Collegedunia NCERT Notes

The Ultimate NCERT Revision Guide for Class 12 Biology

(2026–27 / New NCERT, Full-colour Diagrams)

Chapter 6: Evolution

Class 12 | 12th Biology | Unit VII — Evolution

About this Chapter

Evolution is the unifying theme of biology — it explains how the staggering diversity of life on earth arose from simple beginnings about four billion years ago. This chapter walks you through the origin of life, the historical theories that tried to explain it (special creation, Lamarckism, Darwinism, mutation theory), the multi-layered evidence that biological evolution is real (fossils, homology, analogy, embryology, biogeography, industrial melanism, biochemistry), the mechanism of change (variation, natural selection, genetic drift, gene flow, Hardy–Weinberg equilibrium), the spectacular phenomenon of adaptive radiation (Darwin's finches, Australian marsupials) and ends with the story of human evolution from *Dryopithecus* all the way to *Homo sapiens*. Master this chapter and you have the conceptual scaffolding for almost every NEET question on the topic.

Contents

1 Origin of Life

Life on earth did not appear all at once. It emerged after billions of years of cosmic and chemical events. To understand biological evolution, we first have to understand how the first cell got built — and even before that, how the universe and earth themselves came to exist.

1.1 Origin of the universe and earth

The currently accepted model is the **Big Bang theory**: a singular, unimaginably energetic explosion that gave rise to the universe roughly 13.8 billion years ago. The universe expanded outward, cooling as it did. As temperatures fell, hydrogen and helium formed; under gravitational attraction these gases condensed into stars and galaxies.

The earth condensed within the solar system of the Milky Way galaxy about 4.5 billion years ago. Its early atmosphere was nothing like today's. There was no free oxygen. Water vapour, methane (CH_4), carbon dioxide (CO_2) and ammonia (NH_3)

were released from a molten surface. Ultraviolet rays from the young Sun split water vapour into hydrogen and oxygen — the lighter hydrogen escaped to space while oxygen reacted with ammonia and methane to give water, CO_2 and similar molecules. Eventually an ozone layer formed, the planet cooled, water vapour fell as rain, and the depressions filled to create oceans. Life appeared in these oceans about 500 million years after the earth itself formed, i.e., roughly four billion years ago.

Timeline at a glance

- **Universe** formed ~ 13.8 billion years ago (Big Bang)
- **Earth** formed ~ 4.5 billion years ago
- **First non-cellular life** ~ 3 billion years ago
- **First cellular life** ~ 2 billion years ago
- **Invertebrates** formed ~ 500 million years ago (mya)
- **Jawless fish** ~ 350 mya; first land plants slightly earlier

1.2 Theories on origin of life

Several theories have been proposed to explain the very first appearance of life:

- **Theory of special creation** (religious view): all species were created as they are; diversity is fixed; earth is only ~ 4000 years old. All three claims have been refuted by modern geology, palaeontology and genetics.
- **Panspermia**: an idea favoured by some early Greek thinkers and a few modern astronomers — units of life ("spores") travelled through space and seeded earth from outside.
- **Spontaneous generation (abiogenesis, old sense)**: life arose directly from decaying or rotting non-living matter (straw, mud, etc.). *Louis Pasteur* demolished this idea using pre-sterilised flasks — no life arose from killed yeast in sealed flasks, but new organisms appeared in flasks open to air. So life can only come from pre-existing life under modern earth conditions.
- **Oparin–Haldane theory (chemical evolution)**: the first life arose from pre-existing non-living organic molecules (RNA, proteins, etc.) under the unique conditions of early earth — high temperatures, volcanic activity, and a *reducing atmosphere* rich in CH_4 and NH_3 but lacking free O_2.

Two "biogenesis" words — don't confuse them!

Biogenesis (modern) = life comes only from pre-existing life. Demonstrated by Pasteur.
Abiogenesis / chemical biogenesis (Oparin–Haldane) = the *very first* cellular life arose slowly from non-living organic molecules under early-earth conditions. This is accepted by the majority of scientists today.

1.3 Miller's experiment (1953)

S. L. Miller, an American scientist, set out to test the Oparin–Haldane idea in the laboratory. He recreated the conditions believed to have existed on primitive earth.

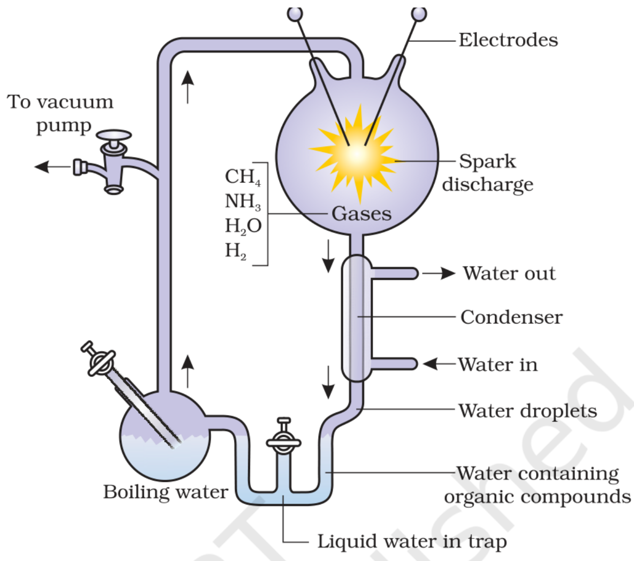


Fig 6.1 — Diagrammatic representation of Miller's experiment.

Miller's set-up

- Closed flask containing CH_4, NH_3, H_2, and water vapour
- Temperature maintained at $800\,°C$
- Electric discharge passed through (mimicking lightning)
- Condenser collected condensed liquid in a trap

Result: formation of **amino acids** (the building blocks of proteins).

Later, similar experiments yielded sugars, nitrogen bases, pigments and fats. Importantly, analysis of meteorite content also revealed comparable organic compounds, suggesting that this kind of pre-biotic chemistry occurs elsewhere in space too. With this evidence, the *first part of the story* — chemical evolution from inorganic to organic — was accepted.

The next step, how these molecules organised into a self-replicating "capsule of life" (giant macromolecules of RNA, protein, polysaccharide), is still not fully understood. The first non-cellular forms of life appear around 3 billion years ago; the first cellular forms about 2 billion years ago, all in water.

Quick Tip

For NEET, remember the exact gas composition of Miller's apparatus: CH_4, NH_3, H_2, water vapour — and *no oxygen* (reducing atmosphere). A common MCQ trap is to add O_2 to the list.

Real-World Application

The same idea — that lightning + simple gases can build complex organic molecules — is now being applied by astrobiologists to study moons like Titan (Saturn) and Europa (Jupiter), where reducing atmospheres and liquid bodies suggest pre-biotic chemistry could be active right now.

2 Evolution of Life Forms — A Theory

Once the first cell existed, the second question is: how did one cell give rise to the millions of species we see today? Several thinkers have tried to answer this.

2.1 Theory of special creation

A pre-scientific view, held by many religious texts. It claims (a) every species was created in its present form, (b) species diversity has not changed and will not change, and (c) earth is only ~ 4000 years old. All three claims were challenged in the nineteenth century.

2.2 Lamarckism — Inheritance of acquired characters

The French naturalist **Jean-Baptiste Lamarck** proposed that evolution occurs through *use and disuse of organs* and that acquired characters are passed on to offspring.

- Classic example: *Giraffes* stretched their necks to browse leaves on tall trees; this elongated neck was passed on to subsequent generations until modern long-necked giraffes evolved.
- Disused organs (e.g., the human appendix) shrink because they are no longer used.

Status today: rejected. We now know that characters acquired during an individual's lifetime (e.g., a body-builder's muscles) cannot be inherited because they are not encoded in the germ-line DNA.

2.3 Darwin's theory of natural selection

Based on his five-year voyage on H.M.S. Beagle (especially observations in the Galapagos Islands), Charles **Darwin** (and independently **Alfred Russel Wallace** from the Malay Archipelago) proposed:

1. Existing species share similarities not only with each other but also with extinct forms found as fossils.
2. Every population has built-in *variation*.
3. Resources are limited; populations therefore compete (idea borrowed from

Thomas Malthus).

4. Individuals with characters that help them survive better in their environment leave more offspring — this is **natural selection**, often summarised as *"survival of the fittest"*.
5. Over many generations, the population changes — new types of organism arise. This is **branching descent**.

Two core ideas of Darwinism

1. **Branching descent** — all living forms share common ancestors that existed at different periods of earth's history.
2. **Natural selection** — nature "selects" individuals whose heritable traits give them better reproductive fitness.

Fitness, according to Darwin, refers ultimately and only to *reproductive* fitness — how many surviving offspring you leave, not how strong you are.

Memory Aid

V-I-S-N for Darwinism:
Variation exists → **I**nheritance of useful variations → **S**truggle for existence → **N**atural selection (and reproductive success).

2.4 Lamarck vs Darwin — side-by-side

Lamarckism (1809)	**Darwinism (1859)**
Driving force: *use and disuse* of organs	Driving force: *natural selection* on existing variation
Acquired characters **are** inherited	Acquired characters are **not** inherited; only heritable variations matter
Evolution is *directional* (toward need)	Evolution is *undirected*; variations are random, selection is non-random
Giraffe's long neck developed by stretching	Long-necked giraffes already existed as variants; nature simply favoured them
Now rejected	Still the foundation of modern evolutionary biology

Common Mistake

Students often think Darwin said variations are caused by the environment. Wrong — Darwin said the environment *selects* from pre-existing variation. The cause of variation itself (mutation, recombination) was figured out later, by deVries and the architects of the Modern Synthesis.

3 Evidences for Evolution

If evolution is real, we should be able to find traces of it across multiple independent lines of evidence. NCERT lists six.

3.1 Palaeontological evidence (fossils)

Fossils are remains or impressions of hard parts of organisms preserved in rocks. Sediments stack into layers (strata) over time. Different-aged strata contain fossils of different organisms — so the deeper the layer, the older the fossil. By comparing fossils across strata we can see that life forms have changed; some have gone extinct (e.g., dinosaurs); new ones have appeared.

Radioactive dating (e.g., ^{14}C, ^{40}K–^{40}Ar) gives the absolute age of a rock or fossil. The principle: a radioactive isotope decays at a constant rate (half-life), so the ratio of parent to daughter isotope tells us how long since the rock solidified.

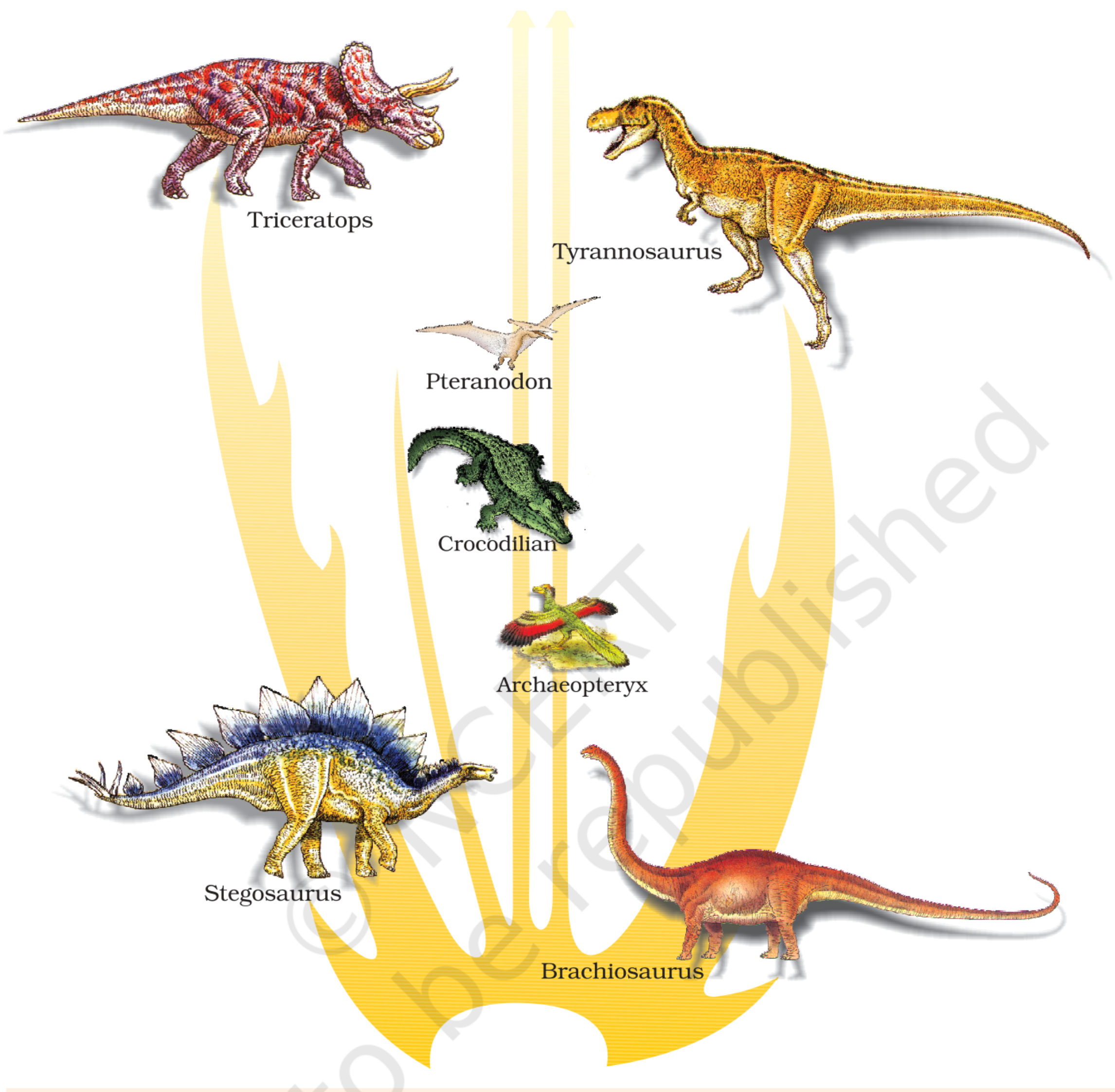


Fig 6.2 — A family tree of dinosaurs and their living modern-day counterpart organisms (crocodiles and birds).

3.2 Comparative anatomy — homologous organs (divergent evolution)

Homologous organs have the same fundamental structure and developmental origin but perform *different* functions in different species. This pattern arises when a common ancestral structure is modified to suit different needs — **divergent evolution**.

NCERT examples:

- Forelimbs of whales, bats, cheetah and humans — all mammals. They all have the same set of bones: *humerus, radius, ulna, carpals, metacarpals, phalanges*. Yet whale-fins, bat-wings, cheetah-paws and human arms do very different jobs.
- Thorn of *Bougainvillea* and tendril of *Cucurbita* — both are modified axillary buds, but one is defensive, the other supportive (Fig 6.3).
- Vertebrate hearts and brains — same basic plan, modified across classes.

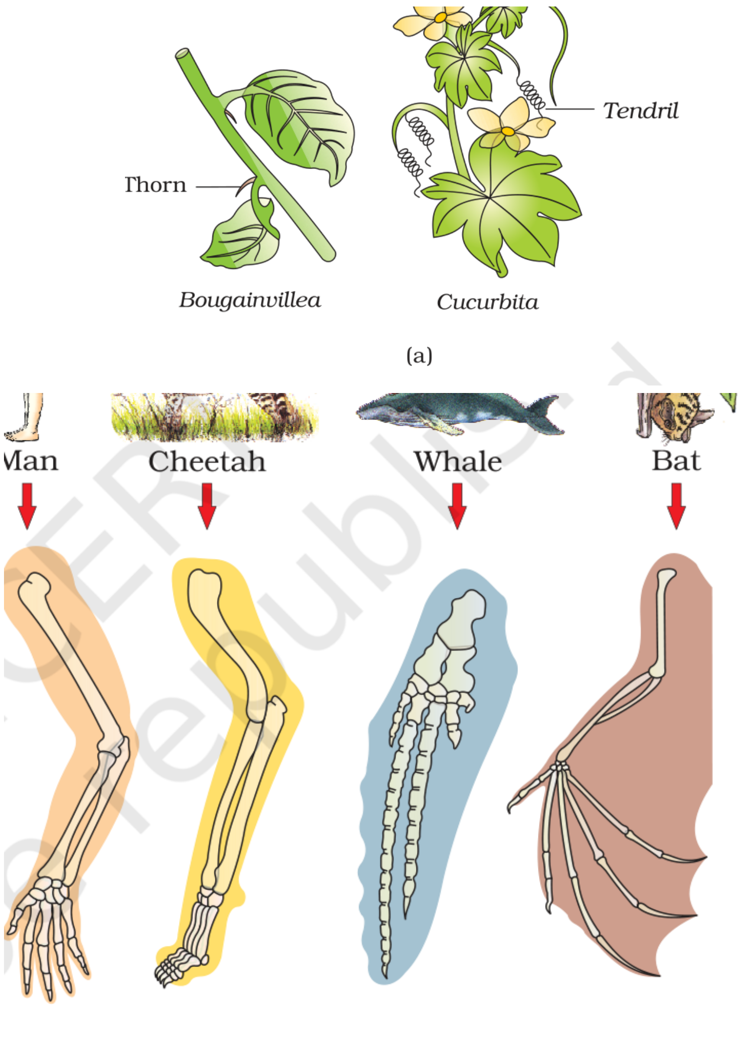


Fig 6.3 — Examples of homologous organs in (a) plants and (b) animals.

3.3 Comparative anatomy — analogous organs (convergent evolution)

Analogous organs have *different* fundamental structure and origin but perform the *same* function. This pattern arises when unrelated organisms evolve similar adaptations to similar environments — **convergent evolution**.

NCERT examples:

- Wings of butterfly (insect) and wings of bird — both fly, but built from totally different tissues.
- Eye of octopus and eye of mammal — camera-type, but evolved independently.
- Flippers of penguins (birds) and dolphins (mammals).
- Sweet potato (modified *root*) vs potato (modified *stem*) — both store food but originate differently.

Quick rule

Same **S**tructure + Different **F**unction → **Homo**logous (divergent).
Different **S**tructure + Same **F**unction → **Ana**logous (convergent).

3.4 Embryological evidence

The German embryologist **Ernst Haeckel** proposed that embryos of all vertebrates show certain features common to all but absent in adults. For example, the embryos of all vertebrates (including humans) develop a row of vestigial *gill slits* just behind the head, even though they only function in adult fish.

However, **Karl Ernst von Baer** later showed on careful study that embryos never pass through the *adult* stages of other animals — so Haeckel's biogenetic law ("ontogeny recapitulates phylogeny") is too strong. The shared embryonic features do still suggest common ancestry, but the claim that an embryo replays adult ancestors was disproved.

Common Mistake

Be very careful in NEET: the current NCERT (2026–27 syllabus) explicitly states that Haeckel's embryological proposal was **disapproved** by Karl Ernst von Baer. Don't write Haeckel's biogenetic law as currently accepted.

3.5 Evidence from artificial selection (domestication)

Humans have intensively bred plants and animals for agriculture, horticulture, sport and security. Dogs are an excellent example — from a wolf ancestor we have bred Chihuahuas, Great Danes, Labradors and Poodles, all within *a few hundred years*.

Argument: if humans can do so much in a few centuries, then *nature* — working over millions of years — can certainly produce the diversity we see today.

3.6 Industrial melanism (peppered moths)

A striking real-time example from England:

- **Before industrialisation (1850s):** tree trunks were covered with whitish lichen. White-winged moths could camouflage; dark moths were spotted and eaten. White moths dominated.
- **After industrialisation (1920):** smoke and soot killed lichens and blackened tree trunks. Now dark (melanised) moths were camouflaged and white ones were eaten by predators. Dark moths dominated.

Fig 6.4 — White-winged moth and dark-winged moth on a tree trunk in (a) unpolluted area and (b) polluted area.

This demonstrates **natural selection in action** — the environment changed; the predators' "selection pressure" reversed; allele frequencies in the moth population shifted in just a few decades. Note that *no variant was completely wiped out* — the recessive allele persists, so the population can re-equilibrate if conditions change again.

Real-World Application

Lichens cannot grow on polluted surfaces. So the abundance of lichen on tree bark is used today as a biological **indicator of air quality**. The same pollution that wiped out lichens also drove the moth-colour shift.

3.7 Evolution by anthropogenic action — resistance

The same logic explains:

- **Antibiotic resistance** in bacteria — bacteria carrying a chance mutation that resists the antibiotic survive and reproduce. Within months or years, the population is dominated by resistant strains.
- **Pesticide/herbicide resistance** in insects and weeds.
- **Drug resistance** in eukaryotic pathogens.

This makes a powerful point: evolution is *not directed* (we did not "ask" bacteria to evolve resistance). It is a **stochastic** (chance-driven) process based on random mutations and non-random selection.

3.8 Biochemical/molecular evidence

Similarities in proteins, DNA and metabolic pathways among diverse organisms reflect common ancestry. The fact that nearly all cells use the *same genetic code* (with minor mitochondrial exceptions) and many of the same enzymes is biochemical proof that life shares an origin.

Quick Tip

For competitive exams remember the six evidence categories: **P-C-E-A-I-M** — Palaeontological, Comparative anatomy (homology/analogy), Embryological, Artificial selection, Industrial melanism, Molecular. NCERT touches on all six.

4 Adaptive Radiation

Adaptive radiation = the process of evolution of different species from a common ancestral type in a given geographical area — each species adapted to a different habitat or way of life. The new species "radiate out" from the ancestral form to fill various ecological roles.

4.1 Darwin's finches

During his stay in the Galapagos Islands, Darwin observed small black birds (now called Darwin's finches). He found many varieties in the same island, all clearly related to each other but with very different beak shapes:

- Some had heavy seed-cracking beaks (the original feeding habit)
- Others had slender insect-catching beaks
- Some had vegetarian beaks for eating fruit

All these arose from a common seed-eating ancestor on the islands themselves, exploiting different food niches. Darwin's finches are textbook adaptive radiation.

Fig 6.5 — Variety of beaks of finches that Darwin found in Galapagos Island.

4.2 Australian marsupials

Australia broke off from the supercontinent Gondwana early, taking marsupial mammals with it. With no competition from placental mammals, the original marsupial stock radiated into many forms — each filling an ecological role that, on other continents, is occupied by a placental mammal.

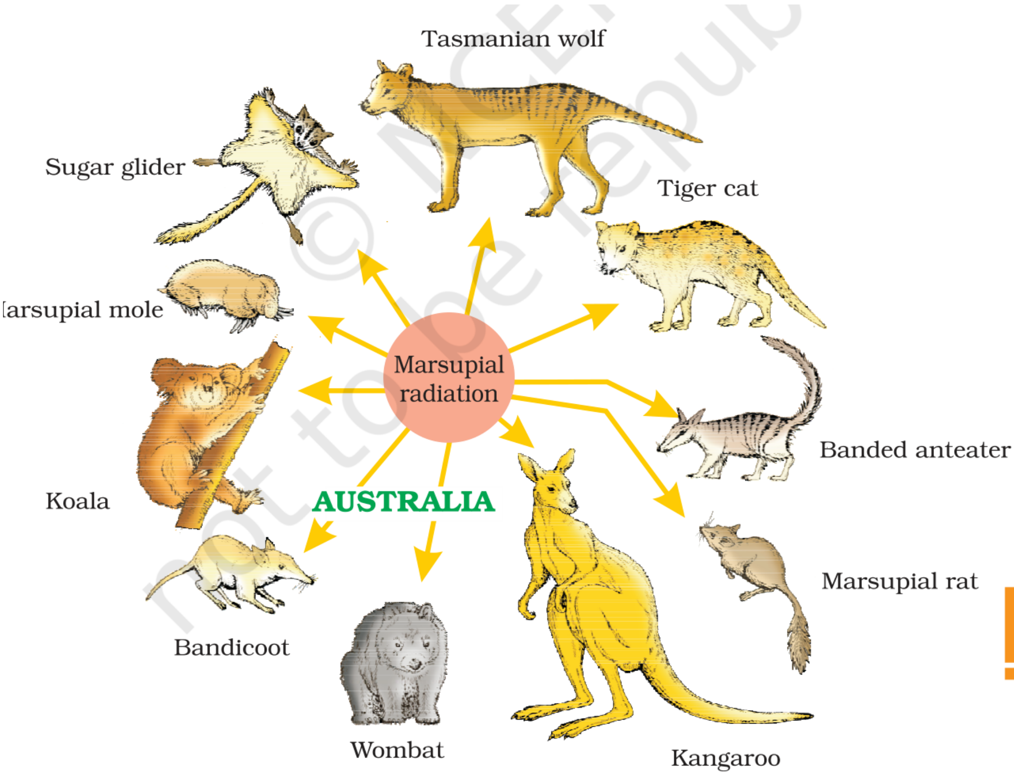


Fig 6.6 — Adaptive radiation of marsupials of Australia.

4.3 Convergent evolution — placental vs marsupial mammals

If more than one adaptive radiation has occurred in two isolated geographical areas *and* the products look strikingly similar, the overall pattern is called **convergent evolution**. Australian marsupials and placental mammals of other continents form the classic example: Tasmanian wolf (marsupial) looks remarkably like the placental wolf, both occupying the role of medium-sized predator.

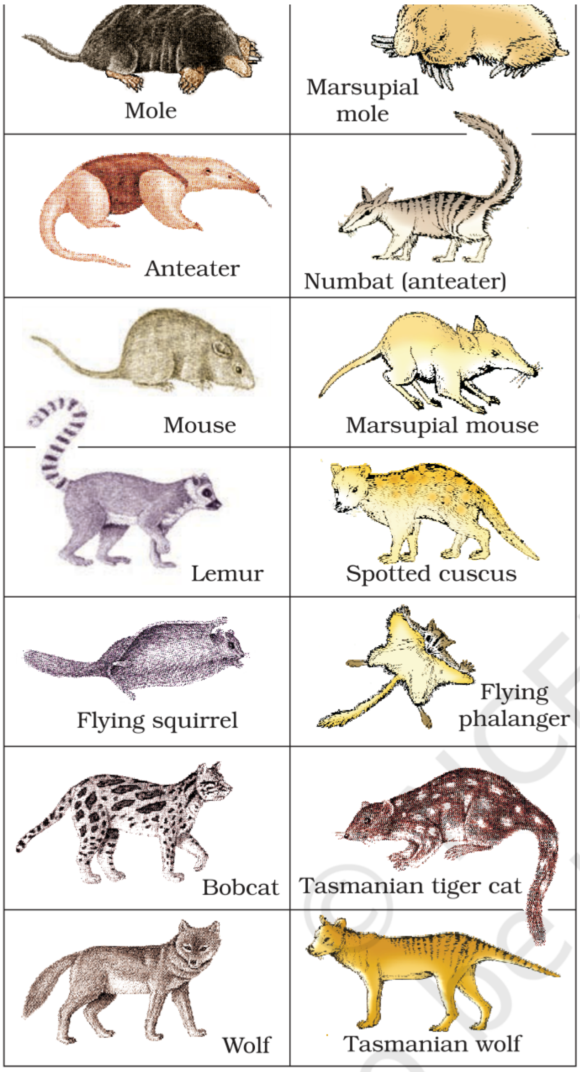


Figure 6.7 Picture showing convergent evolution of Australian Marsupials and placental mammals

Fig 6.7 — Convergent evolution of Australian marsupials and placental mammals.

Adaptive radiation vs convergent evolution

Adaptive radiation happens *within one lineage in one area* — one ancestor diversifies into many forms (analogous to a branching tree).
Convergent evolution happens *across two unrelated lineages in different areas* — the two lineages independently arrive at similar adaptations. When you see two adaptive radiations producing similar-looking organisms (placental wolf vs Tasmanian wolf), the comparison is convergent.

Quick Tip

Is human evolution adaptive radiation? **No.** Adaptive radiation requires that one ancestor produces many descendant species each adapted to a different niche. In humans, only one species (*Homo sapiens*) survives today — the other hominid lines (*H. erectus*, *H. neanderthalensis*, etc.) are extinct. So human evolution is *not* adaptive radiation.

5 Biological Evolution and the Mechanism of Change

5.1 The essence of Darwinian theory — natural selection

True biological evolution by natural selection only really began once the first cellular life forms with metabolic differences existed. From then on:

- Populations have heritable variation.
- Resources are limited (Malthus).
- Better-fit individuals leave more offspring.
- Over generations, allele frequencies change $\rightarrow$ new species can arise.

The *rate* of new-form appearance depends on life cycle length. Microbes (lifespan hours) can throw up new variants within days; vertebrates with year-long generations take millions of years to show comparable change.

Real-World Application

A bacterial colony (call it A) on agar contains genetic variation in metabolic ability. If the medium is changed (say, addition of a new sugar), only the variant cells (call them B) able to use the new sugar grow. Within days, B dominates the colony and behaves as a "new" species. Same logic that produced 4-billion-year-old trends in fish and fowl — just at a much faster clock.

5.2 Origin of variation — the mutation theory

Darwin had no idea where heritable variation came from. **Hugo de Vries**, working with the evening primrose (*Oenothera lamarckiana*) in the first decade of the twentieth century, gave the answer.

de Vries' mutation theory

- Evolution is caused by **mutations** — large, sudden, heritable changes in DNA.
- Mutations are *random* and *directionless* (not goal-driven).
- Speciation by such a single-step large mutation is called **saltation**.

5.3 Darwin vs de Vries

Darwinian variations	de Vries' mutations
Small and continuous	Large and discontinuous
Directional (favoured ones accumulate)	Random and directionless
Evolution is gradual	Evolution can be by saltation (single jump)
Variations supply raw material for natural selection	Mutations themselves can drive speciation

Population genetics later reconciled both: small Darwinian variations and large de Vriesian mutations both contribute. Together with Mendel's particulate genetics, this gave rise to the **Modern Synthetic Theory** of evolution (1930s–40s, by Dobzhansky, Mayr, Huxley, Fisher and others) — the current consensus.

6 Hardy–Weinberg Principle

This is the most "maths-heavy" part of the chapter — and a guaranteed NEET question.

6.1 Statement and assumption

The **Hardy–Weinberg principle** states that *in a large randomly-mating population, allele and genotype frequencies remain constant from generation to generation in the absence of evolutionary forces*. This constancy is called **genetic equilibrium**.

The **gene pool** is the total set of alleles in a population. At equilibrium, this gene pool is unchanging.

Hardy–Weinberg equations

For a single locus with two alleles A (frequency p) and a (frequency q):

$$p + q = 1 \qquad \text{(allele frequencies sum to 1)}$$

$$p^2 + 2pq + q^2 = 1 \qquad \text{(genotype frequencies sum to 1)}$$

where:

- p^2 = frequency of homozygous dominant (AA) individuals
- $2pq$ = frequency of heterozygous (Aa) individuals
- q^2 = frequency of homozygous recessive (aa) individuals

This is simply the binomial expansion $(p + q)^2$.

6.2 When the principle is disturbed — evolution!

If the observed genotype frequencies differ from the predicted $p^2 : 2pq : q^2$, the population is **evolving**. The difference (and its direction) measures the extent of evolutionary change.

Five factors disturb Hardy–Weinberg equilibrium:

1. **Gene migration / gene flow** — when migrants enter or leave a population, alleles are gained or lost. If migration happens repeatedly, there is continuous gene flow.
2. **Genetic drift** — random change in allele frequency due to chance, particularly important in small populations. If the chance change is large enough, the new population may diverge into a new species. When a small group founds a new isolated population whose allele frequencies are very different from the parent, the effect is called the **founder effect**, and the founders are the *founders* of a new species/lineage.
3. **Mutation** — spontaneous heritable change in DNA, the ultimate source of new alleles.
4. **Genetic recombination** — shuffling of alleles during meiosis (crossing over + independent assortment) creates new combinations.
5. **Natural selection** — non-random survival/reproduction of certain genotypes.

Memory Aid

MR. SMG disturbs Hardy–Weinberg equilibrium:
Mutation, **R**ecombination, **S**election (natural), **M**igration (gene flow), **G**enetic drift.

6.3 Worked example (NEET style)

In a population of 10,000 humans, 9 individuals are albino (recessive, aa). Estimate the frequency of carriers (Aa).

Solution. Albino frequency: $q^2 = 9/10000 = 0.0009$, so $q = 0.03$.
Then $p = 1 - q = 0.97$.
Carrier frequency: $2pq = 2 \times 0.97 \times 0.03 = 0.0582$.
So about 582 of the $10{,}000$ individuals carry one copy of the albino allele.

Quick Tip

The frequency of carriers ($2pq$) is far greater than the frequency of affected individuals (q^2) for rare recessive disorders — which is exactly why rare diseases "hide" in populations until two carriers happen to mate.

6.4 Types of natural selection

Once selection is operating, it can shift a quantitative trait in one of three ways:

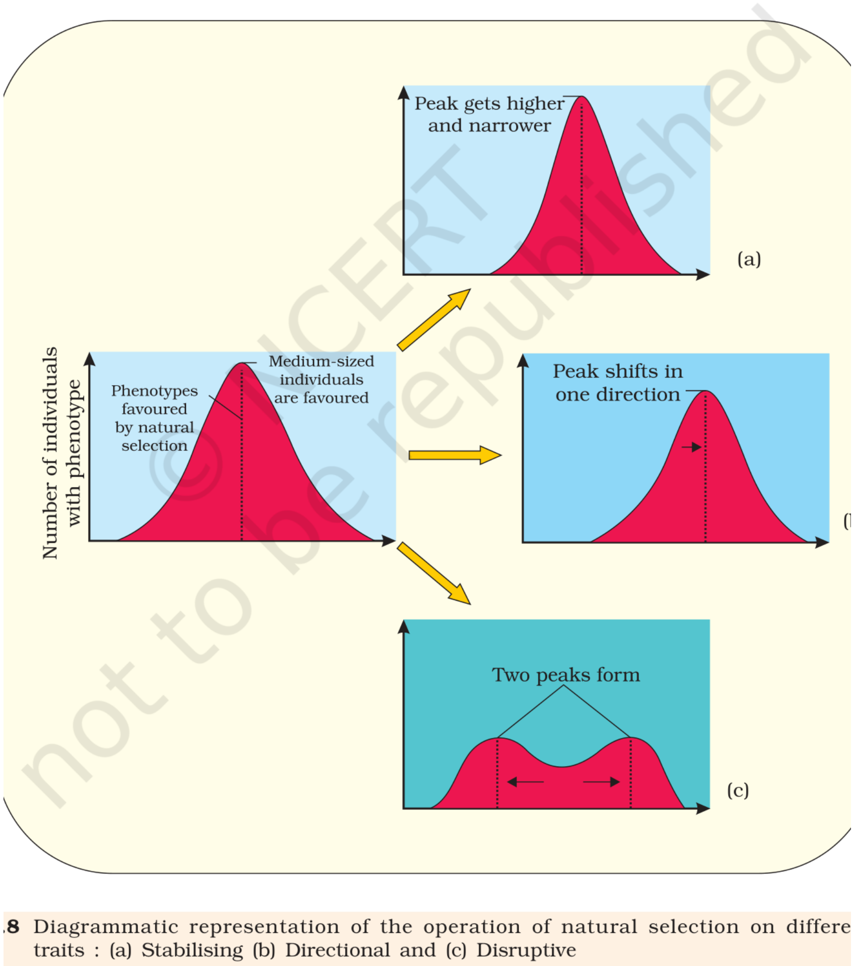


Fig 6.8 — Operation of natural selection on different traits: (a) stabilising, (b) directional, (c) disruptive.

- **Stabilising selection** — the curve becomes higher and narrower around the mean. Average individuals are favoured; extremes are eliminated. *Example:* human birth weight — very small and very large babies have lower survival.
- **Directional selection** — the curve shifts to one side. Individuals at one end of the distribution have higher fitness. *Example:* industrial melanism in peppered moths.
- **Disruptive selection** — the curve splits into two peaks. Individuals at both extremes do better than the mean. *Example:* bill size in certain finches, where small and large beaks each exploit a food type but intermediate beaks do poorly.

How to read the three curves

Stabilising — peak gets higher and narrower (one peak).
Directional — peak shifts in one direction (still one peak).
Disruptive — two peaks form at the ends (a saddle in the middle).

7 A Brief Account of Evolution

This section traces the broad sequence of life on earth on a geological timescale. You don't need to memorise every period in NEET, but knowing the order is fair game.

7.1 Early cells to invertebrates

About 2000 mya, the first **cellular forms of life** appeared on earth. Some had the ability to release oxygen by splitting water (an early form of photosynthesis), slowly oxygenating earth's atmosphere. Single-celled organisms gave rise to multicellular forms. By about 500 mya, **invertebrates** were active in the oceans.

7.2 From water to land — the colonisation event

Plants invaded land first (around 320 mya there were sea-weeds and a few land plants), followed by animals.

In animals, the route on to land went roughly: jawless fish (350 mya) → fish with stout fins (lobefins, e.g., *Coelacanth*, thought extinct but rediscovered in 1938 off South Africa) → first amphibians (ancestors of modern frogs and salamanders) → reptiles (which laid thick-shelled eggs that don't dry up).

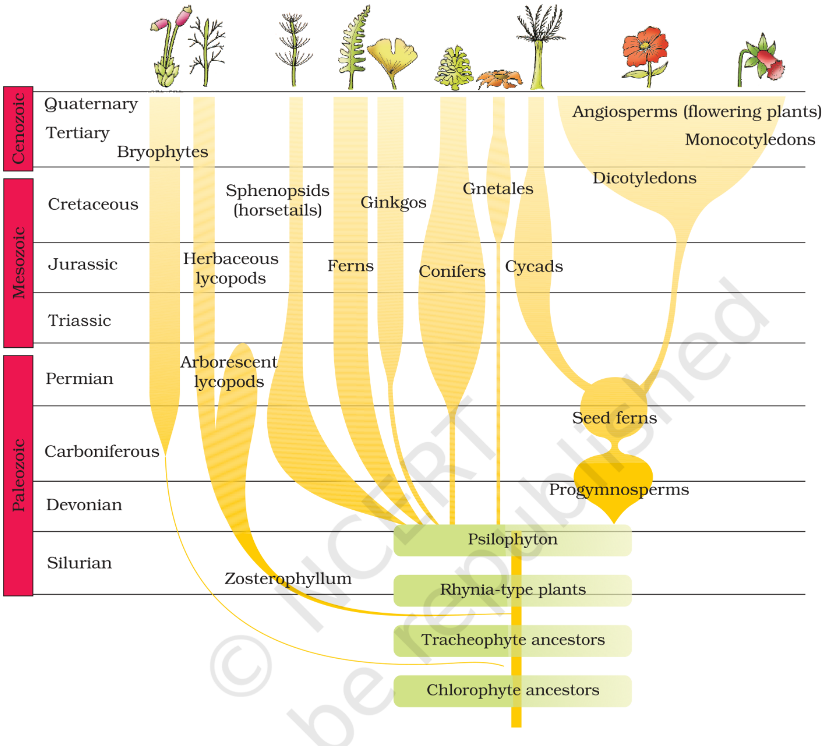


Fig 6.9 — Sketch of the evolution of plant forms through geological periods.

7.3 The age of reptiles

For the next ~ 200 million years, reptiles of many shapes and sizes ruled the earth.

- Giant ferns (pteridophytes) flourished, eventually fell, and gave us coal deposits.
- Some land reptiles re-entered water $\rightarrow$ fish-like reptiles such as *Ichthyosaurus* (about 200 mya).
- On land, **dinosaurs** dominated. *Tyrannosaurus rex* was about 20 feet tall and carried huge dagger-like teeth.
- About **65 mya, dinosaurs suddenly went extinct.** The true reason is debated — climate change is the leading hypothesis; some believe many evolved into birds. Small reptiles of that era still exist as turtles, tortoises, crocodiles and lizards.

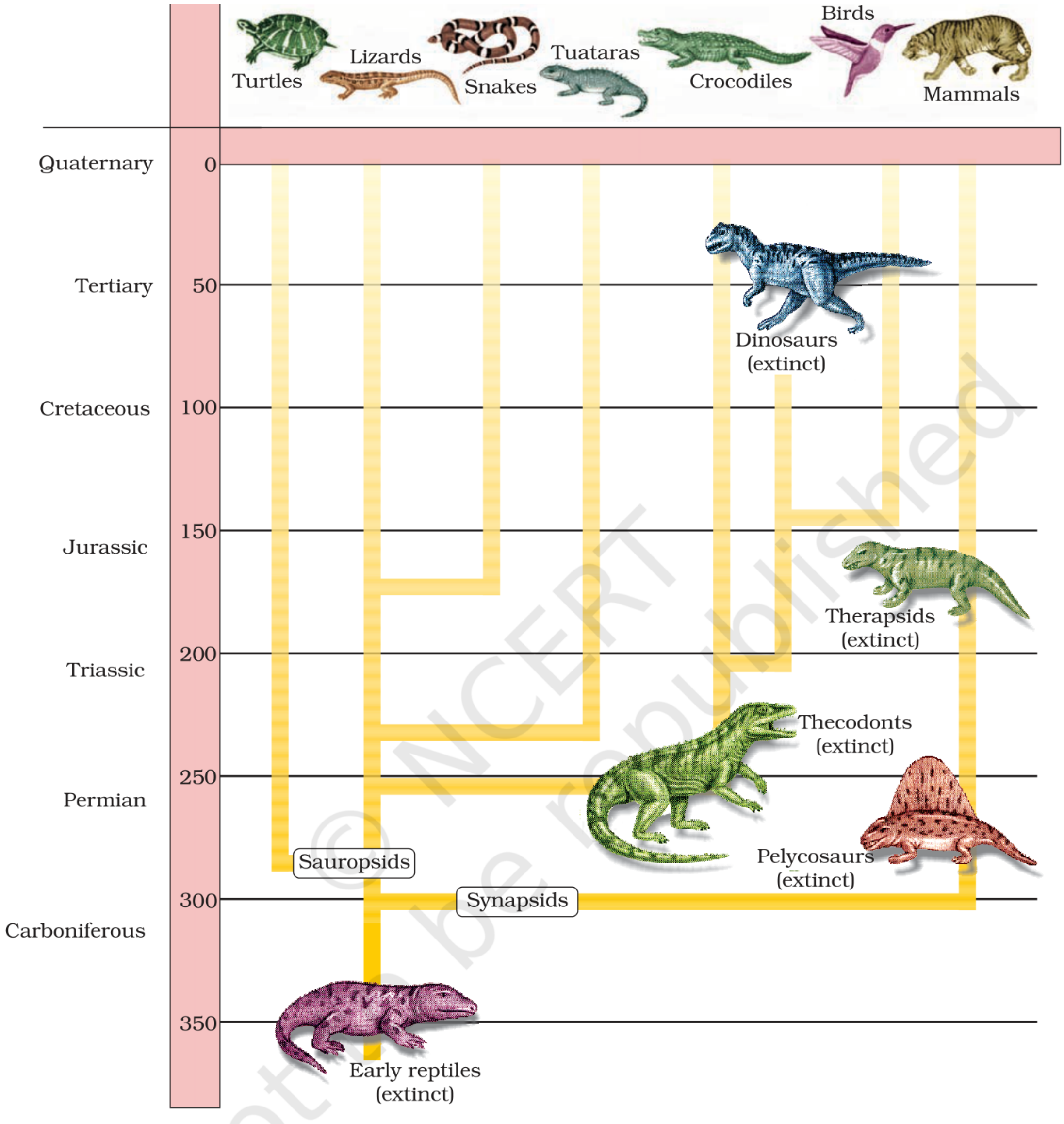


Fig 6.10 — Representative evolutionary history of vertebrates through geological periods.

7.4 The rise of mammals

The earliest mammals were shrew-sized. They were viviparous and protected their young inside the mother's body — a key reproductive advantage. As reptiles declined, mammals took over land.

- In South America, mammals resembling horses, hippos, bears and rabbits arose. When continental drift connected South America to North America, these were largely overrun by North-American fauna.
- Continental isolation *protected* the pouched mammals of Australia — they survived for lack of competition from placentals (the basis of marsupial adaptive radiation we saw earlier).
- Some mammals returned fully to water: whales, dolphins, seals, sea cows.

Quick Tip

The continental-drift link is a favourite NEET trap: "Why did Australian marsupials survive while South American mammals declined?" Answer — because Australia stayed isolated, but South America joined North America and faced competition from placentals.

8 Origin and Evolution of Man

The story of human evolution is one of NEET's most-asked sub-topics. Brain size and bipedal posture are the two big handles to keep track of.

8.1 The earliest primates and hominids

- About 15 mya — primates called **Dryopithecus** and **Ramapithecus** existed. *Dryopithecus* was more ape-like; *Ramapithecus* was more man-like.
- About 3–4 mya — man-like primates walked in eastern Africa. Fossils have been found in **Ethiopia** and **Tanzania**. They were probably not taller than 4 feet but walked *upright*.

8.2 Australopithecus and Homo habilis

- About 2 mya — **Australopithecus** probably lived in East African grasslands. Hunted with stone weapons but essentially ate fruit.
- **Homo habilis** — "the first human-like being". Brain capacity **650–800 cc**. Probably did not eat meat.

8.3 Homo erectus, Neanderthals, Homo sapiens

- **Homo erectus** (about 1.5 mya, fossils discovered in Java in 1891). Brain capacity around **900 cc**. Probably ate meat.
- **Neanderthal man** (*Homo neanderthalensis*, 1,00,000–40,000 years ago, near east and central Asia). Brain capacity **1400 cc**. Used animal hides to protect their bodies and buried their dead.
- **Homo sapiens** arose in Africa and moved across continents, developing into distinct races. During the ice age between 75,000–10,000 years ago, modern *Homo sapiens* arose.
- **Pre-historic cave art** developed about 18,000 years ago. The Bhimbetka rock shelter in Raisen district of Madhya Pradesh has such paintings.
- **Agriculture** came around 10,000 years back; settlements began. The rest is recorded human history.

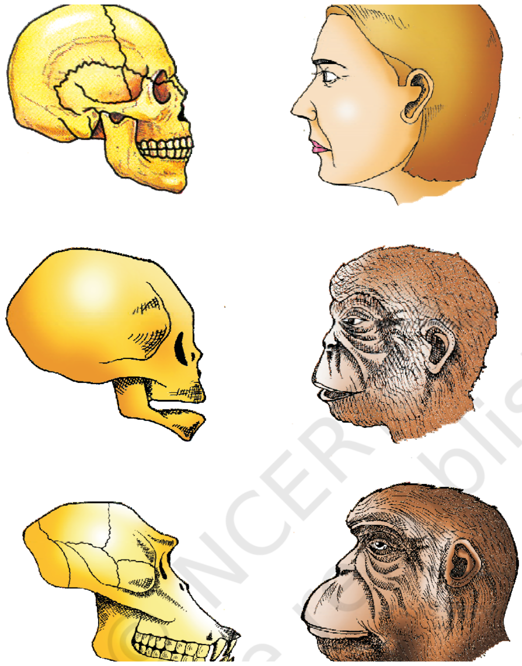
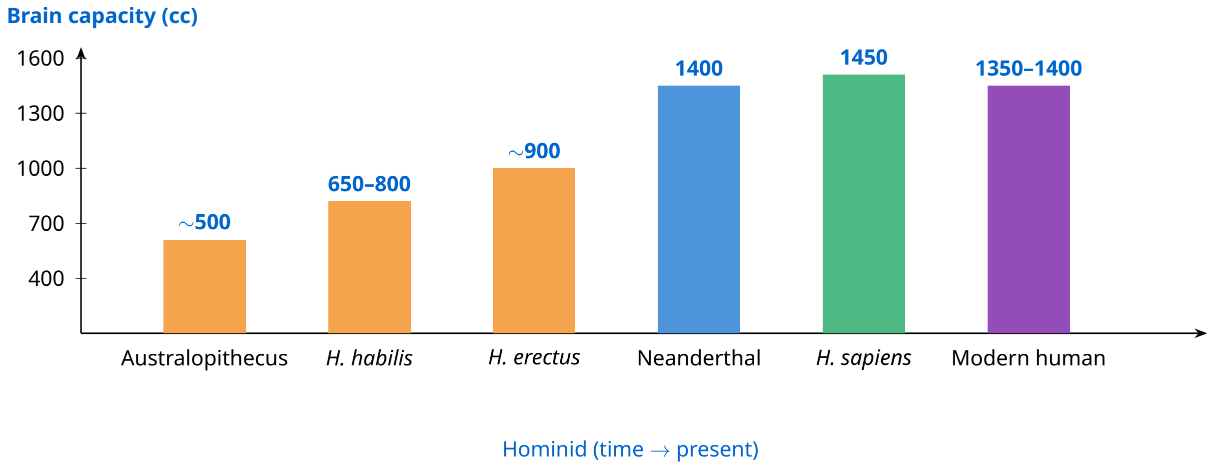


Fig 6.11 — A comparison of the skulls of adult modern human being, baby chimpanzee and adult chimpanzee. The skull of baby chimpanzee is more like adult human skull than adult chimpanzee skull.

8.4 Brain-size trend — the trajectory of human evolution

A visual summary of the brain-capacity trend:



Brain capacity (cc) along the human lineage.

> **Memory Aid**
>
> **Dr. A. H. E. N. S.** for the human evolution sequence (oldest to youngest): **Dr**yopithecus / **Ramapithecus** → **A**ustralopithecus → **H**omo habilis → **H**omo **E**rectus → **N**eanderthal → **S**apiens.

8.5 Key features summarised

Hominid	When	Brain (cc)	Key feature
Dryopithecus	15 mya	—	Ape-like, hairy, walked like gorilla
Ramapithecus	15 mya	—	More man-like than *Dryopithecus*
Australopithecus	2 mya	$\sim$500	East African grasslands; stone tools; fruit-eater
Homo habilis	2 mya	650–800	First hominid; probably did not eat meat
Homo erectus	1.5 mya	$\sim$900	Java 1891; probably ate meat
Neanderthal	1.0–0.4 lakh yr	1400	Hides, buried dead, near east + central Asia
Homo sapiens	75,000–10,000 yr	$\sim$1400	Africa $\rightarrow$ all continents; distinct races; cave art

Common Mistake

A surprisingly common error: writing that *Homo erectus* had a brain of 1400 cc and Neanderthal 900 cc — it's the opposite. **H. erectus** $\approx$ 900 cc; **Neanderthal** $\approx$ 1400 cc.

9 NEET / JEE Extensions Beyond NCERT

A handful of extra ideas that don't appear explicitly in the current 2026–27 NCERT text but routinely show up in competitive exams.

9.1 Hot dilute soup — Haldane's term

J. B. S. Haldane (1929) coined the phrase **"hot dilute soup"** (sometimes "primordial soup") for the ocean of organic molecules that built up under early-earth conditions before the first cell. NEET MCQ alert.

9.2 Coacervates — Oparin's protocells

Oparin called the earliest membrane-bounded aggregates of organic molecules **coacervates**. These were not yet cells, but "protobionts" — the bridge between chemistry and biology.

9.3 Sidney Fox's microspheres

Sidney Fox heated dry amino acids and produced **proteinoid microspheres** — protein-like beads that displayed primitive membrane-like behaviour. Another protobiont model.

9.4 RNA world hypothesis

Modern view: the first informational molecule was probably **RNA**, not DNA. RNA can both store information (like DNA) and catalyse reactions (like enzymes — "ribozymes"). Eventually DNA took over information storage and proteins took over catalysis, but ribosomal RNA still does peptide-bond chemistry in ribosomes.

9.5 Lobefins — the missing link to land

The lobefin fish caught in 1938 off South Africa was *Latimeria chalumnae* (a coelacanth) — considered a "living fossil" representing the ancestral group from which tetrapods evolved.

9.6 Connecting links / living fossils (NEET favourites)

- *Peripatus* — connecting link between annelids and arthropods
- *Archaeopteryx* — between reptiles and birds (fossil, $\sim$150 mya)
- Duck-billed platypus (*Ornithorhynchus*) — between reptiles and mammals (egg-laying mammal)
- Lungfish — between fishes and amphibians
- Living fossils: *Limulus* (king crab), *Latimeria*, *Sphenodon*, *Cycas*, *Ginkgo biloba*, *Peripatus*

9.7 Types of homology in molecules

- **Orthologous genes** — homologous genes in different species, descended from a common ancestor (e.g. haemoglobin β in human and chimp).
- **Paralogous genes** — homologous genes within one species, originated by gene duplication (e.g. haemoglobin α and β in humans).

9.8 Allopatric vs sympatric speciation

- **Allopatric speciation** — new species forms when populations are geographically isolated (most common; Darwin's finches).
- **Sympatric speciation** — new species arises within the same area, usually through reproductive isolation (e.g. polyploidy in plants).

Quick Tip

Allo = "other place"; **Sym** = "same place". If the populations are in different geographies, it's allopatric.

9.9 Vestigial organs in humans

Useful at-a-glance list for MCQs: **vermiform appendix, nictitating membrane (plica semilunaris), wisdom teeth, ear muscles, body hair (pilomotor reflex), tail-bone (coccyx), Darwin's tubercle on the ear**.

Real-World Application

Antibiotic-resistance evolution is now so rapid that the WHO calls it one of the top global health threats. The same Darwinian logic that explains industrial melanism explains why doctors must rotate antibiotic regimens and why over-prescription accelerates the rise of super-bugs.

10 Quick Reference Summary

10.1 Key dates

Event	Approximate date
Big Bang (origin of universe)	13.8 billion years ago
Earth formed	4.5 billion years ago
First life on earth	$\sim$4 billion years ago
First cellular life	$\sim$2 billion years ago
Invertebrates abundant	500 mya
Jawless fish	350 mya
Lobefins / first amphibians	350 mya
Dinosaurs dominant; coal forming	250–65 mya
Dinosaurs go extinct	65 mya
Dryopithecus, *Ramapithecus*	15 mya
Australopithecus	2 mya
Homo erectus	1.5 mya
Neanderthal	1,00,000–40,000 yr ago
Modern *H. sapiens*	75,000–10,000 yr ago
Cave art (Bhimbetka)	18,000 yr ago
Agriculture begins	10,000 yr ago

10.2 Key formulas and equations

Hardy–Weinberg

$$p + q = 1$$
$$p^2 + 2pq + q^2 = 1$$

p^2 = AA frequency, $2pq$ = Aa frequency, q^2 = aa frequency.
Disturbed by: mutation, recombination, gene flow, genetic drift, natural selection.

10.3 Key personalities

Scientist	Contribution
Pasteur	Disproved spontaneous generation; biogenesis
Oparin & Haldane	Chemical-evolution origin of life; "hot dilute soup"
S. L. Miller	1953 lab experiment producing amino acids
Lamarck	Use & disuse; inheritance of acquired characters
Darwin & Wallace	Natural selection; branching descent
Thomas Malthus	Population pressure idea (resources are limited)
Hugo de Vries	Mutation theory (saltation)
Mendel	Particulate inheritance — "factors"
Hardy & Weinberg	Genetic-equilibrium equation
Ernst Haeckel	"Ontogeny recapitulates phylogeny" — disproved by von Baer
Karl Ernst von Baer	Disproved Haeckel's recapitulation

10.4 Top NEET takeaways

- Miller's gases: CH_4 + NH_3 + H_2 + H_2O at $800\,°C$ with electric discharge $\to$ amino acids.
- Homology = divergent (same plan, different jobs). Analogy = convergent (different plan, same job).
- Darwin's finches and Australian marsupials are the two NCERT examples of adaptive radiation.
- Tasmanian wolf vs placental wolf = convergent evolution.
- Five forces disturb Hardy–Weinberg: mutation, gene flow, drift, recombination, selection (**MR. SMG**).
- Brain-size trend: 500 cc (*Australopithecus*) $\to$ 650–800 cc (*H. habilis*) $\to$ 900 cc (*H. erectus*) $\to$ 1400 cc (Neanderthal) $\to$ 1350–1400 cc (modern human).
- Human evolution is *not* an example of adaptive radiation (only one surviving

species).

- Evolution is **stochastic** (chance-driven), not directed.

One-line takeaway

Evolution is the change in the genetic composition of populations over generations under the combined action of mutation, recombination, gene flow, drift and selection — visible in fossils, molecules, embryos, anatomy, and right now in antibiotic resistance.