nearly constant **time period** for a given length, independent of how far it is displaced (Galileo's observation of a swinging lamp). This made **pendulum clocks** possible. **Quartz**

clocks use the steady electrical oscillations of a quartz crystal, and **atomic clocks**, the most accurate of all, count vibrations within caesium atoms — they define the second itself.

Types of Motion

- **Rectilinear (translatory) motion** — along a straight line (a car on a straight road).
- **Circular motion** — along a circular path (Earth around the Sun, a stone whirled on a string).
- **Rotational motion** — spinning about an axis (a fan, a spinning top).
- **Oscillatory / periodic motion** — to-and-fro, repeating at regular intervals (a pendulum, a vibrating string).
- **Random motion** — irregular, unpredictable (a flying insect).

Motion may be **uniform** (equal distances in equal times — constant speed) or **non-uniform** (changing speed).

Describing Motion: Distance, Displacement, Speed, Velocity

- **Distance** — total path length covered (scalar).
- **Displacement** — shortest straight-line distance from start to finish, with direction (vector); it can be zero even when distance is not (a full circular lap).
- **Speed** = distance ÷ time (scalar); **average speed** = total distance ÷ total time.
- **Velocity** = displacement ÷ time (vector).
- **Acceleration** = rate of change of velocity; negative acceleration is **retardation/ deceleration**.

Speed = Distance / Time • **Acceleration** = (v − u) / t

Graphs and Equations of Motion

A **distance-time graph** shows motion at a glance: a straight slanting line means uniform speed, a horizontal line means rest, and a curve means changing speed. In a **velocity-time graph**, the slope gives acceleration and the area under the line gives the distance travelled. For uniformly accelerated motion in a straight line, the three equations of motion apply (where u = initial velocity, v = final velocity, a = acceleration, t = time, s = distance):

$$v = u + at \quad \bullet \quad s = ut + \tfrac{1}{2}at^2 \quad \bullet \quad v^2 = u^2 + 2as$$

Force and Newton's Laws of Motion

A **force** is a push or pull that can change an object's state of rest or motion, its speed, its direction, or its shape. Forces are **balanced** (no change in motion) or **unbalanced** (cause acceleration). Forces may act by contact (friction, muscular, tension) or at a distance (gravity, magnetic, electrostatic).

Law	Statement	Example
First (Law of Inertia)	A body remains at rest or in uniform motion unless an external unbalanced force acts on it.	Passengers jerk forward when a bus stops.
Second	Rate of change of momentum is proportional to the applied force: F = ma.	A loaded trolley needs more force to accelerate.
Third	To every action there is an equal and opposite reaction.	Recoil of a gun; a swimmer pushing water back.

Inertia is the tendency to resist change in state of motion and depends on **mass** — heavier bodies have greater inertia.

Momentum and Its Conservation

Momentum = mass × velocity. It is a vector and measures the "quantity of motion." The **Law of Conservation of Momentum** states that in the absence of external force, the total momentum of a system stays constant — the basis of rocket propulsion and explaining collisions and recoil.

Momentum (p) = mass (m) × velocity (v)

Gravitation

Newton's Law of Universal Gravitation: every mass attracts every other mass with a force proportional to the product of their masses and inversely proportional to the square of the distance between them. Earth's gravity gives every object an acceleration **g ≈ 9.8 m/s^2**.

- **Mass** is the amount of matter (constant everywhere, in kg); **weight** is the force of gravity on it (W = mg, in newtons, and varies with location).
- **Free fall** — motion under gravity alone; all objects fall at the same rate in a vacuum.
- **Weightlessness** — felt by astronauts in orbit, who are in continuous free fall.
- **Escape velocity** — the minimum speed (~11.2 km/s for Earth) needed to escape its gravity.

KEY CONCEPT

Weight changes with gravity but mass does not. On the Moon, gravity is about one-sixth of Earth's, so a person weighs one-sixth as much but has the same mass.

Pressure, Buoyancy and Density

Pressure = force ÷ area (P = F/A). A sharp knife or a needle concentrates force over a tiny area to cut or pierce; a camel's broad feet and snowshoes spread weight to avoid sinking. **Liquid pressure** increases with depth and acts equally in all directions; **atmospheric pressure** at sea level is about 101 kPa and decreases with altitude. **Pascal's law** (pressure applied to an enclosed fluid is transmitted equally) underlies the hydraulic brake and lift.

Buoyancy / Archimedes' Principle: a body immersed in a fluid experiences an upward force equal to the weight of fluid it displaces. An object floats if its density is less than the fluid's, and sinks if greater — which is why ships (hollow, low average density) float while a coin sinks. **Density** = mass ÷ volume; **relative density** compares a substance's density to water.

Friction

Friction opposes relative motion between surfaces in contact. It is **static** (before motion starts), **sliding**, or **rolling** (least of the three — hence ball bearings and wheels). Friction is essential for walking, gripping and braking, but wastes energy as heat and causes wear; it is reduced by lubricants, polishing and streamlining, and increased by treads and grooves.

Simple Machines

Simple machines make work easier by changing the magnitude or direction of force: the **lever** (seesaw, scissors, bottle opener), **pulley** (well, flagpole), **inclined plane** (ramp), **wedge** (axe), **screw** and **wheel-and-axle**. **Mechanical advantage** measures how much a machine multiplies force.

DID YOU KNOW

Atmospheric pressure presses on us from all sides with the force of a 1 kg mass on every square centimetre, yet we don't feel it because the pressure inside our bodies balances it.

EXAM FOCUS

Master scalar vs vector, distance vs displacement, the three Newton's laws, F=ma, p=mv, conservation of momentum, mass vs weight, g and escape velocity, Archimedes' principle and the pressure–area relationship (knives, camels, snowshoes). The seven SI base units and the three equations of motion are frequently tested.

ADVANCED NOTES & KEY FACTS

- **Uniform circular motion** is accelerated motion even at constant speed, because the *direction* of velocity keeps changing; the inward force needed is the **centripetal force**, and the apparent outward pull felt is the (fictitious) centrifugal effect.
- **Impulse** = force × time = change in momentum. This is why airbags, helmets and a cricketer drawing the hands back while catching all increase the time of impact and reduce the force felt.
- The **centre of gravity** is the point where an object's whole weight appears to act; a lower centre of gravity and a wider base give greater stability (racing cars, a person standing with feet apart).
- For a lever, **load × load-arm = effort × effort-arm** (principle of moments); this also explains why a longer spanner loosens a bolt more easily — greater **torque**.

- Galileo showed that, ignoring air resistance, a heavy and a light object fall together — confirmed dramatically on the airless Moon with a hammer and feather.
- **Terminal velocity** is the steady speed a falling body reaches when air resistance balances gravity (a raindrop, a parachutist).

IMPORTANT VALUES & CONSTANTS

g ≈ 9.8 m/s^2 (Earth) • g on Moon ≈ 1.63 m/s^2 (≈ 1/6) • Escape velocity (Earth) ≈ 11.2 km/s • Standard atmospheric pressure ≈ 101.3 kPa • Speed of sound in air ≈ 343 m/s • 1 N = 1 $kg \cdot m/s^2$.

QUICK REVISION

- Scalar = magnitude only; vector = magnitude + direction.
- Distance ≥ displacement; displacement can be zero on a closed path.
- F = ma; momentum p = mv; impulse = change in momentum.
- Inertia depends on mass; conservation of momentum explains recoil & rockets.
- Weight = mg (varies with place); mass is constant.
- Friction: rolling < sliding < static; reduced by lubricants & ball bearings.

PRACTICE QUESTIONS

1. Which quantity has both magnitude and direction — speed or velocity? **Ans: Velocity (it is a vector).**
2. State the SI unit of force. **Ans: Newton (N).**
3. On the Moon a 60 kg astronaut's mass and weight — which changes? **Ans: Weight changes (≈1/6); mass stays 60 kg.**
4. Why do passengers fall forward when a bus brakes suddenly? **Ans: Inertia of motion — the body tends to keep moving.**
5. Name the force that keeps a body moving in a circle. **Ans: Centripetal force (directed toward the centre).**

02 Light

PHYSICS

Light is the form of energy that lets us see. Its behaviour — travelling straight, bouncing, bending and splitting into colours — explains mirrors, lenses, rainbows, the blue sky and the human eye.

Nature of Light

Light travels in **straight lines** (rectilinear propagation), shown by sharp shadows and the pinhole camera. It is an **electromagnetic wave**, needs **no medium**, and moves at about **3×10^8 m/s** in vacuum — the fastest speed in the universe. Light shows both wave and particle (photon) behaviour. We see objects either because they emit light (luminous, like the Sun) or reflect it (non-luminous, like the Moon).

Reflection of Light

Reflection is the bouncing back of light from a surface. **Laws of reflection:** (1) the angle of incidence equals the angle of reflection; (2) the incident ray, reflected ray and the normal all lie in the same plane. **Regular reflection** (from smooth surfaces like mirrors) gives clear images; **diffuse reflection** (from rough surfaces) scatters light and is why we see ordinary objects.

Mirror	Image characteristics	Uses
Plane	Virtual, erect, same size, laterally inverted, behind mirror	Household mirrors, periscopes, kaleidoscopes
Concave (converging)	Real & inverted (object far) or virtual, erect & magnified (object near)	Shaving/make-up mirrors, torch & headlight reflectors, solar cookers, dentist's mirror
Convex (diverging)	Always virtual, erect, diminished; wide field of view	Vehicle rear-view mirrors, security mirrors

For curved mirrors, the **focus**, **centre of curvature** and **focal length** (half the radius of curvature) describe how rays converge; **magnification** tells how large the image is compared with the object.

Refraction of Light

Refraction is the bending of light when it passes from one transparent medium into another because its speed changes. Light bends toward the normal entering a denser medium and away when leaving it. This makes a pencil look bent in water, a pool appear shallower than it is, and a coin in a bowl reappear when water is added. The **refractive index** measures how strongly a medium bends light (it is highest for diamond among common materials).

DID YOU KNOW

Total internal reflection — light trapped inside a denser medium beyond a critical angle — makes optical fibres carry internet and telephone signals over long distances, gives diamonds their sparkle, and creates mirages on hot roads.

Lenses

A **lens** refracts light through curved surfaces. A **convex (converging) lens** bends rays together and can form real or virtual images; a **concave (diverging) lens** spreads rays apart and always forms a virtual, diminished image. The **power of a lens** is measured in **dioptres (D)** — the reciprocal of its focal length in metres; converging lenses have positive power, diverging lenses negative.

Dispersion and the Electromagnetic Spectrum

A glass **prism** splits white light into seven colours — **VIBGYOR** (violet, indigo, blue, green, yellow, orange, red) — because each colour travels at a slightly different speed in glass and bends by a different amount. **Red bends the least, violet the most.** This **dispersion** by raindrops creates the **rainbow**.

Visible light is a tiny slice of the **electromagnetic spectrum**, which runs (increasing energy) from radio waves → microwaves → **infrared** (heat, remote controls, night vision) → visible light → **ultraviolet** (sterilisation, vitamin-D synthesis, sunburn) → X-rays (medical imaging) → gamma rays (cancer therapy).

Scattering of Light

Tiny particles scatter shorter (blue) wavelengths more than longer (red) ones. This explains why the **sky is blue**, why the **Sun looks red at sunrise and sunset** (light travels through more atmosphere, scattering away the blue), and the **Tyndall effect** — the visible beam of light through fog, smoke or a colloid.

The Human Eye and Its Defects

The eye works like a camera. Light enters through the **cornea**, passes the **pupil** (whose size the **iris** controls), is focused by a flexible **lens** onto the light-sensitive **retina**, and the **optic nerve** carries signals to the brain. The lens changes shape (**accommodation**) to focus near and far objects.

Defect	Problem	Correction
Myopia (short sight)	Distant objects blur; image forms before retina	Concave lens
Hypermetropia (long sight)	Near objects blur; image forms behind retina	Convex lens
Presbyopia	Age-related loss of accommodation	Bifocal lenses
Astigmatism	Uneven curvature of cornea	Cylindrical lens
Cataract	Clouding of the lens	Surgery (lens replacement)

Optical Instruments

Lenses and mirrors are combined in the **simple and compound microscope** (to see tiny objects), the **telescope** (distant objects and stars), the **periscope** (seeing over obstacles, in submarines), the **camera**, and the **magnifying glass**. **Persistence of vision** — the eye retaining an image for a fraction of a second — makes films and animation appear to move.

EXAM FOCUS

Remember VIBGYOR with red bending least and violet most; concave mirror = headlight/torch, convex mirror = rear-view; concave lens corrects myopia, convex corrects hypermetropia. The blue sky and red sunset (scattering), Tyndall effect, total internal reflection (optical fibres) and the electromagnetic spectrum order are very high-yield.

ADVANCED NOTES & KEY FACTS

- **Primary colours of light** are red, green and blue (RGB); mixing them gives white — used in TV and phone screens. **Primary colours of pigment** are different (subtractive mixing).
- The **least distance of distinct vision** for a normal eye is about **25 cm**; the eye's lens changes focal length by **accommodation**.
- A **concave mirror** forms a real, inverted image of a distant object at its focus — used to collect solar energy and in reflecting telescopes; the **convex mirror** always gives a small, upright image and a wide field of view.
- **Mirage** and the **twinkling of stars** are both refraction effects in air of varying density.
- The sky is blue and sunsets red because shorter (blue) wavelengths scatter more (Rayleigh scattering); danger signals are red because red scatters least and travels farthest through fog.
- **Power of a lens** $P = 1/f$ (in metres), unit **dioptre (D)**; converging lens = +ve, diverging = −ve.

IMPORTANT VALUES & CONSTANTS

Speed of light in vacuum c ≈ 3×10^8 m/s • Visible range ≈ 400–700 nm (violet→red) • Normal near point ≈ 25 cm • VIBGYOR: violet bends most, red least.

QUICK REVISION

- Reflection: angle of incidence = angle of reflection.
- Concave mirror → headlights/torch/solar cooker; convex mirror → rear-view.
- Concave lens corrects myopia; convex lens corrects hypermetropia.
- Total internal reflection → optical fibres, diamond sparkle, mirage.
- Dispersion → rainbow; scattering → blue sky, red sunset, Tyndall effect.
- EM spectrum order (low→high energy): radio, micro, IR, visible, UV, X-ray, gamma.

PRACTICE QUESTIONS

1. Which lens corrects short-sightedness (myopia)? **Ans: Concave (diverging) lens.**
2. Why does the sky appear blue? **Ans: Blue light is scattered more by air molecules (Rayleigh scattering).**
3. Name the mirror used as a vehicle rear-view mirror. **Ans: Convex mirror (wide field, upright image).**
4. In VIBGYOR, which colour bends the most through a prism? **Ans: Violet.**
5. What is the SI unit of the power of a lens? **Ans: Dioptre (D).**

03 Electricity

PHYSICS

Electricity is the flow and interaction of electric charge. Mastering it transformed civilisation — lighting homes, running machines, and powering every electronic device of the modern world.

Electric Charge and Static Electricity

Matter contains positive charges (protons) and negative charges (electrons). **Like charges repel; unlike charges attract.** Rubbing two objects transfers electrons, leaving them oppositely charged — this is **static electricity** (a comb attracting paper, a shock from a doorknob, lightning). A **conductor** lets charge flow freely (metals); an **insulator** does not (rubber, glass, plastic); a **semiconductor** (silicon, germanium) is in between and is the foundation of all electronics.

Electric Current and Circuits

Electric current is the rate of flow of charge, measured in **amperes (A)** with an **ammeter** (connected in series). By convention current flows from positive to negative terminal — opposite to the actual flow of electrons. A current flows only in a **closed circuit**; a switch opens or closes the path.

Potential Difference, EMF and Resistance

Potential difference (voltage), in **volts (V)**, is the work done to move charge between two points — measured with a **voltmeter** (in parallel). The **electromotive force (EMF)** of a cell is the voltage it provides. **Resistance**, in **ohms (Ω)**, opposes the flow of current.

Ohm's Law: $V = I \times R$

Factors affecting resistance: it increases with the **length** of the wire, decreases with greater **cross-sectional area** (thicker wire), depends on the **material** (its resistivity), and rises with **temperature** in metals. Nichrome has high resistivity, which is why it is used in heating elements.

Series and Parallel Circuits

Feature	Series	Parallel
Path for current	Single path	Multiple paths
Current	Same through all components	Divides among branches
Voltage	Divides across components	Same across each branch
If one device fails	Entire circuit breaks	Others continue working
Total resistance	Adds up (increases)	Decreases below smallest

Household appliances are wired in **parallel** so each receives the full mains voltage and can be switched independently.

Heating Effect of Current

When current flows through a resistance, electrical energy converts to heat — **Joule's heating** ($H = I^2Rt$). This runs electric irons, heaters, geysers, toasters and incandescent bulbs, and is the principle of the fuse. The **tungsten filament** of a bulb glows because of its high melting point.

Electric Power and Energy

Power $P = V \times I = I^2R$ • measured in watts (W)

Electrical **energy** consumed = power × time. The commercial unit is the **kilowatt-hour (kWh)**, popularly called a "unit," which is what the electricity meter records for billing.

Domestic Wiring and Electrical Safety

A house supply has three wires: **live (phase)**, **neutral** and **earth**. The **earth wire** connects the metal body of appliances to the ground so that a fault current flows away safely instead of through a person. A **short circuit** (live and neutral touching directly) or **overloading** (too many appliances) causes a sudden surge of current and heat — and fire.

- **Fuse** — a thin wire that melts and breaks the circuit when current exceeds a safe limit.
- **MCB (Miniature Circuit Breaker)** — a resettable modern switch that trips on overload.
- **Earthing** — protects against electric shock from faulty appliances.

Cells and Batteries

A **cell** converts chemical energy into electrical energy. **Primary cells** (dry cell) cannot be recharged; **secondary cells** (lead-acid battery, lithium-ion battery) can. Several cells joined form a **battery**. Lithium-ion batteries now power phones, laptops and electric vehicles.

DID YOU KNOW

Birds sit safely on a single high-voltage wire because there is no potential difference across their feet — no current flows through them. Danger arises only when a body bridges two points at different potentials, such as a wire and the ground.

EXAM FOCUS

Ohm's law (V=IR) and power (P=VI, $P=I^2R$) are essential, as is energy in kWh. Know factors affecting resistance, series vs parallel rules, that homes use parallel wiring, the roles of fuse/MCB/earth wire, and the difference between primary and secondary cells.

ADVANCED NOTES & KEY FACTS

- Conventional current flows from + to − terminal; electrons actually flow the opposite way.
- **Resistivity** is a property of the material (independent of size); silver and copper have the lowest, which is why copper is used for wiring; alloys like nichrome have high resistivity for heating elements.
- In a **series** circuit resistances add ($R = R_1+R_2+\ldots$); in **parallel** the total resistance is less than the smallest branch — so household parallel wiring keeps overall resistance low and each appliance at full voltage.
- **Joule's law of heating:** $H = I^2Rt$ — heat depends on the square of current, which is why even a small rise in current can overheat wiring.
- Standard Indian mains: ~230 V, 50 Hz AC. Wire colour codes (IS): brown/red = live, black/blue = neutral, green = earth.
- An **LED** bulb converts far more energy into light (less into heat) than an incandescent bulb, making it highly efficient.

IMPORTANT VALUES & CONSTANTS

Indian mains ≈ 230 V, 50 Hz • 1 unit of electricity = 1 kWh = 3.6×10^6 J • Ohm's law V = IR • Power $P = VI = I^2R = V^2/R$ • Charge of electron ≈ 1.6×10^{-19} C.

QUICK REVISION

- Current in amperes (ammeter, series); voltage in volts (voltmeter, parallel).
- Resistance ↑ with length & temperature, ↓ with thickness.
- Homes use parallel wiring; energy billed in kWh (units).
- Fuse/MCB protect against overload & short circuit; earth wire prevents shock.
- Primary cell — non-rechargeable; secondary cell (Li-ion, lead-acid) — rechargeable.

PRACTICE QUESTIONS

1. State Ohm's law. **Ans: $V = I \times R$ (voltage = current × resistance).**
2. In which arrangement are household appliances connected? **Ans: Parallel.**
3. What is the commercial unit of electrical energy? **Ans: Kilowatt-hour (kWh).**
4. What is the function of the earth wire? **Ans: Safely carries fault current to the ground, preventing shock.**
5. Heat produced is proportional to the square of which quantity? **Ans: Current ($H = I^2Rt$).**

04 Magnetism

PHYSICS

Magnetism and electricity are two faces of one force — electromagnetism — which powers generators, motors, transformers and the compass that guided explorers across the oceans.

Magnets and Their Properties

A magnet has two **poles** — north and south — which always occur in pairs; breaking a magnet produces two smaller magnets, never a single isolated pole. **Like poles repel, unlike poles attract.** A freely suspended magnet always settles in the north–south direction. Magnets can be **natural** (lodestone) or **artificial** (bar, horseshoe, electromagnet).

Magnetic materials: ferromagnetic substances (iron, cobalt, nickel) are strongly attracted and can be magnetised; **paramagnetic** are weakly attracted; **diamagnetic** are weakly repelled. **Temporary magnets** (soft iron) lose magnetism quickly; **permanent magnets** (steel) retain it.

Magnetic Field and Field Lines

The region around a magnet where its force acts is the **magnetic field**, represented by **field lines** that emerge from the north pole and enter the south pole outside the magnet. Key properties: field lines never cross; they are closer where the field is stronger; and they form closed loops.

Earth's Magnetism

The Earth behaves like a giant bar magnet, with its magnetic poles near (but not at) the geographic poles. This is why a **compass** needle points north–south, enabling navigation for centuries. Notably, the magnetic field also shields Earth from harmful solar radiation and creates the **auroras**.

Electromagnetism: Current Produces Magnetism

In 1820 Hans Christian Oersted discovered that a current-carrying wire deflects a compass needle — proving that electricity produces magnetism. The direction of the field around a straight wire is given by the **right-hand thumb rule**. Winding the wire into a coil (**solenoid**) with a soft-iron core makes an **electromagnet**, whose strength can be increased by more turns, more current or a stronger core, and switched on and off at will.

Effect	Discoverer / Rule	Application
Current → magnetic field	Oersted; right-hand thumb rule	Electromagnets, cranes, electric bell, MRI, maglev trains
Force on current in a field	Fleming's left-hand rule	Electric motor, loudspeaker, ammeter
Changing field → current	Faraday's induction; Fleming's right-hand rule	Generator, transformer, induction cooktop

Electric Motor

An **electric motor** converts electrical energy into mechanical (rotational) energy. A current-carrying coil placed in a magnetic field experiences a force (Fleming's left-hand rule) that makes it rotate. Motors run fans, pumps, mixers, washing machines and electric vehicles.

Electromagnetic Induction, Generator and Transformer

Michael Faraday discovered **electromagnetic induction**: a changing magnetic field through a coil induces a current. A **generator (dynamo)** uses this in reverse to a motor — mechanical energy (from steam, water or wind turning a coil in a field) produces electricity. This single principle generates almost all the world's electricity.

Generators produce **alternating current (AC)**, whose direction reverses periodically (50 times per second in India), or **direct current (DC)**, which flows one way. A **transformer** uses induction to change AC voltage — a **step-up transformer** raises voltage for efficient long-distance transmission (reducing energy loss in wires), and a **step-down transformer** lowers it for safe domestic use. Transformers work only with AC.

DID YOU KNOW

Maglev (magnetic levitation) trains float above the track on powerful electromagnets, eliminating friction with the rails and reaching speeds above 400 km/h.

EXAM FOCUS

Memorise the three electromagnetic effects and which device uses which: motor = electrical→mechanical, generator = mechanical→electrical. Oersted's discovery, Fleming's left-hand (motor) and right-hand (generator) rules, AC vs DC, and step-up/step-down transformers (AC only) are frequently tested.

ADVANCED NOTES & KEY FACTS

- **Right-hand thumb rule:** thumb points along current, curled fingers show the field direction around a wire.

- **Fleming's left-hand rule** (motor): thumb = force/motion, forefinger = field, middle finger = current. **Fleming's right-hand rule** (generator) gives induced current direction.
- A **solenoid** behaves like a bar magnet; adding a soft-iron core makes a strong, controllable electromagnet — used in cranes, electric bells, relays and MRI machines.
- **AC** changes direction periodically and can be transformed to high voltage for low-loss transmission; **DC** (from cells/solar) flows one way. India transmits power as high-voltage AC.
- A **transformer** conserves power ($V_1I_1 \approx V_2I_2$): step-up raises voltage and lowers current; step-down does the reverse. It works on AC only.
- The Earth's magnetic field protects life by deflecting charged solar particles, producing auroras near the poles.

IMPORTANT VALUES & CONSTANTS

Oersted (1820): current → magnetism • Faraday (1831): changing field → current • India grid: high-voltage AC, 50 Hz • Maglev speeds > 400 km/h.

QUICK REVISION

- Like poles repel; unlike attract; poles always exist in pairs.
- Motor: electrical → mechanical; Generator: mechanical → electrical.
- Fleming's left hand = motor; right hand = generator.
- Electromagnet strength ↑ with turns, current and iron core.
- Transformers work on AC only; step-up for transmission, step-down for homes.

PRACTICE QUESTIONS

1. Who discovered that electric current produces a magnetic field? **Ans: Hans Christian Oersted.**
2. Which device converts electrical energy into mechanical energy? **Ans: Electric motor.**
3. A transformer works with which type of current? **Ans: Alternating current (AC) only.**
4. Which rule gives the direction of force on a current-carrying conductor in a field? **Ans: Fleming's left-hand rule.**
5. What makes the core of a strong electromagnet? **Ans: Soft iron.**

05 Sound

PHYSICS

Sound is a form of energy that travels as a mechanical wave through a medium. It carries speech, music and warnings, and — beyond our hearing — drives sonar, ultrasound imaging and industrial cleaning.

Production and Nature of Sound

Sound is produced by **vibrating objects** — vocal cords, a guitar string, a drum, a tuning fork. These vibrations disturb the surrounding particles, creating alternating regions of **compression** (particles crowded) and **rarefaction** (particles spread out) that travel outward. Sound is a **longitudinal wave**: particles vibrate back and forth along the direction the wave travels. Crucially, sound **needs a material medium** and cannot travel through a vacuum — which is why space is silent.

Wave Terms and the Wave Equation

- **Wavelength (λ)** — distance between two consecutive compressions or rarefactions.
- **Frequency (f)** — number of vibrations per second, in **hertz (Hz)**.
- **Time period (T)** — time for one vibration; $T = 1/f$.
- **Amplitude** — the maximum displacement of particles from rest.

Wave speed v = frequency (f) × wavelength (λ)

Characteristics of Sound

Characteristic	Depends on	What we perceive
Loudness	Amplitude	How soft or loud (measured in decibels, dB)
Pitch	Frequency	How shrill or deep — high or low note
Quality (timbre)	Waveform	Distinguishes voices and instruments playing the same note

Speed of Sound in Different Media

Sound travels fastest in **solids**, slower in **liquids**, and slowest in **gases**, because closely packed particles pass vibrations along more efficiently. In air at about 20 °C it travels at roughly **343 m/s** — far slower than light (which is why thunder is heard after lightning is seen). Speed increases with temperature and humidity.

Range of Hearing

- **Infrasound** (below 20 Hz): produced by earthquakes and volcanoes; sensed by elephants, whales and some animals before disasters.

- **Audible range**: 20 Hz to 20,000 Hz for a healthy young human; the upper limit drops with age.
- **Ultrasound** (above 20,000 Hz): used by bats and dolphins for echolocation; harnessed by humans for many applications.

Reflection of Sound: Echo, Reverberation and Applications

Sound reflects from hard surfaces. An **echo** is a distinct reflected sound, heard only if the reflector is at least about 17 m away (so the reflection arrives more than 0.1 s after the original). **Reverberation** — repeated reflections in a closed hall — is reduced by sound-absorbing materials on walls and ceilings. Multiple reflection is used in the **megaphone, stethoscope, ear trumpet and sound-board** of auditoriums.

Ultrasound and SONAR

Ultrasound has wide use: medical **scans** (imaging the foetus and internal organs), breaking kidney stones, cleaning delicate parts, and detecting cracks in metals. **SONAR** (Sound Navigation And Ranging) sends ultrasound pulses underwater and times their echoes to measure ocean depth and locate submarines, shipwrecks and shoals of fish.

The Human Ear

The ear has three parts: the **outer ear** (pinna and canal collect sound), the **middle ear** (eardrum and three tiny bones amplify vibrations), and the **inner ear** (the cochlea converts vibrations into nerve signals sent to the brain).

Noise Pollution

Unwanted, harmful sound is **noise pollution**. Sources include traffic, industry, loudspeakers and construction. Prolonged exposure above 80–85 dB damages hearing and causes stress, sleep loss and high blood pressure. It is controlled by silencers, sound barriers, green belts of trees and regulation of permissible limits.

EXAM FOCUS

Sound cannot travel in a vacuum and is fastest in solids. Loudness↔amplitude, pitch↔frequency, quality↔waveform. Human audible range is 20 Hz–20 kHz; $v = f\lambda$. Echo needs ~17 m; SONAR and ultrasound applications and the parts of the human ear are commonly asked.

ADVANCED NOTES & KEY FACTS

- Sound is a **longitudinal mechanical wave** needing a medium; it travels by compressions and rarefactions and cannot pass through vacuum.
- **Loudness** (dB) depends on amplitude; **pitch** on frequency; **quality/timbre** on the waveform — which lets us tell a flute from a violin playing the same note.

- Speed of sound rises with temperature (~0.6 m/s per °C) and is greater in humid air; it is highest in solids, lowest in gases.
- An **echo** needs the reflecting surface ≥ ~17 m away (reflection delayed > 0.1 s). **SONAR** uses echo-timing to find depth and objects underwater.
- **Ultrasound** (>20 kHz): scans, breaking kidney stones, cleaning, flaw detection; **infrasound** (<20 Hz): elephants, whales, earthquakes.
- Noise above ~85 dB for long periods damages hearing; the threshold of pain is around 120 dB.

IMPORTANT VALUES & CONSTANTS

Audible range: 20 Hz – 20,000 Hz • Speed of sound in air ≈ 343 m/s (20 °C); water ≈ 1480 m/s; steel ≈ 5000 m/s • $v = f\lambda$ • Echo distance ≥ ~17 m • Safe limit ≈ 85 dB.

QUICK REVISION

- Sound needs a medium; fastest in solids, slowest in gases.
- Loudness↔amplitude, pitch↔frequency, quality↔waveform.
- $v = f \times \lambda$; $T = 1/f$.
- Echo = reflected sound; SONAR uses ultrasound echoes.
- Human ear: outer (pinna) → middle (eardrum, bones) → inner (cochlea).

PRACTICE QUESTIONS

1. Can sound travel through a vacuum? **Ans: No — it needs a material medium.**
2. In which medium does sound travel fastest? **Ans: Solids.**
3. Which characteristic of sound depends on frequency? **Ans: Pitch.**
4. What is the audible frequency range for humans? **Ans: 20 Hz to 20,000 Hz.**
5. Name the technique that uses ultrasound to measure ocean depth. **Ans: SONAR.**

10 Energy

PHYSICS

Energy is the capacity to do work. It exists in many forms, can be converted from one to another, and is never created or destroyed — the single most powerful idea in all of science.

Work, Energy and Power

Work is done when a force moves an object in the direction of the force (W = force × displacement, in joules); no work is done if there is no displacement. **Power** is the rate of doing work (P = work ÷ time, in watts). The commercial unit of electrical energy is the **kilowatt-hour (kWh)**.

Work = Force × Distance • **Power** = Work / Time

Forms of Energy

- **Kinetic energy** — energy of motion ($KE = \frac{1}{2}mv^2$): flowing water, a moving car.
- **Potential energy** — stored due to position or state ($PE = mgh$): water in a dam, a stretched spring, a raised hammer.
- **Mechanical energy** — the sum of kinetic and potential energy.
- **Other forms** — thermal (heat), chemical (fuels, food, batteries), electrical, light, sound, and nuclear energy.

KEY CONCEPT

Law of Conservation of Energy: energy can neither be created nor destroyed, only transformed. In a falling object, potential energy converts to kinetic energy; in a bulb, electrical energy becomes light and heat. The total energy of an isolated system is constant.

Sources of Energy

Category	Sources	Key features
Non-renewable (conventional)	Coal, petroleum, natural gas	Formed over millions of years; finite; major source of CO_2 and pollution
Renewable (non-conventional)	Solar, wind, hydro, tidal, geothermal, biomass	Replenished naturally; clean; key to a low-carbon future
Nuclear	Uranium, thorium (fission); hydrogen (fusion)	Enormous energy density; concern over radioactive waste and safety

Renewable Sources in Detail

- **Solar** — photovoltaic cells convert sunlight directly into electricity; solar heaters and cookers use solar thermal energy.
- **Wind** — turbines convert moving air into electricity; best in coastal and open plains.
- **Hydro** — falling or flowing water spins turbines in dams; a long-established large source.
- **Tidal and wave** — harness the rise and fall and motion of seawater.
- **Geothermal** — taps heat from inside the Earth (hot springs, steam).
- **Biomass and biogas** — energy from plant and animal waste; biogas (mainly methane) is produced by anaerobic decomposition in gobar-gas plants.

Fossil Fuels

Coal, petroleum and natural gas formed from the buried remains of ancient organisms under heat and pressure over millions of years. Petroleum is refined by **fractional distillation** into petrol, diesel, kerosene, LPG and others. Burning fossil fuels releases the greenhouse gas CO_2 and pollutants, driving climate change — the central reason for the global shift to renewables.

Nuclear Energy

Nuclear fission splits heavy nuclei (uranium-235) releasing enormous energy — used in nuclear reactors, where a controlled chain reaction heats water to drive turbines. **Nuclear fusion** joins light nuclei (hydrogen to helium), powering the Sun and stars; controlled fusion on Earth is a major scientific goal because it would be clean and nearly limitless. India follows a three-stage nuclear programme aimed at using its large **thorium** reserves.

India's Energy Transition

India is rapidly scaling **solar and wind** power to cut fossil-fuel imports and emissions. Major thrusts include large solar parks, the International Solar Alliance, the **National Green Hydrogen Mission**, energy-efficiency drives (LED programmes), and a commitment to reach **net-zero emissions by 2070**. Conserving energy — efficient appliances, public transport, reduced wastage — is equally vital.

DID YOU KNOW

The Sun supplies more energy to the Earth in a single hour than the entire human population uses in a whole year — which is why solar power holds such immense promise.

EXAM FOCUS

Master the conservation-of-energy law, work and power formulas, kinetic vs potential energy, and the renewable/non-renewable/nuclear classification. Distinguish fission from fusion. Current-affairs links — green hydrogen, solar alliance, net-zero 2070, three-stage nuclear (thorium) — are highly relevant.

ADVANCED NOTES & KEY FACTS

- **Kinetic energy** KE = $\frac{1}{2}mv^2$ (depends on the square of speed — doubling speed quadruples KE, key to road-safety); **potential energy** PE = mgh.
- Energy continuously transforms: in a pendulum PE↔KE; in a hydro plant PE of water → KE → electrical; in a torch chemical → electrical → light + heat.
- Efficiency = useful output ÷ input; no real machine is 100% efficient because some energy always becomes (low-grade) heat.
- **Fossil fuels** are finite and emit CO_2; **nuclear fission** (U-235) powers reactors; **fusion** (H→He) powers the Sun and is the clean-energy holy grail.
- India's three-stage nuclear plan aims to exploit abundant **thorium**; the country also leads the International Solar Alliance and a National Green Hydrogen Mission.
- **Biogas** (mainly methane) from anaerobic decomposition of dung/waste is a clean rural fuel and good fertiliser by-product.

IMPORTANT VALUES & CONSTANTS

KE = $\frac{1}{2}mv^2$ • PE = mgh • Power in watts (1 W = 1 J/s) • 1 kWh = 3.6 MJ • Sun's energy to Earth in 1 hr > world's yearly use • India net-zero target: 2070.

QUICK REVISION

- Energy is conserved — never created or destroyed, only transformed.
- Work = force × distance; power = work ÷ time.
- Renewable: solar, wind, hydro, tidal, geothermal, biomass.
- Non-renewable: coal, petroleum, natural gas (finite, polluting).
- Fission = splitting heavy nuclei; fusion = joining light nuclei (Sun).

PRACTICE QUESTIONS

1. State the law of conservation of energy. **Ans: Energy can neither be created nor destroyed, only transformed.**
2. Write the formula for kinetic energy. **Ans: KE = $\frac{1}{2}mv^2$.**
3. Give two renewable sources of energy. **Ans: Any two: solar, wind, hydro, tidal, geothermal, biomass.**
4. Which process powers the Sun — fission or fusion? **Ans: Nuclear fusion.**
5. What is the commercial unit of electrical energy? **Ans: Kilowatt-hour (kWh).**

II

Chemistry

The science of matter — what substances are made of, how they combine and change, and how new materials are built atom by atom to serve human needs.

06 Matter

CHEMISTRY

Matter is anything that has mass and occupies space. Understanding its particle nature, its states, and how it can be classified and separated is the gateway to all chemistry.

Particle Nature of Matter

All matter is made of tiny particles. The key evidence and characteristics:

- Particles have **spaces between them** — sugar dissolves into water without raising the level much.
- Particles are **continuously moving** — possessing kinetic energy that increases with temperature.
- Particles **attract one another** — the force of attraction is strongest in solids and weakest in gases.

Diffusion — the intermixing of particles of two substances on their own — proves both the spaces and the motion of particles (the smell of incense spreading, ink spreading in water). Diffusion is fastest in gases and speeds up with temperature. **Brownian motion** — the random zig-zag movement of suspended particles — is further evidence of constant particle motion.

States of Matter

Property	Solid	Liquid	Gas
Shape	Fixed	Takes container's shape	Fills the container
Volume	Fixed	Fixed	Variable
Compressibility	Negligible	Very low	High
Particle arrangement	Tightly packed, vibrate in place	Close, slide past each other	Far apart, move freely & fast
Inter-particle force	Strongest	Moderate	Weakest

Two further states exist: **plasma** — a super-heated, ionised gas found in stars, the Sun and fluorescent tubes; and the **Bose-Einstein condensate (BEC)** — formed at temperatures near absolute zero.

Change of State and Latent Heat

Heating or cooling changes the state without changing the chemical identity — a **physical change**. The transitions are: melting (solid→liquid), freezing/solidification (liquid→solid), vaporisation/boiling (liquid→gas), condensation (gas→liquid), **sublimation** (solid→gas directly, e.g. camphor, naphthalene, dry ice) and **deposition** (gas→solid). **Latent heat** is the heat absorbed or released during a change of state at constant temperature — the reason steam causes more severe burns than boiling water.

Evaporation is the slow change of a liquid to vapour at any temperature, from the surface only. It increases with higher temperature, larger surface area, lower humidity and faster wind. Because evaporation absorbs heat, it **causes cooling** — sweat cooling the body, water staying cool in an earthen pot, and the working of a desert cooler.

> **DID YOU KNOW**
>
> Water can exist in all three states within the everyday range — ice, liquid water and steam — which is why it is the model substance for studying changes of state.

Classification of Matter

Matter is classified by composition into pure substances and mixtures:

- **Pure substances** have a fixed composition: **elements** (made of one kind of atom — metals, non-metals, metalloids) and **compounds** (two or more elements chemically combined in a fixed ratio, e.g. water, common salt). A compound's properties differ entirely from those of its elements.
- **Mixtures** contain two or more substances physically mixed in any ratio: **homogeneous** (uniform throughout — salt solution, air, alloys) and **heterogeneous** (non-uniform — sand in water, oil and water).

Solutions, Suspensions and Colloids

Type	Particle size	Appearance	Example
True solution	Very small (dissolved)	Clear, stable, no Tyndall effect	Salt/sugar in water
Colloid	Intermediate	Appears uniform but scatters light (Tyndall effect)	Milk, fog, gel, blood
Suspension	Large	Cloudy; particles settle on standing	Muddy water, chalk in water

In a solution, the **solute** dissolves in the **solvent**. A solution is **saturated** when no more solute will dissolve at a given temperature; **solubility** generally increases with temperature for solids. The **Tyndall effect** (scattering of light by colloidal particles) is seen when a beam passes through fog or a dusty room.

Separation of Mixtures

Method	Separates	Example
Hand-picking / sieving	Solids of different sizes	Stones from grain
Filtration	Insoluble solid from liquid	Sand from water, tea leaves
Sedimentation & decantation	Heavier insoluble solid from liquid	Muddy water
Evaporation	Dissolved solid from liquid	Salt from seawater
Crystallisation	Pure solid crystals from solution	Purifying salt, copper sulphate
Distillation	Miscible liquids by boiling point	Pure water from salt water
Fractional distillation	Liquids with close boiling points	Petroleum products, air gases
Separating funnel	Immiscible liquids	Oil and water, kerosene and water
Centrifugation	Fine suspended particles	Cream from milk, blood components
Sublimation	Sublimable solid from a mixture	Camphor/ammonium chloride from salt
Chromatography	Dissolved components by adsorption	Dyes in ink, pigments

EXAM FOCUS

Classify substances correctly (element/compound/mixture; homo/heterogeneous). Tyndall effect distinguishes colloids; sublimation examples (camphor, naphthalene, dry ice, ammonium chloride) and the cooling effect of evaporation recur often. Match each separation method to its principle.

ADVANCED NOTES & KEY FACTS

- Particles of matter have spaces between them, are in constant motion, and attract each other — attraction is strongest in solids, weakest in gases.
- **Latent heat** is absorbed/released during a change of state at constant temperature — latent heat of fusion (melting) and of vaporisation (boiling); steam burns are worse than hot-water burns because of latent heat.
- Evaporation causes cooling and increases with temperature, surface area and wind, and decreases with humidity.

- **Tyndall effect** (scattering by colloidal particles) distinguishes a colloid (milk, fog) from a true solution (salt water).
- Concentration of a solution rises until **saturation**; solubility of most solids increases with temperature, while gases dissolve less in warm water.
- Choice of separation method depends on the property exploited — boiling point (distillation), density (centrifugation), solubility (crystallisation), volatility (sublimation).

IMPORTANT VALUES & CONSTANTS

Boiling point of water = 100 °C (373 K); freezing point = 0 °C (273 K) at 1 atm • Kelvin = °C + 273 • Plasma & Bose–Einstein condensate are the 4th & 5th states.

QUICK REVISION

- Solid → fixed shape & volume; liquid → fixed volume; gas → neither.
- Sublimation: solid→gas directly (camphor, naphthalene, dry ice).
- Evaporation → cooling (sweat, earthen pot, desert cooler).
- Element vs compound vs mixture; homo- vs heterogeneous.
- Colloid shows Tyndall effect; true solution does not.

PRACTICE QUESTIONS

1. Name the process: solid changing directly to gas. **Ans: Sublimation.**
2. Why does sweating cool the body? **Ans: Evaporation of sweat absorbs heat from the body.**
3. Which effect distinguishes a colloid from a true solution? **Ans: Tyndall effect (scattering of light).**
4. Convert 27 °C to kelvin. **Ans: 300 K (27 + 273).**
5. Give one method to separate salt from seawater. **Ans: Evaporation (or crystallisation).**

07 Atoms and Molecules

CHEMISTRY

All matter is built from atoms — unimaginably small units that combine according to fixed laws to form everything from the air we breathe to the DNA in our cells.

Laws of Chemical Combination

- **Law of Conservation of Mass** (Lavoisier): mass is neither created nor destroyed in a chemical reaction.
- **Law of Constant (Definite) Proportions** (Proust): a chemical compound always contains the same elements in the same fixed proportion by mass (water is always 1:8 hydrogen to oxygen).

These laws led John **Dalton** to propose his **atomic theory**: matter is made of indivisible atoms; atoms of an element are identical; and atoms combine in small whole-number ratios.

Discovery of the Atom's Structure

Scientist / Model	Key idea
J.J. Thomson	Discovered the electron; "plum-pudding" model — electrons embedded in a positive sphere
Ernest Rutherford	Gold-foil experiment; a tiny, dense, positive nucleus with electrons around it
Niels Bohr	Electrons revolve in fixed energy shells without losing energy
Chadwick	Discovered the neutron

Sub-atomic Particles

Particle	Charge	Relative mass	Location
Proton	+1	1 unit	Nucleus
Neutron	0	1 unit	Nucleus
Electron	−1	~1/1836 unit	Shells around nucleus

Atoms are electrically neutral because the number of protons equals the number of electrons. Almost all the mass is in the nucleus.

Atomic Number, Mass Number and Isotopes

- **Atomic number (Z)** = number of protons — uniquely identifies the element.
- **Mass number (A)** = protons + neutrons.
- **Isotopes** — atoms of the same element with different neutron counts (carbon-12 and carbon-14; uranium-235 and uranium-238). Carbon-14 is used in **radiocarbon dating**; cobalt-60 and iodine-131 in medicine.
- **Isobars** — atoms of different elements with the same mass number.

Electronic Configuration and Valency

Electrons occupy shells named K, L, M, N...; the maximum each can hold is given by $\mathbf{2n^2}$ (K=2, L=8, M=18). The electrons in the outermost shell are **valence electrons**. Atoms react to attain a stable, fully filled outer shell (the **octet rule** — eight electrons, like the noble gases). **Valency** — the combining capacity — equals the electrons an atom gains, loses or shares to achieve stability.

Ions and Chemical Bonding

Atoms that lose electrons become positive **cations**; those that gain electrons become negative **anions**. Bonding occurs in two main ways:

- **Ionic (electrovalent) bond** — transfer of electrons from metal to non-metal (sodium chloride, NaCl). Ionic compounds are crystalline, high-melting, and conduct electricity when molten or dissolved.
- **Covalent bond** — sharing of electrons between non-metals (water, methane, oxygen). Covalent compounds usually have low melting points and poor conductivity.

Molecules, Formulae and the Mole

A **molecule** is a group of atoms bonded together (O_2, H_2O, CO_2). A **chemical formula** shows the kinds and numbers of atoms. **Atomic mass** and **molecular mass** are measured in atomic mass units (u). The **mole** is the chemist's counting unit: one mole contains **Avogadro's number** (about 6.022×10^{23}) of particles and has a mass equal to the substance's atomic/molecular mass in grams.

The Periodic Table

Mendeleev arranged elements by increasing atomic mass into groups of similar properties, even leaving gaps for undiscovered elements. The **modern periodic table** arranges elements by increasing **atomic number** into 18 vertical **groups** and 7 horizontal **periods**. Elements in the same group have the same number of valence electrons and hence similar properties.

Periodic trends: across a period (left→right) atomic size decreases and metallic character decreases; down a group, atomic size increases and metallic character increases. The table is divided into **metals** (left and centre), **non-metals** (top right) and **metalloids** (the staircase between them, e.g. silicon, germanium). Group 18 holds the unreactive **noble gases**.

DID YOU KNOW

Hydrogen and helium make up about 98% of all ordinary matter in the universe; the heavier elements in our bodies — carbon, oxygen, iron — were forged inside ancient stars.

EXAM FOCUS

Atomic number defines the element; isotopes differ in neutrons. Know the charge/mass/location of the three sub-atomic particles, the $2n^2$ shell rule, the octet rule and valency, and ionic vs covalent bonding. Mendeleev vs modern table and periodic trends (group = similar properties) are high-yield.

ADVANCED NOTES & KEY FACTS

- Maximum electrons in a shell = $2n^2$: K=2, L=8, M=18, N=32. The outermost shell holds at most 8 (octet).
- Atoms react to complete their octet — by losing, gaining or sharing electrons; this is the basis of valency and bonding.
- **Ionic bonds** form between metals and non-metals (electron transfer; high melting points; conduct when molten/dissolved); **covalent bonds** form between non-metals (electron sharing; usually low melting points).
- **Isotopes** = same protons, different neutrons (C-12, C-14); **isobars** = same mass number, different elements.
- Modern periodic law: properties are a periodic function of **atomic number** (not mass — correcting Mendeleev).
- Across a period → atomic size decreases, metallic character decreases; down a group → size increases, metallic character increases.

IMPORTANT VALUES & CONSTANTS

Avogadro's number ≈ 6.022×10^{23} per mole • Atomic number = protons • Mass number = protons + neutrons • Modern table: 18 groups, 7 periods • Lightest element: hydrogen.

QUICK REVISION

- Proton +, neutron 0 (nucleus); electron − (shells).
- Atomic number defines the element; isotopes differ in neutrons.
- Shell capacity = $2n^2$; octet rule drives reactivity.
- Ionic = metal+non-metal (transfer); covalent = non-metals (sharing).
- Modern table arranged by atomic number; same group = similar properties.

PRACTICE QUESTIONS

1. What does the atomic number of an element represent? **Ans: The number of protons.**
2. Name the bond formed by sharing of electrons. **Ans: Covalent bond.**
3. How many electrons can the L shell hold? **Ans: 8 ($2n^2$, $n=2$).**
4. What is Avogadro's number approximately? **Ans: 6.022×10^{23}.**
5. Atoms of the same element with different neutrons are called? **Ans: Isotopes.**

08 Chemical Reactions and Equations

CHEMISTRY

A chemical reaction rearranges atoms to form new substances with new properties. Recognising reactions, balancing equations, and understanding acids, bases and salts are core chemistry skills.

Physical vs Chemical Change

A **physical change** (melting ice, dissolving salt, tearing paper) changes only the appearance or state and is usually reversible; no new substance forms. A **chemical change** (burning, rusting, cooking, digestion) produces **new substances** and is usually hard to reverse. Signs of a chemical change include a colour change, evolution of a gas (bubbles), formation of a precipitate, change in temperature, change in smell, or emission of light.

Chemical Equations and Balancing

Because matter is conserved, a chemical equation must be **balanced** — equal numbers of each kind of atom on both sides. Coefficients (not subscripts) are adjusted to balance.

$$2H_2 + O_2 \rightarrow 2H_2O$$

Symbols indicate state: (s) solid, (l) liquid, (g) gas, (aq) aqueous; an arrow shows the direction; conditions (heat, catalyst) are written over the arrow.

Types of Chemical Reactions

Type	What happens	Example
Combination	Two or more substances form one product	Quicklime + water → slaked lime
Decomposition	One substance breaks into two or more (by heat, light or electricity)	Heating limestone → lime + CO_2
Displacement	A more reactive element displaces a less reactive one	Iron + copper sulphate → iron sulphate + copper
Double displacement	Ions of two compounds exchange partners	Precipitation (barium sulphate)
Neutralisation	Acid reacts with base to give salt and water	$HCl + NaOH \rightarrow NaCl + H_2O$

Reactions are also **exothermic** (release heat — combustion, respiration) or **endothermic** (absorb heat — photosynthesis, decomposition of limestone).

Oxidation, Reduction and Their Everyday Effects

Oxidation is gain of oxygen or loss of hydrogen/electrons; **reduction** is the reverse. They always occur together (**redox** reactions). Two important everyday oxidation processes:

- **Corrosion** — slow eating away of metals; **rusting of iron** (needs both air and moisture) is the most common. Prevented by painting, oiling, greasing, galvanising (zinc coating) and using alloys like stainless steel.
- **Rancidity** — oxidation of fats and oils in food, giving a bad smell and taste. Slowed by adding antioxidants, refrigeration, airtight packing and flushing packets with nitrogen gas.

Acids, Bases and the pH Scale

Property	Acids	Bases
Ions released in water	H^+ (hydronium)	OH^- (hydroxide)
Taste	Sour	Bitter; soapy feel
Litmus test	Turn blue litmus red	Turn red litmus blue
Examples	Lemon, vinegar, HCl in stomach, sulphuric acid	Soap, baking soda, lime water, sodium hydroxide

Indicators reveal acidity: natural (litmus, turmeric, red cabbage), synthetic (phenolphthalein, methyl orange) and olfactory (onion, clove). The **pH scale** runs from 0 to 14: below 7 acidic, 7 neutral, above 7 basic. **Strong** acids/bases ionise fully; **weak** ones only partly.

> **KEY CONCEPT**
>
> pH matters everywhere: our stomach uses acid to digest food (antacids neutralise excess); plants grow best in a particular soil pH (lime corrects acidic soil); tooth decay begins when mouth pH falls below 5.5; and acid rain (low pH) harms lakes, crops and monuments.

Salts and Their Uses

A **salt** forms when an acid is neutralised by a base. Important salts:

Salt	Common name / source	Use
Sodium chloride (NaCl)	Common salt	Cooking; raw material for many chemicals
Sodium hydrogen carbonate	Baking soda	Baking, antacid, fire extinguishers
Sodium carbonate	Washing soda	Cleaning, softening hard water, glass-making
Calcium oxychloride	Bleaching powder	Disinfecting water, bleaching textiles
Calcium sulphate hemihydrate	Plaster of Paris	Casts for fractures, ceilings, statues

Some salts hold **water of crystallisation** in fixed amounts — copper sulphate (blue) and washing soda are examples; heating drives off this water.

EXAM FOCUS

Identify and balance the five reaction types; distinguish exothermic vs endothermic. Rusting and rancidity (and their prevention) are favourites. Master the litmus colour changes, the pH scale and its everyday relevance, and the common names and uses of baking soda, washing soda, bleaching powder and plaster of Paris.

ADVANCED NOTES & KEY FACTS

- Balance equations by adjusting coefficients (never subscripts); mass is conserved (atoms equal on both sides).
- Reactions are **exothermic** (release heat: combustion, respiration, neutralisation) or **endothermic** (absorb heat: photosynthesis, thermal decomposition).
- Rusting needs **both air (oxygen) and moisture**; prevented by galvanising, painting, oiling and alloying (stainless steel).
- Rancidity is oxidation of fats/oils; slowed by antioxidants, refrigeration and nitrogen-flushed packaging.
- pH scale 0–14: <7 acidic, 7 neutral, >7 basic. Tooth decay below pH 5.5; blood is tightly held near pH 7.4.
- Useful salts: baking soda (antacid, fire extinguisher), washing soda (cleaning, hard-water softening), bleaching powder (disinfection), plaster of Paris (casts).

IMPORTANT VALUES & CONSTANTS

Neutral pH = 7 • Tooth decay starts below pH 5.5 • Blood pH ≈ 7.4 • Stomach acid: HCl • Litmus: acid→red, base→blue • Plaster of Paris from gypsum heated to ~373 K.

QUICK REVISION

- Five reaction types: combination, decomposition, displacement, double-displacement, neutralisation.
- Oxidation = gain O_2/lose e^-; reduction = reverse; they occur together (redox).
- Acid → H^+, turns blue litmus red; base → OH^-, turns red litmus blue.
- pH: <7 acidic, 7 neutral, >7 basic.
- Prevent rusting: galvanising, painting, oiling, alloying.

PRACTICE QUESTIONS

1. What two conditions are needed for iron to rust? **Ans: Air (oxygen) and moisture (water).**
2. Acid + base gives which two products? **Ans: Salt and water (neutralisation).**
3. What is the pH of a neutral solution? **Ans: 7.**
4. Name the chemical used as both an antacid and in baking. **Ans: Sodium hydrogen carbonate (baking soda).**
5. Oxidation of fats in food leading to bad smell is called? **Ans: Rancidity.**

09 Metals and Non-Metals

CHEMISTRY

Most elements are metals; a smaller group are non-metals, with a few metalloids in between. Their contrasting properties shape everything from electrical wiring and bridges to the oxygen we breathe.

Physical Properties

Property	Metals	Non-metals
Lustre	Shiny	Dull (except iodine, diamond)
State at room temp.	Solid (except mercury, liquid)	Solid, liquid (bromine) or gas
Conductivity	Good (heat & electricity)	Poor insulators (except graphite)
Malleability/ Ductility	Can be beaten into sheets & drawn into wires	Brittle (when solid)
Sonority	Ring when struck	Not sonorous
Melting point	Generally high	Generally low

Chemical Properties

- **With oxygen:** metals form basic oxides (which turn red litmus blue when soluble); non-metals form acidic oxides. Some metal oxides (aluminium, zinc) are **amphoteric** — reacting with both acids and bases.
- **With water:** very reactive metals (sodium, potassium) react violently; some (magnesium, iron) react slowly; gold and silver do not react.
- **With acids:** most metals displace **hydrogen gas** from dilute acids; non-metals generally do not react with acids.

The Reactivity Series

Metals can be arranged by decreasing reactivity: **Potassium > Sodium > Calcium > Magnesium > Aluminium > Zinc > Iron > Lead > (Hydrogen) > Copper > Silver > Gold.** A more reactive metal **displaces** a less reactive one from its salt solution. This series governs how metals are extracted, why some corrode and others don't, and the outcome of displacement reactions.

Occurrence and Extraction (Metallurgy)

Metals occur in the Earth's crust as **minerals**; a mineral from which a metal can be profitably extracted is an **ore**. Extraction depends on reactivity:

Reactivity	Extraction method	Example
Most reactive (K, Na, Ca, Al)	Electrolysis of molten ore	Aluminium, sodium
Moderately reactive (Zn, Fe, Pb)	Roasting/calcination then reduction of the oxide	Iron (blast furnace)
Least reactive (Cu, Ag, Au)	Found native or by heating the ore alone	Gold, silver, copper

General steps: **enrichment** of the ore, **roasting** (heating sulphide ores in air) or **calcination** (heating carbonate ores in limited air) to form the oxide, **reduction** to the metal, and **refining** (often **electrolytic refining**) for purity. The **thermite reaction** (aluminium reducing iron oxide) is used to weld railway tracks.

Corrosion and Its Prevention

Metals slowly degrade when exposed to air and moisture: iron **rusts** (reddish-brown), copper develops a green coating, silver tarnishes black. Prevention methods include painting, oiling/greasing, **galvanisation** (coating with zinc), electroplating, anodising and alloying.

Alloys

An **alloy** is a homogeneous mixture of a metal with other metals or non-metals, made to improve strength, hardness or corrosion resistance.

Alloy	Composition	Use
Steel	Iron + carbon	Construction, tools, machinery
Stainless steel	Iron + chromium + nickel	Cutlery, utensils, surgical tools
Brass	Copper + zinc	Utensils, fittings, instruments
Bronze	Copper + tin	Statues, medals, bells
Solder	Lead + tin	Joining electrical wires
Duralumin	Aluminium + copper + magnesium	Aircraft bodies (light & strong)
Amalgam	Any alloy containing mercury	Dental fillings

Important Non-Metals and Allotropes

Non-metals are vital to life and industry: **oxygen** (respiration, combustion), **nitrogen** (fertilisers, inert packing), **carbon** (all organic life and fuels), **sulphur** and **phosphorus** (fertilisers, matches). Some elements exist in different physical forms — **allotropes** — most famously carbon as **diamond** (hardest natural substance), **graphite** (soft, conducts electricity — the non-metal exception), and modern forms such as fullerenes and graphene. Group 18 **noble gases** (helium, neon, argon) are almost inert and used in balloons, lights and inert atmospheres.

DID YOU KNOW

Gold is so unreactive that ancient gold ornaments survive thousands of years without tarnishing, while mercury is the only metal that is liquid at room temperature and bromine the only liquid non-metal.

EXAM FOCUS

Memorise the reactivity series order — it explains displacement, corrosion and extraction methods. Know the metal vs non-metal property contrasts, the metallurgy steps (roasting, calcination, reduction, refining), the thermite reaction, alloy compositions (steel, brass, bronze, duralumin, amalgam), and that graphite is the conducting non-metal.

ADVANCED NOTES & KEY FACTS

- Reactivity series (high→low): K, Na, Ca, Mg, Al, Zn, Fe, Pb, (H), Cu, Ag, Au. A higher metal displaces a lower one from its salt.
- Extraction by reactivity: most reactive → electrolysis; medium → reduction of oxide (blast furnace); least → found native/simple heating.
- **Roasting** = heating sulphide ore in air; **calcination** = heating carbonate ore in limited air — both give the metal oxide for reduction.
- The **thermite reaction** (Al + Fe_2O_3) releases intense heat to weld railway tracks.
- Amphoteric oxides (Al_2O_3, ZnO) react with both acids and bases.
- Alloys improve properties: steel (strength), stainless steel (rust-proof), brass/bronze (durability), duralumin (light & strong for aircraft), solder (low melting, joins wires).

IMPORTANT VALUES & CONSTANTS

Only liquid metal: mercury • Only liquid non-metal: bromine • Most reactive metals: K, Na • Least reactive (noble) metals: Au, Pt • Hardest natural substance: diamond (carbon) • Best conducting non-metal: graphite.

QUICK REVISION

- Metals: lustrous, malleable, ductile, good conductors, sonorous.
- Non-metals: dull, brittle, poor conductors (except graphite).
- Reactivity series governs displacement & extraction.
- Galvanisation = zinc coating to prevent rusting.
- Allotropes of carbon: diamond, graphite, fullerene, graphene.

PRACTICE QUESTIONS

1. Name the only metal that is liquid at room temperature. **Ans: Mercury.**
2. Which non-metal conducts electricity? **Ans: Graphite (an allotrope of carbon).**
3. Coating iron with zinc to prevent rusting is called? **Ans: Galvanisation.**
4. Brass is an alloy of which two metals? **Ans: Copper and zinc.**
5. Which gas is released when a metal reacts with dilute acid? **Ans: Hydrogen.**

III

Biology

The study of life in all its forms — from a single cell to entire ecosystems — and of how living things grow, function, reproduce and depend on one another.

11 Cells and Tissues

BIOLOGY

The cell is the basic structural and functional unit of life. Every living organism — from a single bacterium to a blue whale — is built from one or many cells organised into tissues, organs and systems.

Discovery and the Cell Theory

Robert **Hooke** first saw and named "cells" in cork; Leeuwenhoek observed living cells; and Schleiden, Schwann and Virchow framed the **cell theory**: all living things are made of cells, the cell is the basic unit of life, and every cell arises from a pre-existing cell. The **microscope** made all this possible. Cells vary enormously in size and shape — from tiny bacteria to the long nerve cell and the large ostrich egg.

Types of Cells

Feature	Prokaryotic	Eukaryotic
Nucleus	No true (membrane-bound) nucleus	True membrane-bound nucleus
Membrane-bound organelles	Absent	Present
Size	Smaller (1–10 μm)	Larger (10–100 μm)
Examples	Bacteria, cyanobacteria	Plants, animals, fungi, protists

Cell Organelles and Their Functions

- **Cell membrane (plasma membrane)** — selectively permeable boundary controlling entry and exit of substances.
- **Cell wall** — rigid outer covering of cellulose in plant cells (absent in animals); gives shape and support.
- **Nucleus** — the control centre; contains DNA in chromosomes and the nucleolus.
- **Mitochondria** — the "powerhouse"; site of aerobic respiration, producing energy (ATP). Have their own DNA.
- **Chloroplasts** — in green plant cells; contain chlorophyll; site of photosynthesis.
- **Endoplasmic reticulum (ER)** — a network of channels; rough ER (with ribosomes) makes proteins, smooth ER makes lipids.
- **Ribosomes** — protein factories.
- **Golgi apparatus** — modifies, packages and dispatches materials.
- **Lysosomes** — "suicide bags"; digest waste and worn-out parts.
- **Vacuole** — storage sac; large and central in plant cells, small in animal cells.
- **Plastids** — in plants; chloroplasts (green), chromoplasts (colour) and leucoplasts (storage).

KEY CONCEPT

Plant cells differ from animal cells by having three extra features: a cellulose cell wall, chloroplasts and a large central vacuole. Animal cells are usually rounder and have a centrosome (for cell division).

Movement Across the Membrane

Diffusion moves particles from high to low concentration. **Osmosis** is the movement of water across a semi-permeable membrane. A cell placed in a **hypotonic** solution swells (water enters), in a **hypertonic** solution shrinks (water leaves), and in an **isotonic** solution stays the same — important in understanding how plants stay turgid and how kidneys work.

Cell Division

Cells multiply by division. **Mitosis** produces two identical cells for growth and repair. **Meiosis** produces gametes (sex cells) with half the chromosome number, essential for sexual reproduction and variation.

Tissues

A **tissue** is a group of similar cells performing a common function.

Plant tissues	Animal tissues
Meristematic (growth: apical, lateral, intercalary)	**Epithelial** — covering and lining (skin, gut lining)
Parenchyma, collenchyma, sclerenchyma (support & storage)	**Connective** — blood, bone, cartilage, ligament, tendon, fat
Xylem — transports water & minerals upward	**Muscular** — striated, smooth and cardiac; enables movement
Phloem — transports food (sugars)	**Nervous** — neurons; carries electrical impulses

EXAM FOCUS

Mitochondria = powerhouse; chloroplast = photosynthesis; nucleus = control; lysosome = suicide bag. Know the three features unique to plant cells, osmosis (hypo/hyper/isotonic), mitosis vs meiosis, and the plant/animal tissue types — especially xylem (water) vs phloem (food).

ADVANCED NOTES & KEY FACTS

- Cell theory: all organisms are made of cells; the cell is the basic unit of life; cells come from pre-existing cells (Virchow).

- Mitochondria and chloroplasts have their own DNA — evidence they were once free-living bacteria (endosymbiosis).
- Lysosomes are "suicide bags"; ribosomes build proteins; Golgi packages and dispatches; rough ER (with ribosomes) vs smooth ER.
- Osmosis: cell swells in hypotonic, shrinks in hypertonic, unchanged in isotonic solution; plant cells stay turgid by water uptake.
- Mitosis → 2 identical cells (growth, repair); meiosis → 4 cells with half chromosomes (gametes, variation).
- Animal connective tissues include blood, bone, cartilage, tendon, ligament and fat; muscle types are striated (voluntary), smooth (involuntary) and cardiac.

IMPORTANT VALUES & CONSTANTS

Cell discovered by Robert Hooke (1665) in cork • Plant cell extras: cell wall, chloroplast, large vacuole • Powerhouse = mitochondria • Control centre = nucleus.

QUICK REVISION

- Prokaryote = no true nucleus (bacteria); eukaryote = true nucleus.
- Mitochondria = ATP/energy; chloroplast = photosynthesis; nucleus = control.
- Plant cell extras: cell wall, chloroplast, large central vacuole.
- Osmosis = water movement across a semi-permeable membrane.
- Xylem = water transport; phloem = food transport.

PRACTICE QUESTIONS

1. Who discovered the cell? **Ans: Robert Hooke.**
2. Which organelle is called the powerhouse of the cell? **Ans: Mitochondria.**
3. Name three features unique to plant cells. **Ans: Cell wall, chloroplasts, large central vacuole.**
4. Which cell division produces gametes? **Ans: Meiosis.**
5. Which plant tissue transports food? **Ans: Phloem.**

12 Plant Organisms

BIOLOGY

Plants are the producers that sustain almost all life, turning sunlight, water and air into food and releasing the oxygen we breathe.

Classification of the Plant Kingdom

Group	Features	Example
Thallophyta (algae)	Simple, no true roots/stems/leaves	Spirogyra, Chara
Bryophyta	"Amphibians of the plant kingdom"; no vascular tissue	Moss, Marchantia
Pteridophyta	First with vascular tissue; reproduce by spores	Fern
Gymnosperms	Naked seeds (no fruit)	Pine, Cycas
Angiosperms	Flowering plants; seeds in fruit; monocots & dicots	Mango, wheat, rose

Parts of a Plant and Their Functions

- **Roots** — anchor the plant and absorb water and minerals; may be modified for storage (carrot, radish).
- **Stem** — supports the plant and transports water and food; may be modified (potato tuber, ginger).
- **Leaves** — make food by photosynthesis and exchange gases through stomata; venation may be reticulate (dicots) or parallel (monocots).
- **Flower** — the reproductive organ.
- **Fruit and seed** — protect and disperse the next generation.

The Flower and Reproduction

A typical flower has four whorls: **calyx** (sepals), **corolla** (petals), **androecium** (stamens — the male part producing pollen) and **gynoecium** (pistil — the female part with ovary, style and stigma).

Pollination is the transfer of pollen from anther to stigma — **self-pollination** (same flower) or **cross-pollination** (different flowers), carried out by wind, water and animals (especially insects). It is followed by **fertilisation**, after which the ovule becomes the seed and the ovary becomes the fruit. Plants also reproduce **asexually** — by cuttings, grafting, layering, tubers and runners. **Seed dispersal** by wind, water, animals and explosion spreads the species.

Photosynthesis

In the presence of sunlight and the green pigment **chlorophyll**, leaves combine carbon dioxide and water to make glucose, releasing oxygen.

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2 \text{ (light energy)}$$

It occurs in two phases — the light reaction (captures sunlight, splits water, releases oxygen) and the dark reaction (fixes CO_2 into glucose). The rate depends on light intensity, CO_2 concentration, temperature and water. Gas exchange and water vapour loss occur through tiny pores called **stomata**, guarded by guard cells.

Transport, Transpiration and Respiration

Xylem carries water and minerals upward from roots; **phloem** carries food made in leaves to all parts (translocation). **Transpiration** — loss of water vapour from leaves — creates a pull that draws water up, cools the plant and helps mineral transport. Plants also **respire** day and night, taking in oxygen and releasing CO_2.

Plant Hormones and Movements

Hormone	Main role
Auxin	Cell elongation; growth toward light
Gibberellin	Stem growth, seed germination
Cytokinin	Cell division
Abscisic acid	Inhibits growth; closes stomata in stress; dormancy
Ethylene	Fruit ripening

Tropic movements are directional growth responses: **phototropism** (toward light), **geotropism** (roots toward gravity), **hydrotropism** (toward water) and **thigmotropism** (touch, in climbers). The folding of the touch-me-not (Mimosa) leaves is a fast **nastic** movement.

> **EXAM FOCUS**
>
> Photosynthesis equation, the roles of chlorophyll and stomata, and xylem vs phloem are core. Know the plant kingdom groups (gymnosperm = naked seed, angiosperm = flowering), flower parts, pollination types and agents, the five plant hormones, and tropic movements (photo-, geo-, hydro-, thigmotropism).

ADVANCED NOTES & KEY FACTS

- Plant kingdom progression: Thallophyta → Bryophyta → Pteridophyta → Gymnosperms → Angiosperms (mono- and dicots).
- Photosynthesis has a **light reaction** (splits water, releases O_2, makes ATP) and a **dark reaction** (fixes CO_2 into glucose).

- Stomata open/close via guard cells, balancing CO_2 intake against water loss (transpiration); transpiration also pulls water up and cools the plant.
- Hormones: auxin (growth toward light), gibberellin (stem elongation, germination), cytokinin (cell division), abscisic acid (stress, dormancy), ethylene (ripening).
- Tropisms: phototropism (light), geotropism (gravity), hydrotropism (water), thigmotropism (touch — climbers).
- Cross-pollination increases variation; agents are wind, water and animals (especially insects).

IMPORTANT VALUES & CONSTANTS

Photosynthesis: $6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$ (in light) • Pigment: chlorophyll (green) • Gymnosperm = naked seeds; Angiosperm = seeds in fruit.

QUICK REVISION

- Roots absorb & anchor; leaves photosynthesise; flowers reproduce.
- Chlorophyll + sunlight + CO_2 + water → glucose + O_2.
- Stomata: gas exchange & transpiration.
- Five hormones: auxin, gibberellin, cytokinin, abscisic acid, ethylene.
- Phototropism toward light; geotropism toward gravity.

PRACTICE QUESTIONS

1. Which pigment is essential for photosynthesis? **Ans: Chlorophyll.**
2. Through which pores do leaves exchange gases? **Ans: Stomata.**
3. Name the hormone responsible for fruit ripening. **Ans: Ethylene.**
4. Plants with naked seeds belong to which group? **Ans: Gymnosperms.**
5. Growth of a shoot toward light is called? **Ans: Phototropism.**

13 Animal Organisms

BIOLOGY

Animals are consumers that depend on other organisms for food. Their bodies are organised into specialised systems and they show remarkable diversity in structure and lifestyle.

Classification of the Animal Kingdom

Phylum	Key feature	Example
Porifera	Pore-bearing; simplest, sponges	Sponge
Coelenterata (Cnidaria)	Hollow body cavity; stinging cells	Hydra, jellyfish
Platyhelminthes	Flatworms	Tapeworm, planaria
Nematoda	Roundworms	Ascaris
Annelida	Segmented (ringed) bodies	Earthworm, leech
Arthropoda	Jointed legs; exoskeleton; largest phylum	Insects, spiders, crabs
Mollusca	Soft body, often with a shell	Snail, octopus
Echinodermata	Spiny-skinned; marine	Starfish
Chordata	Notochord; includes all vertebrates	Fish to mammals

The Five Vertebrate Classes

Class	Distinguishing features	Example
Pisces (fish)	Gills, fins, scales; cold-blooded; aquatic	Rohu, shark
Amphibia	Live in water and on land; moist skin; lay eggs in water	Frog, toad
Reptilia	Dry scaly skin; lay shelled eggs on land; cold-blooded	Snake, lizard, crocodile
Aves (birds)	Feathers, beak, wings; lay eggs; warm-blooded	Sparrow, eagle
Mammalia	Hair/fur, mammary glands, give birth (mostly); warm-blooded	Human, cow, whale, bat

Organ Systems

- **Digestive** — ingests and breaks down food for absorption.

- **Respiratory** — gas exchange via gills (fish), trachea (insects), lungs (mammals, birds, reptiles) or moist skin (amphibians, earthworm).
- **Circulatory** — heart and blood vessels; may be **open** (insects) or **closed** (vertebrates).
- **Nervous** — brain, spinal cord and nerves coordinate responses.
- **Excretory** — kidneys (vertebrates) remove nitrogenous waste.
- **Skeletal & muscular** — provide support and movement.
- **Reproductive** — produces offspring.

Reproduction and Development

Most animals reproduce **sexually** by union of male and female gametes; simple animals reproduce **asexually** by **binary fission** (Amoeba), **budding** (Hydra) or **regeneration** (Planaria). Animals are **oviparous** (egg-laying, e.g. birds, reptiles, most fish) or **viviparous** (give birth to live young, e.g. mammals). Some undergo **metamorphosis** — a dramatic change of form, as a tadpole becomes a frog or a caterpillar a butterfly.

Warm-blooded vs Cold-blooded; Adaptation

Cold-blooded (ectothermic) animals (fish, amphibians, reptiles) depend on the surroundings for body heat; **warm-blooded (endothermic)** animals (birds, mammals) maintain a constant body temperature. Animals show striking **adaptations** — the camel's water conservation, the polar bear's fur and fat, gills in fish, hollow bones in birds for flight.

DID YOU KNOW

Arthropoda is the largest animal phylum, making up over three-quarters of all known animal species — insects alone outnumber all other animals combined.

EXAM FOCUS

Know one feature per phylum and the five vertebrate classes with one distinguishing trait each. Open vs closed circulation, oviparous vs viviparous, warm- vs cold-blooded, the modes of asexual reproduction, and metamorphosis are frequently asked.

ADVANCED NOTES & KEY FACTS

- Animal phyla (simple→complex): Porifera, Coelenterata, Platyhelminthes, Nematoda, Annelida, Arthropoda, Mollusca, Echinodermata, Chordata.
- Arthropoda is the largest phylum (jointed legs, exoskeleton); Chordata includes all vertebrates (notochord).
- Five vertebrate classes: Pisces, Amphibia, Reptilia, Aves, Mammalia — only birds and mammals are warm-blooded.
- Respiration varies: gills (fish), trachea (insects), lungs (mammals/birds/reptiles), moist skin (amphibians, earthworm).

- Circulation is open (insects — blood bathes organs) or closed (vertebrates — blood in vessels).
- Asexual modes: binary fission (Amoeba), budding (Hydra), regeneration (Planaria). Oviparous lay eggs; viviparous give live birth.

IMPORTANT VALUES & CONSTANTS

Largest phylum: Arthropoda • Warm-blooded: birds & mammals • Only egg-laying mammal: platypus • Metamorphosis: tadpole→frog, caterpillar→butterfly.

QUICK REVISION

- Vertebrates have a backbone; invertebrates do not.
- Five vertebrate classes: fish, amphibians, reptiles, birds, mammals.
- Warm-blooded = birds & mammals; rest are cold-blooded.
- Oviparous = egg-laying; viviparous = live birth.
- Asexual: binary fission, budding, regeneration.

PRACTICE QUESTIONS

1. Which is the largest animal phylum? **Ans: Arthropoda.**
2. Name two warm-blooded vertebrate classes. **Ans: Birds (Aves) and mammals (Mammalia).**
3. How does Hydra reproduce asexually? **Ans: By budding.**
4. Animals that give birth to live young are called? **Ans: Viviparous.**
5. Through which organ do fish breathe? **Ans: Gills.**

14 Life Processes

BIOLOGY

Life processes are the essential functions that keep an organism alive: nutrition, respiration, transport, excretion, control and coordination, and reproduction.

Nutrition

Autotrophs (green plants) make their own food by photosynthesis. **Heterotrophs** obtain food from others — **holozoic** (ingest solid food, e.g. humans), **saprophytic** (feed on dead matter, e.g. fungi), and **parasitic** (live on a host, e.g. tapeworm).

Human digestion follows the alimentary canal: the **mouth** (teeth and salivary amylase begin starch digestion) → **oesophagus** → **stomach** (hydrochloric acid and pepsin digest protein) → **small intestine** (bile from the liver and enzymes from the pancreas complete digestion; nutrients are absorbed through finger-like **villi**) → **large intestine** (absorbs water) → rectum and anus (egestion). The **liver** and **pancreas** are key associated glands.

Respiration

Respiration releases energy from glucose. **Aerobic respiration** (with oxygen) yields a large amount of energy plus carbon dioxide and water; **anaerobic respiration** (without oxygen) yields less — producing lactic acid in muscles during heavy exercise (causing cramps), and alcohol or CO_2 in yeast (used in baking and brewing).

Glucose + Oxygen → Carbon dioxide + Water + Energy (ATP)

In humans, air enters through the nose → trachea → bronchi → **lungs**, where gas exchange occurs across millions of tiny air sacs (**alveoli**). The diaphragm and rib muscles drive breathing.

Transportation

The **circulatory system** carries oxygen, nutrients, hormones and wastes. **Blood** consists of **plasma** (fluid), **red cells** (carry oxygen via haemoglobin), **white cells** (fight infection) and **platelets** (help clotting). The human **heart** has four chambers and pumps in a **double circulation** (lung circuit and body circuit). **Arteries** carry blood away from the heart (mostly oxygenated), **veins** return it, and thin **capillaries** allow exchange with tissues. **Blood groups** (A, B, AB, O and the Rh factor) matter for safe transfusions. In plants, xylem and phloem perform transport.

Excretion

The human **excretory system** centres on the **kidneys**, which filter blood through about a million tiny units called **nephrons**, removing urea and excess salts as urine, stored in the bladder. When kidneys fail, **dialysis** performs this filtration artificially. Plants excrete excess water by transpiration and store wastes in leaves, bark and old tissues.

Control and Coordination

Two systems coordinate the body. The **nervous system** gives rapid, short-lived responses: the **neuron** is its basic unit, the **brain** (cerebrum for thought, cerebellum for balance, medulla for involuntary actions) and spinal cord are the control centres. A **reflex action** (jerking the hand from something hot) is processed by the spinal cord for speed, via a reflex arc.

The **endocrine system** gives slower, longer-lasting control through chemical **hormones**:

Gland	Hormone	Function
Thyroid	Thyroxine	Regulates metabolism (needs iodine)
Pancreas	Insulin	Lowers blood sugar (deficiency → diabetes)
Adrenal	Adrenaline	"Fight or flight" emergency response
Pituitary	Growth hormone	Controls growth; "master gland"
Testes / Ovaries	Testosterone / Oestrogen	Sexual development

EXAM FOCUS

Autotroph vs heterotroph (holozoic/saprophytic/parasitic); the order of human digestion and role of villi; aerobic vs anaerobic respiration and products; alveoli; blood components, four-chambered heart and artery vs vein; the nephron and dialysis; reflex arc; and the gland–hormone–function table (insulin, thyroxine, adrenaline) are all very high-yield.

ADVANCED NOTES & KEY FACTS

- Nutrition types: autotrophic (plants); heterotrophic — holozoic (humans), saprophytic (fungi), parasitic (tapeworm).
- Digestion: mouth (amylase) → stomach (HCl + pepsin) → small intestine (bile + pancreatic enzymes; absorbed via villi) → large intestine (water).
- Aerobic respiration yields much more energy than anaerobic; muscles produce lactic acid (cramp) under low oxygen, yeast produces alcohol + CO_2.
- Blood: plasma + RBC (haemoglobin/O_2) + WBC (defence) + platelets (clotting); four-chambered heart, double circulation; arteries away, veins toward heart.
- Kidneys filter blood through nephrons; dialysis substitutes when kidneys fail.
- Hormones: insulin (lowers sugar; deficiency→diabetes), thyroxine (metabolism; needs iodine), adrenaline (emergency), growth hormone (pituitary = master gland).

IMPORTANT VALUES & CONSTANTS

Human heart: 4 chambers • Excretory waste: urea • Pancreatic hormone: insulin • Thyroid hormone: thyroxine (iodine) • Universal donor blood: O^-; universal recipient: AB^+.

QUICK REVISION

- Autotroph makes own food; heterotroph depends on others.
- Aerobic (with O_2) gives more energy than anaerobic.
- Arteries carry blood away; veins carry it back.
- Kidney filters blood via nephrons → urine; dialysis if it fails.
- Insulin↓sugar, thyroxine→metabolism, adrenaline→fight/flight.

PRACTICE QUESTIONS

1. Which gland secretes insulin? **Ans: Pancreas.**
2. What is the basic filtering unit of the kidney? **Ans: Nephron.**
3. Name the pigment that carries oxygen in blood. **Ans: Haemoglobin.**
4. A fast, automatic response like withdrawing the hand is called? **Ans: Reflex action.**
5. Deficiency of which hormone causes diabetes? **Ans: Insulin.**

15 Food and Crops

BIOLOGY

Feeding a growing population sustainably is one of the great challenges of our age. Nutrition, agriculture, animal husbandry and food security all meet on this topic.

Nutrients and a Balanced Diet

Nutrient	Function	Sources
Carbohydrates	Main energy source	Rice, wheat, potato, sugar
Proteins	Growth and repair (body-building)	Pulses, eggs, milk, meat, soya
Fats	Concentrated energy; insulation	Oils, butter, ghee, nuts
Vitamins	Protective; regulate body functions	Fruits, vegetables
Minerals	Bones, blood, nerves	Milk, greens, salt
Roughage (fibre)	Aids digestion	Whole grains, vegetables
Water	Transport, temperature control	Drinks, fruits

A **balanced diet** contains all nutrients in the right proportion. Vitamins are **fat-soluble** (A, D, E, K) or **water-soluble** (B-complex, C).

DEFICIENCY DISEASES

Vitamin A → night blindness; B1 → beri-beri; B12/iron → anaemia; Vitamin C → scurvy; Vitamin D → rickets (and osteomalacia in adults); Iodine → goitre; Calcium → weak bones; Protein deficiency → kwashiorkor and marasmus.

Crop Seasons in India

Season	Period	Major crops
Kharif	Monsoon (Jun–Oct)	Rice, maize, cotton, soybean, groundnut, bajra
Rabi	Winter (Oct–Mar)	Wheat, gram, mustard, peas, barley
Zaid	Summer (Mar–Jun)	Watermelon, muskmelon, cucumber, fodder

Crop Production Practices

Good farming follows steps: **soil preparation** (ploughing, levelling), **sowing** (seeds of good quality, by drill or broadcasting), adding **manure and fertilisers** (manure is organic and improves soil; fertilisers supply specific nutrients like N, P, K), **irrigation** (wells, canals, sprinkler and efficient drip systems), **weeding**, **protection** from pests and diseases, **harvesting**, and proper **storage** to prevent loss from moisture and pests. Practices such as **crop rotation** and **mixed cropping** keep soil fertile.

Crops are grouped as **cereals** (rice, wheat), **pulses** (gram, lentil — nitrogen-fixing legumes), **oilseeds** (mustard, groundnut) and **cash crops** (cotton, sugarcane, jute).

Animal Husbandry

Rearing animals for food and other products: **dairy and cattle farming** (milk, draught), **poultry** (eggs, meat), **fishery / aquaculture** (fish), and **apiculture** (bee-keeping for honey and wax). Good breeding, feeding and disease control raise productivity.

Agricultural Revolutions and Food Security

- **Green Revolution** — high-yielding wheat and rice varieties boosted foodgrain output.
- **White Revolution (Operation Flood)** — made India the world's largest milk producer.
- **Blue** — fisheries; **Yellow** — oilseeds; **Pink** — meat/poultry; **Golden** — fruits/horticulture.

Food security means everyone has access to enough nutritious food. India supports it through buffer stocks, the **Public Distribution System (PDS)**, and the National Food Security Act. Challenges include **malnutrition**, food wastage, and the environmental cost of over-using chemicals — addressed by organic farming, fortification and genetically modified (GM) crops.

> **EXAM FOCUS**
>
> Match each vitamin/mineral to its deficiency disease (a near-guaranteed question). Know Kharif vs Rabi vs Zaid crops, the difference between manure and fertiliser, the colour-coded revolutions, and food-security schemes (PDS, NFSA) — strong current-affairs links.

ADVANCED NOTES & KEY FACTS

- A balanced diet supplies carbohydrates, proteins, fats, vitamins, minerals, roughage and water in the right proportions.
- Fat-soluble vitamins: A, D, E, K; water-soluble: B-complex and C.
- Pulses (legumes) host nitrogen-fixing bacteria, naturally enriching the soil — hence their role in crop rotation.
- Manure is bulky organic matter that improves soil structure; fertilisers supply concentrated N, P, K but overuse harms soil and water.
- Drip and sprinkler irrigation save water versus flooding; proper storage prevents losses to moisture, pests and fungi.
- India's revolutions: Green (grains), White (milk), Blue (fish), Yellow (oilseeds), Pink (meat), Golden (horticulture).

IMPORTANT VALUES & CONSTANTS

Deficiencies: Vit A→night blindness, B1→beri-beri, C→scurvy, D→rickets, iron→anaemia, iodine→goitre • Kharif (monsoon), Rabi (winter), Zaid (summer).

QUICK REVISION

- Carbohydrate = energy; protein = growth/repair; fat = stored energy.
- Vit C→scurvy; Vit D→rickets; iodine→goitre; iron→anaemia.
- Kharif = rice/maize/cotton; Rabi = wheat/gram/mustard.
- Manure (organic) vs fertiliser (concentrated nutrients).
- Green→grains, White→milk, Blue→fish, Yellow→oilseeds.

PRACTICE QUESTIONS

1. Deficiency of vitamin C causes which disease? **Ans: Scurvy.**
2. Goitre is caused by the deficiency of which element? **Ans: Iodine.**
3. Name two Kharif crops. **Ans: Rice and cotton (also maize, soybean).**
4. The White Revolution is associated with which product? **Ans: Milk.**
5. Which nutrient is mainly responsible for body growth and repair? **Ans: Proteins.**

16 Natural Phenomenon

BIOLOGY

From lightning and earthquakes to eclipses and cyclones, natural phenomena reveal the powerful forces shaping our atmosphere, oceans and planet.

Static Electricity and Lightning

Rubbing objects transfers charge (**charging by friction**); an **electroscope** detects charge. In storm clouds, charges separate until a massive spark — **lightning** — jumps between clouds or to the ground. The sudden heating of air creates the shock wave we hear as **thunder** (heard after the flash because light travels far faster than sound). Tall buildings are protected by a **lightning conductor** — a metal rod that safely channels the charge into the earth. During a storm, open ground and tall isolated trees are dangerous; a closed vehicle is relatively safe.

Earthquakes

The Earth's rigid outer shell is broken into moving **tectonic plates**. Stress builds at their boundaries and is suddenly released as **seismic waves**, shaking the ground — an **earthquake**. The point of origin underground is the **focus (hypocentre)**; the point directly above on the surface is the **epicentre**. A **seismograph** records the waves; magnitude is measured on the **Richter scale** and intensity on the Mercalli scale. India is divided into seismic zones II–V, with the Himalayan belt and the Northeast in the highest-risk Zone V. Earthquake-resistant construction and preparedness save lives.

Volcanoes and Tsunamis

Volcanoes erupt molten rock (magma below ground, lava above), ash and gases through vents, often at plate boundaries. Undersea earthquakes or eruptions can suddenly displace huge volumes of water, generating a **tsunami** — a series of fast, low waves in deep ocean that rise into towering walls of water near the coast, as in the devastating 2004 Indian Ocean tsunami. Warning systems now give coastal communities precious time to evacuate.

Cyclones

A **cyclone** is an intense low-pressure system with rapidly rotating winds, fed by warm, moist ocean air. It has a calm central **eye** surrounded by violent eye-wall winds. India's east coast (Bay of Bengal) is especially prone; cyclones are named under a regional system. Early-warning satellites, alerts and shelters have sharply reduced casualties. Related disasters include **floods, droughts** and **landslides**.

Climate Phenomena: El Niño and La Niña

El Niño is an abnormal warming of the central and eastern Pacific that disrupts weather worldwide and can weaken the Indian monsoon; **La Niña** is the opposite cooling phase, often linked to a good monsoon. These cycles strongly affect agriculture and water supply.

Sky Phenomena

- **Rainbow** — dispersion and internal reflection of sunlight in raindrops.
- **Mirage** — bending of light in unevenly heated air, creating a water-like illusion on hot roads.
- **Solar eclipse** — the Moon comes between the Sun and Earth (total, partial or annular).
- **Lunar eclipse** — the Earth's shadow falls on the full Moon.
- **Twinkling of stars** — refraction of starlight through the moving atmosphere; planets, being nearer, twinkle far less.

EXAM FOCUS

Distinguish focus vs epicentre; know the Richter scale and seismograph, the cause of tsunamis, cyclone anatomy (eye), and El Niño/La Niña effects on the monsoon. Solar vs lunar eclipse and the lightning conductor are common, with strong disaster-management current-affairs value.

ADVANCED NOTES & KEY FACTS

- Lightning results from charge separation in clouds; a lightning conductor channels charge safely to earth; thunder is the shock wave of suddenly heated air.
- Earthquake terms: focus (origin underground), epicentre (surface point above); measured by seismograph on the Richter scale; India has seismic zones II–V.
- Tsunamis are triggered by undersea quakes/eruptions; waves are low in deep sea but rise enormously near the coast (2004 Indian Ocean tsunami).
- A cyclone has a calm **eye** ringed by violent winds; warm seas fuel it; India's east coast is highly prone.
- El Niño (Pacific warming) can weaken the Indian monsoon; La Niña (cooling) often strengthens it.
- Eclipses: solar (Moon between Sun & Earth — new moon), lunar (Earth's shadow on Moon — full moon); types include total, partial and annular.

IMPORTANT VALUES & CONSTANTS

Earthquake magnitude → Richter scale; recorded by seismograph • Highest seismic risk: Zone V (Himalayas, NE India) • Cyclone centre = eye • Solar eclipse on new moon; lunar on full moon.

QUICK REVISION

- Focus = origin; epicentre = point on surface above it.
- Tsunami caused by undersea earthquakes/eruptions.
- Cyclone: low pressure, rotating winds, calm eye.
- El Niño weakens monsoon; La Niña strengthens it.
- Solar eclipse → new moon; lunar eclipse → full moon.

PRACTICE QUESTIONS

1. What is the point of origin of an earthquake underground called? **Ans: Focus (hypocentre).**
2. On which scale is earthquake magnitude measured? **Ans: Richter scale.**
3. The calm centre of a cyclone is called? **Ans: The eye.**
4. A solar eclipse occurs on which lunar phase? **Ans: New moon.**
5. Which ocean phenomenon can weaken the Indian monsoon? **Ans: El Niño.**

17 Our Environment

BIOLOGY

The environment is the web of living and non-living things around us. Keeping its delicate balance is essential for the survival of every species — including our own.

Ecosystem and Its Components

An **ecosystem** is a community of living organisms interacting with their physical surroundings. It has **abiotic** components (air, water, soil, sunlight, temperature) and **biotic** components in three roles:

- **Producers** — green plants and algae that make food by photosynthesis.
- **Consumers** — herbivores (primary), carnivores and omnivores (secondary/tertiary).
- **Decomposers** — bacteria and fungi that break down dead matter and recycle nutrients.

Ecosystems may be **natural** (forest, pond, ocean, desert) or **artificial** (crop field, aquarium).

Food Chains, Webs and Energy Flow

Energy flows in one direction: Sun → producers → herbivores → carnivores, forming a **food chain**; many interconnected chains make a **food web**. Each step is a **trophic level**. By the **ten per cent law**, only about 10% of energy passes to the next level, which limits chains to a few links and is shown by the **ecological pyramid**. Non-biodegradable toxins (like certain pesticides) become more concentrated up the chain — **biomagnification** — harming top predators most.

Biogeochemical Cycles

Nutrients are recycled through nature: the **carbon cycle** (photosynthesis, respiration, combustion, decomposition), the **nitrogen cycle** (fixation by bacteria and lightning, then nitrification and denitrification), the **water cycle** (evaporation, condensation, precipitation) and the **oxygen cycle**. These cycles keep the biosphere in balance.

Biodiversity and Its Conservation

Biodiversity — the variety of life — exists at the genetic, species and ecosystem levels. India is one of the world's **megadiverse** countries with recognised biodiversity hotspots (the Western Ghats, Himalayas, Indo-Burma, Sundaland). Conservation is **in-situ** (in natural habitat — national parks, wildlife sanctuaries, biosphere reserves) or **ex-situ** (zoos, seed banks, botanical gardens). Flagship efforts include Project Tiger and Project Elephant.

Pollution and Its Control

Type	Major causes	Effects
Air	Vehicle and factory emissions, burning	Respiratory disease, smog, acid rain
Water	Sewage, industrial effluents, fertilisers	Disease, eutrophication, dead aquatic life
Soil	Plastics, chemicals, mining	Loss of fertility, toxic crops
Noise	Traffic, industry, loudspeakers	Hearing loss, stress

Solutions include the **3 Rs** (Reduce, Reuse, Recycle), waste segregation into **biodegradable** and **non-biodegradable**, sewage treatment, cleaner fuels and afforestation.

Global Environmental Issues

- **Greenhouse effect & global warming** — gases like CO_2 and methane trap heat, raising temperatures, melting glaciers and raising sea levels.
- **Ozone depletion** — CFCs thin the protective ozone layer; the **Montreal Protocol** phased out CFCs and the ozone hole is now slowly healing.
- **Acid rain** — SO_2 and NO_x emissions make rain acidic, damaging soil, water and monuments (e.g. the Taj Mahal).
- **Climate agreements** — the Kyoto Protocol and the **Paris Agreement** commit nations to cut emissions; India targets net-zero by 2070.

Sustainable development meets present needs without compromising future generations — through renewable energy, conservation and responsible consumption.

> **EXAM FOCUS**
>
> Producers/consumers/decomposers, the ten per cent law, biomagnification, trophic levels and the carbon/nitrogen cycles are core. The greenhouse effect, ozone depletion (Montreal Protocol), acid rain, Paris Agreement, biodiversity hotspots and the 3 Rs are reliable exam staples with heavy current-affairs overlap.

ADVANCED NOTES & KEY FACTS

- Ecosystem = biotic (producers, consumers, decomposers) + abiotic (air, water, soil, sunlight) components.
- Ten-per-cent law: only ~10% of energy transfers between trophic levels, limiting food-chain length.
- Biomagnification concentrates non-biodegradable toxins up the chain, harming top predators most.

- Greenhouse gases (CO_2, CH_4, N_2O) cause global warming; CFCs deplete ozone (tackled by the Montreal Protocol); SO_2/NO_x cause acid rain.
- Conservation: in-situ (national parks, sanctuaries, biosphere reserves) and ex-situ (zoos, seed banks); India is megadiverse with hotspots like the Western Ghats.
- Climate accords: Kyoto Protocol and Paris Agreement; India targets net-zero by 2070; the 3 Rs reduce waste.

IMPORTANT VALUES & CONSTANTS

Energy transfer ≈ 10% per trophic level • Montreal Protocol → ozone protection • Paris Agreement → emission cuts • India net-zero: 2070 • Biodiversity hotspot e.g. Western Ghats.

QUICK REVISION

- Producers → consumers → decomposers; energy flows one way.
- Ten-per-cent law limits trophic levels; biomagnification harms top predators.
- Greenhouse gases → global warming; CFCs → ozone hole.
- Montreal Protocol (ozone); Paris Agreement (climate).
- Conservation: in-situ (parks) & ex-situ (zoos/seed banks); 3 Rs.

PRACTICE QUESTIONS

1. What percentage of energy passes to the next trophic level? **Ans: About 10%.**
2. Which agreement phased out ozone-depleting CFCs? **Ans: The Montreal Protocol.**
3. Name the three organism roles in an ecosystem. **Ans: Producers, consumers, decomposers.**
4. What is the increasing concentration of toxins along a food chain called? **Ans: Biomagnification.**
5. By which year does India aim to reach net-zero emissions? **Ans: 2070.**

18 Biotechnology

BIOLOGY

Biotechnology uses living organisms and their components to make useful products — from ancient bread, curd and wine to today's life-saving vaccines, GM crops and gene editing.

What Is Biotechnology?

Traditional biotechnology uses microbes for fermentation — bread, curd, cheese, idli, alcohol and antibiotics. **Modern biotechnology** manipulates genes directly through **genetic engineering** to give organisms new, useful traits.

DNA, Genes and Genetic Engineering

DNA (deoxyribonucleic acid) carries hereditary information in the sequence of its four bases; a **gene** is a segment of DNA coding for a trait. In **recombinant DNA technology**, scientists use molecular tools — **restriction enzymes** (molecular scissors that cut DNA), **DNA ligase** (molecular glue), and **vectors** (such as plasmids that carry genes into host cells) — to insert a desired gene into another organism, creating a **genetically modified organism (GMO)**. A landmark success is bacteria engineered to produce **human insulin** for diabetics.

Key Techniques

- **PCR (polymerase chain reaction)** — rapidly copies tiny amounts of DNA; vital for diagnosis and forensics.
- **Gene cloning** — making many identical copies of a gene.
- **Tissue culture** — growing whole plants from a few cells; used for rapid, disease-free propagation.
- **Hybridoma technology** — produces **monoclonal antibodies** for diagnosis and treatment.
- **CRISPR** — a precise gene-editing tool that edits DNA letter by letter, opening doors to curing genetic diseases (and raising serious ethical questions).

Applications

Field	Applications
Medicine	Insulin, vaccines, gene therapy, stem-cell therapy, antibiotics, monoclonal antibodies
Agriculture	Bt cotton (pest resistance), Golden Rice (vitamin A), biofertilisers, biopesticides, tissue-cultured plants
Industry	Enzymes in detergents and food, biofuels (ethanol)
Environment	Bioremediation — microbes that clean oil spills and pollutants
Forensics	DNA fingerprinting for crime, paternity and wildlife protection

Vaccines and Modern Medicine

Vaccines train the immune system to fight disease. Types include live-attenuated, inactivated, subunit and the newer **mRNA vaccines** used against COVID-19, which deliver genetic instructions so our own cells make a harmless viral protein that triggers immunity — a major biotechnology milestone. **Gene therapy** aims to treat disease by correcting faulty genes, and **stem cells** offer hope of regenerating damaged tissue.

The Human Genome Project and DNA Fingerprinting

The **Human Genome Project** mapped the complete set of human genes, transforming medicine and biology. **DNA fingerprinting** identifies individuals from their unique DNA pattern and is used in criminal investigation, paternity testing and conservation.

Bioethics, Biosafety and Regulation

Powerful tools demand responsibility. Debates surround GMO safety and labelling, the ethics of editing human embryos, **biopiracy** (exploiting biological resources and traditional knowledge), and fair access to gene therapies. **Intellectual property rights (patents)** and **biosafety** rules try to balance innovation with safety. In India, the **Genetic Engineering Appraisal Committee (GEAC)** regulates GM organisms, while institutions such as the DBT promote responsible research.

> **DID YOU KNOW**
>
> The mRNA vaccine technology that helped end the COVID-19 emergency had been in development for decades — and earned its pioneers the Nobel Prize, showing how long-term basic research can suddenly save millions of lives.

EXAM FOCUS

Distinguish traditional vs modern biotechnology. Know the tools (restriction enzymes, ligase, vectors/plasmids) and flagship examples: insulin from bacteria, Bt cotton, Golden Rice, PCR, tissue culture, CRISPR, mRNA vaccines and DNA fingerprinting. Bioethics, biopiracy and India's GEAC are increasingly tested current-affairs topics.

ADVANCED NOTES & KEY FACTS

- Tools of genetic engineering: restriction enzymes (cut DNA), DNA ligase (join), vectors/plasmids (carry genes into hosts).
- PCR rapidly amplifies tiny DNA samples; tissue culture grows whole disease-free plants from a few cells.
- Bacteria engineered to make **human insulin** was an early triumph; **Bt cotton** resists pests; **Golden Rice** adds vitamin A.
- mRNA vaccines instruct our cells to make a harmless viral protein, triggering immunity (used against COVID-19).
- CRISPR edits DNA letter-by-letter — promising for genetic diseases, but ethically sensitive (especially in human embryos).
- India's GEAC regulates GM organisms; concerns include biosafety, biopiracy and equitable access.

IMPORTANT VALUES & CONSTANTS

Restriction enzyme = molecular scissors • Vector = gene carrier (plasmid) • DNA fingerprinting → forensics/paternity • India's GM regulator: GEAC • mRNA vaccine: COVID-19.

QUICK REVISION

- Traditional biotech = fermentation; modern = genetic engineering.
- rDNA tools: restriction enzymes, ligase, vectors.
- Insulin, Bt cotton, Golden Rice, mRNA vaccines, CRISPR.
- DNA fingerprinting identifies individuals.
- GEAC regulates GMOs in India; bioethics matters.

PRACTICE QUESTIONS

1. What are 'molecular scissors' used to cut DNA? **Ans: Restriction enzymes.**
2. Name the first human hormone made by genetically engineered bacteria. **Ans: Insulin.**
3. Which gene-editing tool edits DNA precisely? **Ans: CRISPR.**
4. Bt cotton is engineered to resist what? **Ans: Pests (insects).**
5. Which body regulates GM organisms in India? **Ans: GEAC (Genetic Engineering Appraisal Committee).**

IV

Technology & Applied Science

How scientific principles are turned into real-world power — from rockets and missiles to computers, nanomaterials, vaccines and artificial intelligence.

19 Space Technology

TECHNOLOGY

Space technology launches and uses satellites and spacecraft for communication, navigation, weather, science and exploration — a field in which India has become a global leader.

Satellites and Orbits

A **satellite** is any object that orbits a larger body; artificial satellites are placed in orbit by rockets. They are classified by purpose:

Type	Purpose
Communication	TV, telephone, internet relay
Remote sensing / Earth observation	Mapping, agriculture, forestry, disaster monitoring
Navigation	Positioning (GPS, NavIC)
Weather (meteorological)	Forecasting, cyclone tracking
Scientific	Astronomy and space research

Orbits are grouped by altitude: **Low Earth Orbit (LEO)**, **Medium Earth Orbit (MEO)** and the high **Geostationary Orbit (GEO)**. A **geostationary satellite** sits about 36,000 km above the equator and revolves in step with the Earth, so it appears fixed in the sky — ideal for communication and weather. A **polar / sun-synchronous orbit** passes near the poles at low altitude, covering the whole Earth strip by strip — ideal for remote sensing.

Launch Vehicles

Rockets work on Newton's third law — burning fuel is expelled downward, pushing the rocket up. They are **multi-stage**, dropping empty stages to shed weight. India's main launch vehicles include the reliable **PSLV** (Polar Satellite Launch Vehicle), the more powerful **GSLV** and **GSLV Mk III / LVM3** (for heavy and crewed missions), and the small **SSLV** for small satellites. **Cryogenic engines**, which burn super-cooled liquid hydrogen and oxygen, give the high thrust needed for heavy payloads.

India's Space Programme (ISRO)

The Indian Space Research Organisation (ISRO), founded under Vikram Sarabhai, has achieved remarkable milestones:

Mission	Significance
Aryabhata (1975)	India's first satellite
Chandrayaan-1 (2008)	First lunar mission; found evidence of water on the Moon
Mangalyaan / MOM (2013)	Mars orbiter — India became the first nation to reach Mars on its first attempt
Chandrayaan-3 (2023)	Soft landing near the Moon's south pole
Aditya-L1 (2023)	India's first solar observatory mission
Gaganyaan	India's planned first crewed spaceflight

NavIC is India's own regional navigation system (an alternative to GPS). ISRO is also known for low-cost, high-reliability missions and a record number of satellites launched on a single rocket.

Applications and the New Space Economy

Space technology underpins daily life: weather forecasting and cyclone warnings, telecommunication and broadcasting, GPS/NavIC navigation, remote sensing for agriculture, mapping, mining and disaster management, and tele-education and tele-medicine. Globally, **private companies** have transformed the field with reusable rockets and satellite-internet constellations, sharply lowering launch costs.

DID YOU KNOW

Mangalyaan reached Mars at a cost lower than that of many science-fiction films — a striking example of ISRO's reputation for frugal, efficient engineering.

ADVANCED NOTES & KEY FACTS

- Rockets obey Newton's third law and use multi-stage design to shed dead weight; cryogenic engines burn liquid hydrogen + oxygen for high thrust.
- Geostationary orbit (~36,000 km, equatorial) → satellite appears fixed (communication, weather); polar/sun-synchronous low orbit → full-Earth coverage (remote sensing).
- PSLV is ISRO's workhorse; GSLV/LVM3 lift heavy and crewed payloads; SSLV serves small satellites.
- NavIC is India's regional navigation system; an alternative to the American GPS.
- Mangalyaan made India the first country to reach Mars on its maiden attempt; Chandrayaan-3 soft-landed near the lunar south pole.
- Gaganyaan is India's planned first human spaceflight; Aditya-L1 studies the Sun.

IMPORTANT VALUES & CONSTANTS

Geostationary orbit ≈ 36,000 km • First Indian satellite: Aryabhata (1975) • ISRO founder: Vikram Sarabhai • India's navigation system: NavIC • Mars mission: Mangalyaan/MOM (2013).

QUICK REVISION

- Satellites: communication, remote-sensing, navigation, weather, scientific.
- Geostationary = fixed over equator; polar/sun-synchronous = full coverage.
- Launch vehicles: PSLV (workhorse), GSLV/LVM3 (heavy), SSLV (small).
- NavIC = India's GPS alternative.
- Milestones: Aryabhata, Chandrayaan, Mangalyaan, Aditya-L1, Gaganyaan.

PRACTICE QUESTIONS

1. At what approximate altitude is a geostationary satellite placed? **Ans: About 36,000 km above the equator.**
2. What is India's regional navigation system called? **Ans: NavIC.**
3. Which was India's first satellite? **Ans: Aryabhata (1975).**
4. Which mission made India the first to reach Mars on its first try? **Ans: Mangalyaan (Mars Orbiter Mission).**
5. Which ISRO launch vehicle is called the 'workhorse'? **Ans: PSLV.**

20 Defence Technology

TECHNOLOGY

Defence technology applies advanced science to national security — missiles, aircraft, ships, radar and electronic systems — with India steadily building indigenous capability.

Missiles: Classification

A **missile** is a guided self-propelled weapon. Missiles are classified in several ways:

Basis	Types
Trajectory	Ballistic (follows a high arc, powered then free-falling) vs Cruise (flies low, powered throughout, like an aircraft)
Launch–target	Surface-to-surface, surface-to-air, air-to-air, air-to-surface, anti-tank, anti-ship
Range	Short, medium, intermediate and intercontinental (ICBM)

India's Missile Systems

Developed largely under the Integrated Guided Missile Development Programme, India's notable missiles include:

Missile	Type / Role
Agni series	Long-range surface-to-surface ballistic missiles
Prithvi	Short-range surface-to-surface ballistic missile
BrahMos	Supersonic cruise missile (India–Russia)
Akash	Surface-to-air missile (air defence)
Nag	Anti-tank guided missile
Astra	Air-to-air missile

Indigenous Defence Platforms

India's defence research body, the **DRDO**, and public-sector units have developed home-grown systems: the **Tejas** Light Combat Aircraft, the **Arjun** main battle tank, indigenous warships and aircraft carriers, and submarines. India also possesses a **nuclear triad** — the ability to launch nuclear weapons from land, air and sea — and follows a declared "No First Use" policy.

Modern Defence Trends

Contemporary defence increasingly relies on **electronics and software**: radar and stealth technology, satellite-based surveillance and communication, **drones (UAVs)**, precision-guided munitions, anti-satellite (ASAT) capability, cyber-defence and electronic warfare. India's policy push for **self-reliance (Atmanirbhar Bharat)** in defence manufacturing and exports is a major current theme.

DID YOU KNOW

BrahMos is among the world's fastest operational cruise missiles, travelling at nearly three times the speed of sound — its name combines the Brahmaputra and Moskva rivers.

ADVANCED NOTES & KEY FACTS

- Ballistic missiles follow a high arc (powered then free-fall); cruise missiles fly low and are powered throughout, like a fast aircraft.
- Agni = long-range ballistic; Prithvi = short-range ballistic; BrahMos = supersonic cruise; Akash = surface-to-air; Nag = anti-tank; Astra = air-to-air.
- DRDO is India's defence R&D body; indigenous platforms include Tejas (aircraft), Arjun (tank), and home-built warships and submarines.
- India has a nuclear triad (land, air, sea launch) with a declared 'No First Use' policy.
- Modern defence depends on radar, stealth, drones, satellites, precision weapons and cyber/electronic warfare.
- 'Atmanirbhar Bharat' pushes self-reliance and defence exports.

IMPORTANT VALUES & CONSTANTS

Ballistic = arc trajectory; Cruise = low, powered flight • BrahMos ≈ Mach 3 (supersonic) • DRDO = defence research body • Nuclear triad = land+air+sea.

QUICK REVISION

- Ballistic vs cruise missiles — trajectory is the key difference.
- Agni (long-range), Prithvi (short-range), BrahMos (cruise).
- Akash = SAM, Nag = anti-tank, Astra = air-to-air.
- DRDO develops indigenous systems (Tejas, Arjun).
- India has a nuclear triad with No First Use policy.

PRACTICE QUESTIONS

1. What distinguishes a cruise missile from a ballistic missile? **Ans: A cruise missile flies low and is powered throughout; a ballistic missile follows a high arc.**
2. Name India's supersonic cruise missile. **Ans: BrahMos.**
3. Which body leads India's defence research? **Ans: DRDO.**
4. What is India's indigenous light combat aircraft called? **Ans: Tejas.**
5. Agni missiles are of which type? **Ans: Long-range surface-to-surface ballistic missiles.**

21 Nuclear Science and Technology

TECHNOLOGY

Nuclear science harnesses the immense energy locked in the atom's nucleus — for electricity, medicine, agriculture and research — while demanding the highest standards of safety.

Radioactivity

Some heavy atoms have unstable nuclei that spontaneously emit radiation — **radioactivity**, discovered by Henri Becquerel and the Curies. There are three main types:

Radiation	Nature	Penetrating power
Alpha (α)	Helium nuclei (+)	Low — stopped by paper
Beta (β)	Fast electrons (−)	Moderate — stopped by aluminium
Gamma (γ)	High-energy EM rays	Very high — needs thick lead/concrete

The **half-life** is the time for half of a radioactive sample to decay — constant for each isotope and the basis of **radiometric dating** (carbon-14 for fossils, uranium for rocks).

Fission and Fusion

Nuclear fission splits a heavy nucleus (uranium-235, plutonium-239) into lighter ones, releasing enormous energy and more neutrons that sustain a **chain reaction** — controlled in reactors, uncontrolled in bombs. **Nuclear fusion** joins light nuclei (hydrogen → helium), releasing even more energy; it powers the Sun and stars and is the goal of clean future energy.

Nuclear Reactors

A reactor produces controlled fission. Key parts: **fuel** (enriched uranium), **moderator** (slows neutrons — heavy water or graphite), **control rods** (absorb neutrons to control the rate — cadmium/boron), **coolant** (carries heat away) and **shielding** (protects against radiation). The heat boils water to drive turbines and generate electricity.

India's Three-Stage Nuclear Programme

Designed by Homi Bhabha to use India's modest uranium but large **thorium** reserves:

1. **Stage 1:** Pressurised Heavy Water Reactors using natural uranium, producing plutonium.
2. **Stage 2:** Fast Breeder Reactors using plutonium, breeding more fuel and converting thorium.
3. **Stage 3:** Advanced reactors running on the abundant thorium cycle.

Applications and Safety

Beyond power, nuclear technology serves **medicine** (cancer radiotherapy, diagnostic isotopes, sterilising equipment), **agriculture** (improved crop varieties, pest control, food preservation) and **industry** (gauging, dating). Safety is paramount: the accidents at **Chernobyl** and **Fukushima** shaped strict global protocols. India's programme is led by the Department of Atomic Energy and BARC, under international safeguards.

DID YOU KNOW

A single kilogram of uranium-235 can release as much energy as several thousand tonnes of coal — which is why nuclear power packs such an extraordinary energy density.

ADVANCED NOTES & KEY FACTS

- Three radiations: alpha (helium nuclei, least penetrating), beta (electrons), gamma (EM rays, most penetrating).
- Half-life is constant for an isotope and underlies carbon-14 dating of fossils and uranium dating of rocks.
- Reactor parts: fuel (uranium), moderator (heavy water/graphite), control rods (cadmium/boron), coolant, shielding.
- India's three-stage plan: PHWR (uranium) → Fast Breeder (plutonium) → Thorium-based reactors, to exploit large thorium reserves.
- Applications: power, cancer radiotherapy, medical isotopes, crop improvement, food preservation, dating.
- Chernobyl and Fukushima accidents shaped strict global nuclear-safety norms; India's DAE/BARC lead the programme.

IMPORTANT VALUES & CONSTANTS

Alpha < Beta < Gamma (penetrating power) • Fission fuel: U-235, Pu-239 • Control rods: cadmium/boron • Moderator: heavy water/graphite • India: 3-stage thorium programme • Father of Indian nuclear programme: Homi Bhabha.

QUICK REVISION

- Radioactivity emits alpha, beta and gamma radiation.
- Half-life = time for half the sample to decay.
- Fission splits heavy nuclei; fusion joins light nuclei.
- Reactor: fuel, moderator, control rods, coolant, shielding.
- India's 3-stage programme aims to use thorium.

PRACTICE QUESTIONS

1. Which radiation has the greatest penetrating power? **Ans: Gamma rays.**
2. What is the half-life of a radioactive substance? **Ans: The time for half the sample to decay.**
3. Which material is used in control rods? **Ans: Cadmium or boron (neutron absorbers).**
4. Which element is India's three-stage programme designed to exploit? **Ans: Thorium.**
5. Name the father of India's nuclear programme. **Ans: Homi Bhabha.**

22 Information and Communication Technology

TECHNOLOGY

> *Information and Communication Technology (ICT) is the backbone of the modern world — the computers, networks and software that store, process and move information at the speed of light.*

Computer Basics

A computer has **hardware** (physical parts) and **software** (programs). Core hardware: the **CPU** (central processing unit — the "brain"), **memory** (RAM for temporary work, ROM permanent), **storage** (hard disk, SSD), and input/output devices. Software is **system software** (the operating system, e.g. Windows, Linux, Android) or **application software** (browsers, editors). Data is measured in **bits** and **bytes** (1 byte = 8 bits; then KB, MB, GB, TB).

Networks and the Internet

Computers connect in **networks** — a **LAN** (local, e.g. an office) or a **WAN** (wide, spanning regions). The **Internet** is the global network of networks; the **World Wide Web (WWW)** is the system of linked web pages accessed over it. Data travels as **packets** using protocols like **TCP/IP**. Mobile communication has advanced through generations — **2G, 3G, 4G and 5G** — each faster, with 5G enabling very high speeds and low delay for smart devices.

Modern Computing Concepts

Concept	Meaning
Cloud computing	Storing and processing data on remote internet servers instead of local machines
Big data	Extremely large data sets analysed for patterns
Internet of Things (IoT)	Everyday devices connected to the internet (smart homes, wearables)
Artificial Intelligence	Machines performing tasks needing human-like intelligence
Blockchain	A secure, distributed digital ledger (used in cryptocurrencies)

Cyber Security

As life moves online, protecting data matters. Threats include **viruses and malware**, **phishing** (fraudulent messages), **hacking** and identity theft. Defences include strong passwords, encryption, firewalls, antivirus software and safe online habits. Governments enforce cyber laws and run cyber-crime cells.

Digital India

India's digital transformation includes the world's largest biometric ID system (**Aadhaar**), the **UPI** real-time payments system that made India a global leader in digital transactions, e-governance services, and a booming IT and software-services industry. Bridging the **digital divide** — ensuring rural and poorer citizens get access — remains a key goal.

DID YOU KNOW

India processes more real-time digital payments than any other country in the world, thanks largely to the UPI system that links banks through a single mobile interface.

ADVANCED NOTES & KEY FACTS

- Hardware = physical parts (CPU, RAM, storage, I/O); software = system (OS) and application programs.
- 1 byte = 8 bits; units rise KB → MB → GB → TB.
- LAN = local network; WAN = wide network; the Internet is a network of networks using TCP/IP; the WWW is linked web pages on it.
- Mobile generations 2G→5G improve speed and reduce delay; 5G enables IoT and smart devices.
- Key concepts: cloud computing, big data, IoT, AI, blockchain.
- India leads in digital payments (UPI) and biometric ID (Aadhaar); cyber security guards against malware, phishing and hacking.

IMPORTANT VALUES & CONSTANTS

1 byte = 8 bits • CPU = brain of computer • RAM = temporary memory; ROM = permanent • Internet protocol: TCP/IP • India's payment system: UPI; ID system: Aadhaar.

QUICK REVISION

- Hardware vs software; CPU is the processing brain.
- 1 byte = 8 bits; KB→MB→GB→TB.
- LAN (local) vs WAN (wide); Internet uses TCP/IP.
- 5G enables IoT and smart devices.
- Cyber threats: virus, malware, phishing, hacking.

PRACTICE QUESTIONS

1. How many bits are there in one byte? **Ans: 8 bits.**
2. What does CPU stand for? **Ans: Central Processing Unit.**
3. What is the difference between the Internet and the WWW? **Ans: The Internet is the network of networks; the WWW is the linked web pages accessed over it.**
4. Name India's real-time digital payment system. **Ans: UPI (Unified Payments Interface).**
5. A fraudulent message trying to steal data is called? **Ans: Phishing.**

23 Nanotechnology and New Materials

TECHNOLOGY

Nanotechnology works with matter at the scale of atoms and molecules, where materials gain surprising new properties — promising breakthroughs in medicine, electronics and the environment.

The Nanoscale

A **nanometre** is one-billionth of a metre — about the width of a few atoms. At this scale, materials behave very differently from their bulk form: they may become stronger, more reactive, better conductors, or change colour. **Nanotechnology** designs and builds useful structures atom by atom.

Important Nanomaterials

Material	Feature	Use
Carbon nanotubes	Extremely strong and light; conduct electricity	Electronics, strong composites
Graphene	One-atom-thick carbon sheet; super strong and conductive	Flexible electronics, sensors, batteries
Nanoparticles	Tiny, high surface area, very reactive	Medicine, catalysts, cosmetics
Quantum dots	Nano-crystals that emit specific colours	Displays, medical imaging

Applications

- **Medicine** — targeted drug delivery (carrying medicine straight to diseased cells), better diagnostics and imaging.
- **Electronics** — ever-smaller, faster chips; flexible and wearable devices.
- **Energy & environment** — efficient solar cells, better batteries, water purification and pollution clean-up.
- **Textiles & coatings** — stain-resistant, antibacterial and self-cleaning surfaces.

Other New Materials

Semiconductors (silicon) sit between conductors and insulators and are the heart of all electronics; controlling them gave us the transistor and the microchip. **Superconductors** conduct electricity with zero resistance at very low temperatures — used in MRI magnets and maglev trains. **Smart materials** respond to their environment, such as shape-memory alloys and self-healing materials.

DID YOU KNOW

Graphene is about 200 times stronger than steel yet so thin that a sheet covering a football field would weigh less than a gram — earning its discoverers a Nobel Prize.

ADVANCED NOTES & KEY FACTS

- A nanometre is one-billionth of a metre; at the nanoscale, materials gain new strength, reactivity, conductivity or colour.
- Carbon nanotubes and graphene are super-strong, light and conductive; graphene is one atom thick.
- Applications: targeted drug delivery, faster electronics, efficient solar cells, water purification, self-cleaning textiles.
- Semiconductors (silicon) are the basis of transistors and microchips; controlling them built all modern electronics.
- Superconductors carry current with zero resistance at very low temperatures (MRI, maglev).
- Smart materials (shape-memory alloys, self-healing) respond to their environment.

IMPORTANT VALUES & CONSTANTS

1 nanometre = 10^{-9} m • Graphene ≈ 200× stronger than steel • Semiconductor: silicon • Superconductor: zero resistance at low temperature • Quantum dots emit specific colours.

QUICK REVISION

- Nanoscale = billionth of a metre; new properties emerge.
- Graphene & carbon nanotubes: strong, light, conductive.
- Uses: medicine, electronics, energy, water, textiles.
- Semiconductors = heart of electronics; superconductors = zero resistance.
- Smart materials respond to their surroundings.

PRACTICE QUESTIONS

1. What is a nanometre? **Ans: One-billionth of a metre (10^{-9} m).**
2. Name a one-atom-thick form of carbon used in nanotech. **Ans: Graphene.**
3. Which material is the basis of all microchips? **Ans: Silicon (a semiconductor).**
4. What special property do superconductors have? **Ans: Zero electrical resistance (at very low temperature).**
5. Give one medical use of nanotechnology. **Ans: Targeted drug delivery.**

24 Health, Disease and the Human Body

TECHNOLOGY

Modern medical science protects and restores health by understanding diseases, the body's defences, and the tools — vaccines, drugs and diagnostics — that combat illness.

Types of Disease

Diseases are broadly **communicable** (infectious — spread from person to person by germs) or **non-communicable** (not spread; due to lifestyle, genetics or environment).

Cause	Examples
Bacteria	Tuberculosis, cholera, typhoid, tetanus
Viruses	Common cold, influenza, dengue, COVID-19, AIDS, polio
Protozoa	Malaria, amoebic dysentery
Fungi / Worms	Ringworm; intestinal worm infections
Non-communicable	Diabetes, hypertension, heart disease, cancer

Diseases spread through air (cough/sneeze), water, food, vectors (mosquitoes for malaria and dengue), and contact.

The Immune System and Vaccination

The body's **immune system** defends against germs. **Innate immunity** is the general first line (skin, stomach acid, white blood cells); **acquired immunity** is specific and develops after exposure, producing **antibodies** and memory. **Vaccination** trains immunity safely by introducing a harmless form or part of a germ, so the body can fight the real one later — the principle that eradicated **smallpox** and is close to eliminating polio.

Medicines and Antibiotic Resistance

Antibiotics (such as penicillin, discovered by Alexander Fleming) kill or stop bacteria but do **not** work against viruses. Overuse and misuse breed **antibiotic resistance** — "superbugs" that drugs can no longer kill — now a serious global health threat (antimicrobial resistance, AMR). **Antiviral** drugs and **vaccines** tackle viruses.

Lifestyle, Nutrition and Public Health

Many modern diseases are linked to lifestyle — poor diet, inactivity, tobacco and alcohol. A balanced diet, exercise, clean water, sanitation and hygiene prevent much illness. **Public-health** measures — immunisation drives, sanitation, safe drinking water and disease surveillance — protect whole populations. The world's experience with pandemics has underlined the value of preparedness, testing and rapid vaccine development.

DID YOU KNOW

Smallpox is the only human disease ever completely eradicated worldwide, thanks to a global vaccination campaign — a triumph of medical science and international cooperation.

ADVANCED NOTES & KEY FACTS

- Communicable diseases spread via air, water, food, vectors and contact; non-communicable diseases (diabetes, cancer, heart disease) do not spread.
- Pathogens: bacteria (TB, typhoid), viruses (dengue, COVID, AIDS), protozoa (malaria), fungi/worms.
- Immunity: innate (general first line) and acquired (specific, antibody-based, has memory).
- Vaccination primes immunity safely; it eradicated smallpox and nearly polio.
- Antibiotics work on bacteria, not viruses; misuse causes antibiotic/antimicrobial resistance (AMR).
- Public health relies on clean water, sanitation, immunisation and surveillance.

IMPORTANT VALUES & CONSTANTS

Malaria & dengue spread by mosquitoes • Antibiotics: bacteria only (not viruses) • Penicillin discovered by Alexander Fleming • Only eradicated human disease: smallpox.

QUICK REVISION

- Communicable (infectious) vs non-communicable diseases.
- Pathogens: bacteria, viruses, protozoa, fungi, worms.
- Innate vs acquired immunity; vaccines build immunity.
- Antibiotics target bacteria, not viruses; overuse → resistance.
- Smallpox is the only fully eradicated human disease.

PRACTICE QUESTIONS

1. Are antibiotics effective against viruses? **Ans: No — only against bacteria.**
2. Which organism causes malaria? **Ans: A protozoan (Plasmodium), spread by mosquitoes.**
3. Which human disease has been completely eradicated worldwide? **Ans: Smallpox.**
4. What does a vaccine do? **Ans: Trains the immune system to fight a germ safely in advance.**
5. What is AMR? **Ans: Antimicrobial resistance — germs becoming resistant to drugs.**

25 Emerging Technologies

TECHNOLOGY

A wave of new technologies is reshaping economies and daily life. Understanding their promise — and their challenges — is essential to navigating the future.

Artificial Intelligence and Robotics

Artificial Intelligence (AI) enables machines to learn, reason and make decisions. **Machine learning** lets systems improve from data rather than fixed rules; **deep learning** uses brain-inspired neural networks. AI now powers translation, image recognition, recommendations, self-driving research and generative tools that create text and images. **Robotics** builds machines that sense and act — from factory arms and surgical robots to drones and planetary rovers. These bring great benefits but also raise concerns about jobs, bias, privacy and the need for responsible, ethical use.

Quantum Computing

Quantum computers use the strange rules of quantum physics — bits called **qubits** that can represent many states at once — to tackle certain problems vastly faster than ordinary computers. Though still developing, they promise breakthroughs in chemistry, materials, cryptography and optimisation.

Green and Clean Technologies

Technology	Role
Electric vehicles (EVs)	Cut oil use and urban air pollution
Green hydrogen	Clean fuel made using renewable electricity
Advanced solar & wind	Cheaper, cleaner power generation
Carbon capture	Removing CO_2 to fight climate change

Other Frontier Technologies

- **3D printing (additive manufacturing)** — builds objects layer by layer, from prototypes to printed organs and houses.
- **Drones (UAVs)** — delivery, agriculture, surveying, disaster relief and defence.
- **Biotechnology and gene editing** — CRISPR-based therapies and crops (see Chapter 18).
- **Augmented and virtual reality (AR/VR)** — immersive learning, training and entertainment.
- **5G and the Internet of Things** — connecting billions of smart devices.

Opportunities and Challenges

These technologies promise faster growth, better healthcare, cleaner energy and new jobs. But they also bring challenges: job displacement, the digital divide, data privacy and security, ethical questions around AI and gene editing, and the need for sensible regulation. The goal is **responsible innovation** — harnessing technology for human welfare and sustainable development.

DID YOU KNOW

Generative AI tools that can write, draw and code went from research curiosities to everyday apps used by hundreds of millions of people in just a few years — one of the fastest technology adoptions in history.

ADVANCED NOTES & KEY FACTS

- AI lets machines learn and decide; machine learning improves from data; deep learning uses neural networks.
- Robotics builds sensing, acting machines — factory arms, surgical robots, drones, rovers.
- Quantum computers use qubits (many states at once) to solve certain problems far faster.
- Green tech: electric vehicles, green hydrogen, advanced solar/wind, carbon capture.
- Other frontiers: 3D printing, drones, gene editing (CRISPR), AR/VR, 5G + IoT.
- Challenges: jobs, digital divide, privacy, security, ethics — hence the call for responsible innovation.

IMPORTANT VALUES & CONSTANTS

AI = machine intelligence • ML = learning from data • Qubit = quantum bit (multiple states) • Green hydrogen = clean fuel from renewables • 3D printing = additive manufacturing.

QUICK REVISION

- AI → machine learning → deep learning (neural networks).
- Robotics = machines that sense and act.
- Quantum computers use qubits for huge speed-ups.
- Green tech: EVs, green hydrogen, solar/wind, carbon capture.
- Frontiers: 3D printing, drones, CRISPR, AR/VR, 5G/IoT.