Chapter 6: Evolution

Exercises — Chapter-end Exercises

Q1 Explain antibiotic resistance observed in bacteria in light of Darwinian selection theory.

SOLUTION

Bacteria reproduce rapidly and populations naturally harbour genetic variation due to random mutations. When a population of bacteria is exposed to an antibiotic, most individuals are killed, but a few that carry a mutation conferring resistance survive.

According to Darwinian selection theory, those individuals that are better adapted to the environment — in this case, those resistant to the antibiotic — have a higher fitness. They survive and reproduce while the susceptible individuals are eliminated. Over successive generations, the resistant bacteria multiply and come to dominate the population.

The antibiotic does not create the resistance mutation; the mutation pre-existed in the population. The antibiotic merely acts as the selecting agent, favouring the resistant variants. This is a classic example of natural selection operating within a very short time scale — months or years rather than millions of years — because bacteria have extremely short generation times and large population sizes.

The result is that the originally effective antibiotic becomes ineffective against the evolved bacterial population. This is why overuse or misuse of antibiotics accelerates the emergence of resistant strains.

Answer: Pre-existing random mutations confer resistance in a few bacteria; the antibiotic selects for these resistant individuals, which survive and reproduce while sensitive bacteria are eliminated — a direct demonstration of Darwinian natural selection.

Q2 Find out from newspapers and popular science articles any new fossil discoveries or controversies about evolution.

SOLUTION

This is an activity-based question requiring students to consult current newspapers, science journals (such as Nature, Science, or Scientific American), or science news websites.

Examples of areas where ongoing discoveries and debates occur include:
— Discovery of new hominin fossils (e.g., Homo naledi, Homo luzonensis) that challenge the linear view of human evolution.
— Controversies around the timeline and geographic origin of Homo sapiens.
— Feathered dinosaur fossils that strengthen the theropod origin of birds.
— Fossil discoveries pushing back the appearance of multicellular life.
— Debates on punctuated equilibrium versus gradualism in interpreting the fossil record.

Students should read at least two recent articles, note the fossil name, geological age, location of discovery, and what the find adds to or changes in our understanding of evolution.

Answer: Activity-based question: consult newspapers and popular science sources for recent fossil discoveries (e.g., new hominid fossils, feathered dinosaurs) or evolutionary controversies and summarise the findings.

Q3 Attempt giving a clear definition of the term species.

SOLUTION

A species can be defined as a group of organisms that share a common gene pool, are capable of interbreeding among themselves under natural conditions to produce fertile (viable) offspring, and are reproductively isolated from all other such groups.

This is broadly the Biological Species Concept proposed by Ernst Mayr. Key elements of this definition are:
— Shared morphological, physiological, and genetic characteristics.
— Ability to interbreed naturally and produce fertile offspring.
— Reproductive isolation from other groups, which prevents gene flow between species.

Limitations: This definition applies best to sexually reproducing organisms and cannot be applied to asexually reproducing organisms (like bacteria) or fossils. Alternative concepts include the Morphological Species Concept (based on structural similarity) and the Phylogenetic Species Concept (based on shared evolutionary ancestry).

A working definition for NCERT-level: A species is the basic unit of classification; it is a group of organisms with similar morphology, physiology, and behaviour that can interbreed freely and produce fertile offspring, and are reproductively isolated from other groups.

Answer: A species is a group of organisms that can interbreed freely under natural conditions to produce fertile offspring and are reproductively isolated from all other such groups.

Q4 Try to trace the various components of human evolution (hint: brain size and function, skeletal structure, dietary preference, etc.)

SOLUTION

Human evolution can be traced through the following successive stages:

1. Dryopithecus and Ramapithecus (~15 mya): Hairy primates. Dryopithecus was more ape-like; Ramapithecus was more man-like. Walked like gorillas and chimpanzees.

2. Early hominid fossils (~3–4 mya): Man-like primates discovered in Ethiopia and Tanzania. Walked upright but were probably not taller than 4 feet. Brain size not well documented for this stage.

3. Australopithecines (~2 mya): Lived in East African grasslands. Hunted with stone weapons but primarily ate fruit. Walked upright.

4. Homo habilis (~2 mya): First human-like hominid. Brain capacity: 650–800 cc. Used stone tools. Probably did not eat meat. Bipedal locomotion.

5. Homo erectus (~1.5 mya): Fossils discovered in Java. Brain size ~900 cc. Probably ate meat. More advanced tool use. Upright posture similar to modern humans.

6. Neanderthal man (~1,00,000–40,000 years ago): Lived in near east and central Asia. Brain size ~1400 cc. Used hides to protect body. Buried their dead — indicating social behaviour.

7. Homo sapiens (~75,000–10,000 years ago, during ice age): Arose in Africa, migrated across continents, developed into distinct races. Cave art appeared ~18,000 years ago (e.g., Bhimbetka, Madhya Pradesh). Agriculture began ~10,000 years ago.

Key trends across human evolution:
— Brain size: progressively increased from ~650 cc (H. habilis) → 900 cc (H. erectus) → 1400 cc (Neanderthal) → ~1450 cc (modern H. sapiens).
— Posture: progressively more upright; bipedalism established early.
— Diet: shift from frugivore → omnivore (meat-eating from H. erectus onward).
— Tool use and culture: stone tools → more refined tools → cave art → agriculture.
— Cranial capacity and facial structure: reduced jaw and brow ridge, expanded cranium.

Answer: Human evolution progressed from ape-like Dryopithecus/Ramapithecus (~15 mya) through Homo habilis (650–800 cc brain), Homo erectus (900 cc, ate meat), Neanderthal (1400 cc, buried dead), to modern Homo sapiens (~75,000 years ago), with increasing brain size, upright posture, refined tool use, and dietary shift to omnivory.

Q5 Find out through internet and popular science articles whether animals other than man has self-consciousness.

SOLUTION

This is a research and discussion activity. Students are expected to explore scientific literature and popular science sources on animal cognition.

Current scientific understanding suggests that self-consciousness, or at least a degree of self-awareness, exists in several non-human animals. Evidence comes primarily from the mirror self-recognition (MSR) test, in which an animal placed in front of a mirror is marked on its body and observed to see whether it inspects the mark on itself (indicating it recognises its own reflection).

Animals that have shown evidence of self-recognition or self-awareness include:
— Great apes (chimpanzees, bonobos, orangutans, gorillas) — pass the mirror test.
— Bottlenose dolphins — pass the mirror test.
— Asian elephants — some individuals pass the mirror test.
— European magpies — the only bird species shown to pass the mirror test.
— Some research suggests limited self-awareness in cleaner wrasse fish, though this remains debated.

However, self-consciousness as experienced by humans — involving language, abstract thought, and metacognition — is considered unique to Homo sapiens. The chapter notes that the evolution of man with language skills and self-consciousness is the most successful story of

evolution.

Answer: Activity-based question: current evidence from mirror self-recognition tests indicates that great apes, dolphins, Asian elephants, and European magpies show some degree of self-awareness, though full human-level self-consciousness with language and abstract thought is considered unique to Homo sapiens.

Q6 List 10 modern-day animals and using the internet resources link it to a corresponding ancient fossil. Name both.

SOLUTION

This is a research activity. The following is a representative list linking 10 modern animals to their ancient fossil ancestors:

1. Modern: Horse (Equus caballus) → Fossil: Eohippus (Hyracotherium) — small, multi-toed early horse.
2. Modern: Elephant (Elephas maximus) → Fossil: Moeritherium — early proboscidean, pig-sized.
3. Modern: Whale (Balaenoptera musculus) → Fossil: Pakicetus — land-dwelling ancestor with terrestrial limbs.
4. Modern: Crocodile (Crocodylus niloticus) → Fossil: Protosuchus — early Jurassic crocodyliform.
5. Modern: Bird (pigeon, Columba livia) → Fossil: Archaeopteryx — transitional bird-dinosaur from Jurassic.
6. Modern: Human (Homo sapiens) → Fossil: Homo erectus — upright walking ancestor, 1.5 mya.
7. Modern: Shark (Carcharodon carcharias) → Fossil: Carcharodon megalodon — giant extinct shark.
8. Modern: Fern (Pteridium aquilinum) → Fossil: Pecopteris — Carboniferous tree fern.
9. Modern: Horseshoe crab (Limulus polyphemus) → Fossil: Mesolimulus — virtually unchanged since Jurassic (living fossil).
10. Modern: Coelacanth (Latimeria chalumnae) → Fossil: Macropoma — Cretaceous lobe-finned fish; coelacanth was thought extinct until 1938 (South Africa).

Students should verify current names and dates using school library resources or reliable websites such as the Smithsonian National Museum of Natural History or the Palaeontological Research Institution.

Answer: Activity-based research question — representative examples: Horse↔Eohippus; Elephant↔Moeritherium; Whale↔Pakicetus; Crocodile↔Protosuchus; Bird↔Archaeopteryx; Human↔Homo erectus; Shark↔Megalodon; Fern↔Pecopteris; Horseshoe crab↔Mesolimulus; Coelacanth↔Macropoma.

Q7 Practise drawing various animals and plants.

SOLUTION

This is a practical drawing activity. Students should practise free-hand diagrams of the following, which appear in this chapter and are relevant for board examinations:

Animals:
— Darwin's Finches (showing variety of beak shapes — seed-eating, insectivorous, vegetarian forms).
— Marsupials of Australia (kangaroo, Tasmanian wolf, numbat).
— Homologous forelimbs of whale, bat, cheetah, and human.
— Evolutionary sequence of vertebrates (fish → amphibian → reptile → bird/mammal).
— Human evolutionary skulls (Homo habilis, Homo erectus, Neanderthal, Homo sapiens).

Plants:
— Homologous structures: thorn of Bougainvillea vs tendril of Cucurbita.
— Giant ferns (pteridophytes) of the Carboniferous era.

Practice drawings should include correct labels, appropriate scale, and neat presentation as required in CBSE board examinations.

Answer: Practical activity: practise labelled diagrams of Darwin's finches (beak diversity), marsupials of Australia, homologous forelimbs of vertebrates, and evolutionary stages of man.

Q8 Describe one example of adaptive radiation.

SOLUTION

Adaptive radiation is the process of evolution of different species in a given geographical area, starting from a single ancestral stock and diversifying into multiple forms, each adapted to a different ecological niche.

Example: Darwin's Finches of the Galapagos Islands

Charles Darwin observed a remarkable diversity of small black birds (later called Darwin's Finches) on the Galapagos Islands. All the varieties are believed to have evolved from a single ancestral seed-eating finch that colonised the islands.

Over time, different populations adapted to different food sources available in different habitats on the islands. The beak structure underwent modification in each group:
— Seed-eaters retained the original thick, crushing beak.
— Insectivorous finches developed thin, pointed beaks suited to picking insects.
— Vegetarian finches developed beaks suited to eating plant material.
— Woodpecker finches evolved a beak to probe bark for insects, even using cactus spines as tools.

From a single ancestral stock, multiple species with diverse beak forms and feeding habits evolved — all within the isolated geographic area of the Galapagos Islands. This radiation of forms from a common ancestor into different ecological niches is the essence of adaptive

radiation.

Another well-known example is the adaptive radiation of marsupials in Australia, where a single ancestral marsupial stock gave rise to diverse forms such as the kangaroo, Tasmanian wolf, and numbat, each adapted to different habitats and lifestyles within the Australian continent.

Answer: Darwin's Finches on the Galapagos Islands: from a single ancestral seed-eating finch, multiple species with different beak forms (seed-eating, insectivorous, vegetarian) evolved by adapting to different food sources — a classic example of adaptive radiation from a common ancestor within an isolated geographic area.

Q9 Can we call human evolution as adaptive radiation?

SOLUTION

Adaptive radiation refers to the evolution of different species from a common ancestral stock, diversifying into multiple forms adapted to different ecological niches, typically within an isolated geographical area.

Human evolution does share some features with adaptive radiation: modern Homo sapiens arose in Africa and subsequently spread across continents, with different populations adapting to diverse climates, diets, and environments. This resulted in the development of distinct racial groups with morphological differences.

However, human evolution cannot be strictly called adaptive radiation for the following reasons:
— Human evolution is largely a linear (anagenetic) progression — one form giving rise to the next (e.g., Homo habilis → Homo erectus → Homo sapiens) — rather than a branching radiation into multiple distinct species occupying different ecological niches simultaneously.
— Adaptive radiation typically involves the emergence of multiple new species from a common ancestor. In human evolution, Homo sapiens is the only surviving species of the genus Homo; the others (Homo habilis, Homo erectus, Neanderthal) went extinct rather than co-existing as distinct ecological specialists.
— Human ecological diversification is largely cultural and technological, not primarily through genetic/morphological specialisation to different niches as seen in Darwin's Finches or Australian marsupials.

Conclusion: Human evolution shows some parallels to adaptive radiation (spread across diverse habitats, development of racial variation) but does not fully qualify as adaptive radiation because it did not produce multiple co-existing species each occupying distinct ecological niches from a single ancestor.

Answer: No — human evolution is not strictly adaptive radiation. It is largely a linear progression (Homo habilis → Homo erectus → Homo sapiens) without branching into multiple co-existing ecologically distinct species; any divergence into racial groups is cultural and morphological adaptation, not speciation into separate ecological niches.

Q10 Using various resources such as your school Library or the internet and discussions with your teacher, trace the evolutionary stages of any one animal, say horse.

SOLUTION

This is a research activity. The evolution of the horse is one of the most well-documented examples of anagenetic evolution in the fossil record.

Evolutionary stages of the horse (Family Equidae):

1. Eohippus (Hyracotherium) — ~55 mya (Eocene): The earliest horse ancestor. Size of a fox (about 30 cm tall). Four toes on the front feet and three on the hind feet. Low-crowned teeth suited for browsing soft forest vegetation. Lived in forests of North America and Europe.

2. Mesohippus — ~40–30 mya (Oligocene): Slightly larger. Three toes on all feet. Teeth slightly more complex for tougher vegetation.

3. Merychippus — ~25–15 mya (Miocene): Size of a modern pony. Three toes but only the middle toe (hoof) bore the body weight. High-crowned (hypsodont) teeth for grazing grasses. Grassland expansion drove this dietary shift.

4. Pliohippus — ~12–6 mya (Pliocene): Single-toed (effectively). First true one-toed horse. Longer limbs for running on open grasslands.

5. Equus (modern horse) — ~4 mya to present: Single hoof (one functional digit). Large body (~150 cm at shoulder). High-crowned molars for grazing tough grasses. Evolved in North America, spread to Asia, Europe, Africa (went extinct in Americas ~10,000 years ago; reintroduced by Spanish explorers).

Key evolutionary trends in horse evolution:
— Increase in body size.
— Reduction in number of toes from 4 → 3 → 1 (specialisation for running).
— Elongation and strengthening of limbs.
— Development of high-crowned (hypsodont) teeth for grazing.
— Shift in habitat from forest browsing to grassland grazing.

This is a classic example of directional evolution driven by changing environment (forest → grassland) over millions of years.

Answer: Horse evolution progressed from the small, four-toed, forest-browsing Eohippus (~55 mya) through Mesohippus (three toes), Merychippus (grazing teeth), Pliohippus (single toe), to the modern single-hoofed, large-bodied grassland grazer Equus (~4 mya), showing increase in size, toe reduction, and tooth modification.