Unit 19 · Evidence of Evolution

STUDY NOTES

WHAT NEB'S GRADE 11 EXAM ASKS

- **CDC's grid (2077):** Evolutionary Biology (Units 18–21 together): 9 of 75 marks; in one group with Faunal Diversity, Units 22–26 (28 marks)
- **The paper:** 11 MCQs × 1 · 8 short × 5 · 3 long × 8; 3 hours; 1 mark per expected point
- **CDC's model paper:** MCQ: wings of a dragonfly, *Pteranodon*, hawk and bat: what kind of organs (analogous)
- **MCQ (1 mark)**
  - father of organic evolution
  - microevolution; retrogressive evolution
  - homologous organs; atavism
  - paleozoology; petrified; molds and casts
  - embryology; Haeckel's law
  - what serology shows; enzymes and hormones
- **Short and long (in parts)**
  - an example of convergent evolution
  - *Archaeopteryx*: bird and reptile characters; its role as a link
  - connecting links between named groups; why they matter
  - vestigial organs as evidence
  - significance of fossils; fossilization and the kinds of fossil
  - embryology and recapitulation
  - horse: changes from *Hyracotherium* to *Equus*

Key terms

Organic evolution (*evolvere*, unroll): change in inherited characters of **populations** over generations; new species from earlier ones; Darwin: **descent with modification**; slow, continuous, not reversible.

Homologous organs: same basic structure and **origin**, **different jobs** → common ancestry, divergent evolution.

Analogous organs: **same job**, different origin and structure → convergent evolution.

Vestigial organs: reduced, little or none of the job they do in related animals; worked in ancestors.

Atavism (reversion): sudden reappearance, in one individual, of an ancestral character lost long ago.

Paleontology: study of **fossils** (remains, impressions, traces in rock); the only **direct** evidence; **paleozoology** (animals), **paleobotany** (plants).

Connecting link: organism with characters of two groups; fossil ones = **missing links**.

Index fossil: common, widespread, short-lived species → dates its layer.

Half-life: time for half of a radioactive sample to decay.

Ontogeny: development of an individual; **phylogeny**: evolutionary history of its group.

People

- **Darwin** (1809–1882): father of organic evolution; *Origin of Species* 1859
- **Herbert Spencer**: made the word "evolution" popular
- **Leonardo da Vinci**: pioneer of paleontology; **Cuvier**: founded modern paleontology; extinction (mammoth, 1796)
- **Haeckel** (1866): biogenetic law; **von Baer** (1828): early stages alike
- **Nuttall** (~1904): precipitin test

Patterns of evolution

Pattern	What	Example
Micro	gene frequencies in a population; few generations	peppered moths blackened; antibiotic resistance
Macro	new species and above; speciation, adaptive radiation	Galápagos finches
Progressive	simple → complex	heart 2 → 3 → 4 chambers
Retrogressive	complex → simple	tapeworm (no gut); snakes (no legs); *Herdmania*
Convergent	**unrelated**, alike independently	shark, *Ichthyosaurus*, dolphin: fusiform
Divergent	one ancestor → many forms (adaptive radiation)	cichlids; mammal forelimbs
Parallel	**related** lines, same change after splitting	marsupial and placental look-alikes (thylacine, wolf)

Morphology and comparative anatomy

- **homologous**: pentadactyl forelimb (**humerus**, **radius and ulna**, **carpals**, **metacarpals**, **phalanges**) of human, horse, bat, bird, whale, mole (grasp, run, fly, swim, dig); frog: radio-ulna fused; muscles, nerves, vessels alike
  - also: insect mouthparts (biting, sucking, piercing); thorn of *Bougainvillea* and tendril of pumpkin (stems); vertebrate hearts, brains
- **analogous**: wings of butterfly (membrane, veins, no bones) and bird (feathers on arm bones); stings of honeybee (egg-laying tube) and scorpion (tail tip); eyes of octopus and human; wings of insect and bat
- fish fin vs whale flipper: analogous as paddles; built differently (bony rays vs arm bones)

Homologous	Analogous
same structure and origin	different structure and origin
different jobs	same job
common ancestry	no close kinship
divergent evolution	convergent evolution

Vestigial organs in humans

- **appendix** ← cecum of plant-eaters (cellulose); diet → omnivore
- **coccyx** (4 fused tail vertebrae) ← tail
- **ear muscles** ← ears turned to sound
- **plica semilunaris** ← nictitating membrane
- **wisdom teeth** ← grinding teeth of longer jaws
- **body hair**, goosebumps ← fur
- other animals: hind-limb bones of python and whale; wings of kiwi, ostrich; eyes of cave fish
- "useless" too strong: lost their **main job** (appendix: lymph tissue)
- explained only by descent from ancestors in which they worked

Atavism

- baby with a short **tail**; **extra nipples**; thick body hair; long pointed canines; horse with **extra toes**
- old genes still there, switched off

Paleontology

Fossilization

- body **buried quickly** in fine sediment, away from O_2; mostly in water (sea, lakes, rivers)
- soft parts rot; hard parts (shell, bone, teeth, wood) buried under layers → **sedimentary rock**; minerals replace them
- **older fossils deeper**

Types of fossil

- **intact**: whole, soft parts too; frozen, dried, in amber (Siberian mammoth, insects in amber)
- **petrified**: hard parts replaced by minerals (petrified wood, dinosaur bones)
- **mold and cast**: hollow mold left in rock; minerals fill it → cast (trilobites, ammonites)
- **compression**: plant pressed flat → carbon film
- **imprints**: footprints, feather, skin prints, trails (**trace fossils**)
- **pseudofossils**: mineral look-alikes (manganese dendrites)

Significance

- phylogeny of groups (horse, elephant)
- different groups at different times; extinct groups (trilobites, dinosaurs)
- older → younger strata: **simple** → **complex**
- **intermediate forms** (connecting links)
- dates rocks; finds oil, coal

Dating fossils

- **relative** (order only)
  - **stratigraphy**: **superposition**: younger layers above older
  - **biostratigraphy**: index fossils
- **absolute** (radiometric; years)
  - **carbon-14**: half-life **5,730 years**; up to **~50,000 years**
  - **potassium–argon**: K-40 → Ar-40, half-life **~1.25 billion years**; volcanic rocks
  - **uranium-series**: U-234 → Th-230; a few thousand to ~500,000 years
  - fossil dated by volcanic ash layers above and below
- ⅛ of C-14 left = 3 half-lives = $3 \times 5{,}730 \approx 17{,}000$ years

Connecting links

- virus: living and non-living
- *Euglena*: plants and animals
- *Proterospongia*: Protozoa and Porifera
- *Neopilina*: Annelida and Mollusca
- *Peripatus*: Annelida and Arthropoda
- *Balanoglossus*: non-chordates and chordates
- *Chimaera*: cartilaginous and bony fishes
- *Protopterus* (lungfish): fishes and amphibians
- *Archaeopteryx*: reptiles and birds
- platypus, echidna: reptiles and mammals
- *Euglena*: chloroplasts, but no cellulose wall, flagellum, eats in the dark
- *Peripatus*: segments, paired kidneys (annelid); claws, jaws, tracheae, open blood system (arthropod)
- *Protopterus*: gills and fins + lungs, part-divided heart
- platypus: hair, milk + **lays eggs**, cloaca

Archaeopteryx ("ancient wing"; Solnhofen, Germany; **Jurassic**, ~150 million years; found 1861; crow-sized)

Like a reptile	Like a bird
teeth in jaws	**feathers** (flight feathers)
three clawed fingers, free	**wings**
long **bony tail** (~21 vertebrae)	**wishbone** (furcula)
dinosaur-like skull and brain	large eye sockets, part-fused skull
no keel; belly ribs	feathers along the tail

- reptile skeleton in bird's feathers → birds evolved from small feathered dinosaurs

Geological time scale (million years ago)

Era	Means	Life
Archeozoic (4,000–2,500)	primitive life	bacteria, cyanobacteria
Proterozoic (2,500–539)	early life	eukaryotes, algae; soft-bodied animals
Paleozoic (539–252)	ancient life	sea invertebrates, fishes, land plants, amphibians, first reptiles
Mesozoic (252–66)	middle life	age of **reptiles**; first mammals, birds; gymnosperms, first flowering plants
Cenozoic (66–now)	recent life	age of **mammals**, flowering plants; humans

- six eras: + **Azoic** (no life) before Archeozoic; Cenozoic = Tertiary + Quaternary (from 2.6 million years)

Phylogeny of the horse

- *Eohippus* (*Hyracotherium*, dawn horse): ~55 million years, **Eocene**; fox-size, ~30 cm; forest browser; **44 teeth**, low-crowned; **4 toes front, 3 hind**
- → *Mesohippus*, *Miohippus* (3 toes) → *Parahippus*, *Merychippus* (on the middle toe; high-crowned teeth) → *Pliohippus* (1 toe) → *Equus* (~4 million years)
- changes
  - body larger
  - neck longer, more mobile
  - toes 4 → 1; middle toe's hoof; side toes → **splints**
  - front of skull longer
  - lower legs longer; wrist, ankle lifted
  - premolars, molars large, high-crowned, ridged for grass
  - metacarpals, metatarsals → **cannon bone**; radius–ulna, tibia–fibula fused
- cause: forests → **grasslands**; a **bush**, not a ladder (*Hipparion* in Nepal's Siwaliks)

Embryology

- all start as **zygote** → morula → blastula → gastrula → **ectoderm, mesoderm, endoderm**
- early vertebrate embryos (fish, frog, tortoise, pigeon, rabbit, human) alike: **notochord**, **pharyngeal pouches** ("gill slits"), **tail**, 2-chambered heart; kidneys, arteries same pattern
- **recapitulation theory** (biogenetic law, Haeckel 1866): **"ontogeny recapitulates phylogeny"**
  - frog **tadpole**: gills, 2-chambered heart, finned tail → fish-like ancestor
  - *Herdmania* larva: notochord, dorsal nerve cord, tail → adult loses tail and notochord; nerve cord → ganglion → chordate
- not true as Haeckel meant: embryos share **early embryonic** stages, never pass through adult ancestors (von Baer)

Biochemistry and physiology

- **same chemistry**: C, H, O, N (P, S); carbohydrates, lipids, proteins, nucleic acids; DNA, same **genetic code**, 20 amino acids, **ATP** → one ancestor
- **serological (precipitin) test**
  - human serum → rabbit → antibodies → **anti-human serum**
  - mixed with other sera: more alike → **more precipitate**
  - great apes > Old World monkeys > New World monkeys > lemurs > dogs (none)
  - whales closest to **even-toed hoofed mammals** (hippo); king crab *Limulus* → **arachnids**
- **enzymes, hormones**: trypsin, amylase, lipase everywhere; pig and cattle **insulin** for diabetics; mammal thyroxine → tadpole changes early
- **cytochrome c**: chimp identical, rhesus 1, dog ~11, yeast ~44 differences

COMMON MISTAKES

✗ Fish fin and whale flipper: safe analogous example
✓ use **wings of insect and bird**, **stings of bee and scorpion**.

✗ Vestigial organs are useless
✓ reduced; lost their **main** job.

✗ Coccyx is atavism
✓ coccyx is **vestigial**; a baby's tail is atavism.

✗ Convergent and parallel the same
✓ convergent: **unrelated**; parallel: **related** lines.

✗ Embryos repeat adult ancestors
✓ share **early embryonic** stages only.

✗ Horse's teeth became smaller
✓ **larger**, high-crowned, ridged.

✗ Evolution changes an individual
✓ changes **populations** over generations.