Unit 20 · Theories 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:** short (5): how Darwinism explains organic evolution
- **MCQ (1 mark)**
  - not a postulate of Lamarckism (struggle for existence)
  - organs used often (more developed)
  - experiment against acquired characters (Weismann)
  - not one of Darwin's five facts (use and disuse)
  - random change in gene frequency (genetic drift)
  - isolation by barriers (geographical)
- **Short (5 marks, in parts)**
  - Lamarck's postulates with examples; use and disuse
  - Weismann's experiment; germplasm; neo-Lamarckism
  - Darwin's five facts; enormous fertility; three struggles
  - survival of the fittest; natural selection → new species
  - examples: giraffe, DDT, peppered moth
  - criticisms of Lamarckism; of Darwinism
  - Lamarckism vs Darwinism
  - recombination; chromosomal vs gene mutation
  - genetic drift: bottleneck, founder effect
  - reproductive isolating mechanisms

Key terms

Acquired character: change an individual gets in its lifetime (by use, disuse, injury); not inherited.

Somatoplasm: body (somatic) cells; die with the body.

Germplasm: germ cells that make eggs and sperm; only their changes are inherited.

Natural selection: individuals with useful variations survive and **reproduce more**; nature "selects", with no aim.

Fittest: best fitted to the surroundings, leaving the **most young**; not the strongest.

Gene pool: all the alleles of all individuals in a population.

Mutation: sudden, **heritable** change in the genetic material; only source of **new alleles**.

Genetic recombination: reshuffling of two parents' genes into new combinations in the young.

Gene flow (gene migration): movement of alleles between populations by migrants that breed.

Genetic drift (Sewall Wright effect): random change in allele frequencies by **chance**, not selection; strongest in **small** populations.

Isolation: separation of populations so they can no longer interbreed.

Isolating mechanism: Dobzhansky's term (1937): what keeps related populations in one area from interbreeding.

Lamarckism (inheritance of acquired characters)

- **Lamarck** (1744–1829), French; *Philosophie zoologique* (**1809**); first full theory of evolution
- organisms change gradually, over generations, in response to the **environment**; acquired changes passed to the young

Four postulates

- i. **tendency to increase in size**: organisms and parts grow larger, more complex; internal **vital force**
- ii. **direct influence of environment**: new environment → new **needs** → new habits (run faster from a new predator)
- iii. **use and disuse**: organ used → stronger, larger; not used → weakens, shrinks, disappears
- iv. **inheritance of acquired characters**: changes passed to offspring; add up → new species

Lamarck's examples

- **giraffe**: short-necked ancestors stretched necks, legs for high leaves → longer neck inherited
- **duck**: land ancestors paddled; skin between toes stretched → webs
- **snake**: legs not used in narrow places → weakened, lost
- **human appendix**: large, working cecum and appendix for tough plant food; diet changed → small

Criticisms of Lamarckism

- i. not always larger: giant clubmosses, tree ferns → later shrubs, herbs, grasses
- ii. a **new organ** can't grow from need or will
- iii. **injuries, mutilations not inherited**: dogs' ears and tails cut, Chinese girls' feet bound, circumcision → young normal
- iv. use doesn't always improve an organ; what use builds isn't handed on (wrestler's, blacksmith's muscles)

Weismann's tailless mice (1880s)

- tails of white mice cut, **5 generations**, starting with **68** mice
- **901** young: **none** tailless or shorter-tailed
- → body injury **not inherited**

Continuity of germplasm (Weismann, 1892)

- **somatic cells** (somatoplasm): body; die with it
- **germ cells** (germplasm): eggs, sperm in ovaries, testes; passed on
- only **germ-cell** changes inherited; body = carrier of germ cells

Neo-Lamarckism

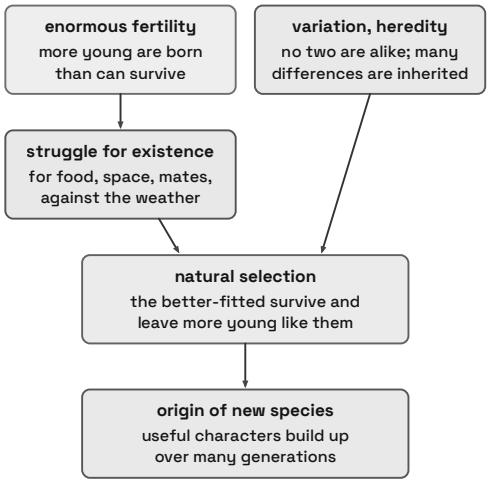
- environment acts **directly on germ cells** (or on the body in ways that reach them) → heritable change
- modern support, in a different form:
  - X-rays, UV, chemicals → **mutations** in germ cells (random, not fitted to need)
  - **bacteria** take up genes, pass them on
  - **epigenetics**: environment-set marks on genes passed a few generations (plants, worms; rare in mammals)
- none makes a used organ grow or an acquired body change hereditary
- what stays true: body characters = **heredity × environment**

Darwinism (natural selection)

- **Darwin** (1809–1882): naturalist on **HMS** *Beagle*, **1831–1836**; South America, **Galápagos**, Australia
- **Wallace** reached the same idea; papers read together **1858**; *On the Origin of Species* **1859**
- Galápagos: ~a dozen related **finches**, beaks of every shape, from one ancestor

Five facts and inferences

- a. **enormous fertility** (prodigality of production): far more young than survive; numbers would grow in **geometric ratio**
  - oyster: up to ~100 million eggs a year
  - starfish: millions of eggs a season
  - *Paramecium*: divides 2–3 times a day
  - Atlantic salmon: 8,000–25,000 eggs
  - elephant (slowest breeder): one pair → **~19 million** in **~750 years**
- b. **struggle for existence**: food, space limited → compete; "struggle" = food, escaping enemies, mates, weather
  - **intraspecific**: same species; **sharpest** (same needs); sal seedlings for light, street dogs over scraps
  - **interspecific**: different species; predator–prey, competitors; tigers and leopards for deer; elephants, rhinos raid crops
  - **environmental**: floods, droughts, cold, landslides, fires
- c. **variation and heredity**: no two alike; variations **useful**, **harmful** or **useless** (neutral); many inherited
- d. **natural selection** (**survival of the fittest**): useful variations → survive, reproduce; phrase by **Herbert Spencer** (1864)
- e. **origin of new species**: useful variations build up over generations; isolated population → new species



Darwin's argument as a chain: overproduction → struggle → variation, inherited → better-fitted leave more young → species changes.

Examples of natural selection

- **giraffe**: necks already varied; low leaves short in dry seasons → long-necked survived, left more young → average neck longer; no neck grew by stretching
- **mosquitoes and DDT** (from 1950s; Nepal's Terai too): a few carried resistance genes → survived, multiplied; DDT **selected**, didn't cause resistance; DDT restricted

(Stockholm Convention 2001); same with bacteria and antibiotics

- **industrial melanism**: **peppered moth** (*Biston betularia*)
  - pale form on lichen-covered bark; black (melanic) form first recorded 1848, Manchester
  - soot killed lichens, blackened bark → birds ate pale moths → by **1895 ~98%** black
  - **Kettlewell** (1950s): marked moths; birds took the form that showed up
  - clean-air laws → bark pale → pale form back (black rare by ~2000)

Criticisms of Darwinism

- i. **no explanation of heredity**: how variations arise, are inherited (Mendel unknown)
- ii. how **small**, not yet useful variations are kept and built up
- iii. **over-specialized** organs: elephant's tusks, deer's antlers (later: **sexual selection**)
- iv. **survival** of the fittest, not **arrival** of the fittest
- v. no distinction between **somatic** and **germinal** variations
- gaps filled by **genetics** → modern synthetic theory

Lamarckism vs Darwinism

Lamarckism	Darwinism
Lamarck, 1809	Darwin (and Wallace), 1858–1859
inheritance of acquired characters	natural selection
variation from need, use and disuse	variations already exist, by chance
environment changes the organism	environment selects among variants
every individual changes the same way	only those with useful variations reproduce
no overproduction or struggle	overproduction, struggle central
giraffe stretched its neck	long-necked giraffes survived droughts
disproved	accepted; joined with genetics

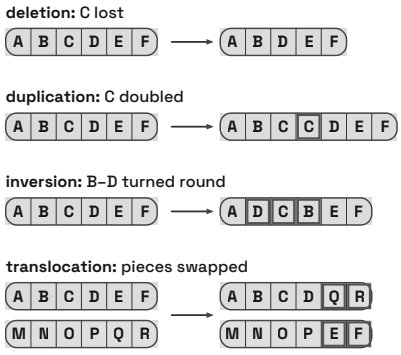
- alike: species change gradually; new from old; organisms come to fit the environment

Modern synthetic theory (neo-Darwinism)

- **~1918–1950**: Darwin's selection + **Mendel's genetics** + populations
  - population genetics: **Fisher**, **Haldane**, **Sewall Wright**
  - **Dobzhansky**, *Genetics and the Origin of Species* (**1937**): foundation book
  - **Mayr** (species), **Julian Huxley** (named it, 1942), **Simpson** (fossils), **Stebbins** (plants)
- **Stebbins**, *Processes of Organic Evolution* (1966): five processes
  - gene mutation
  - chromosome structure and number
  - genetic recombination
  - natural selection
  - reproductive isolation
- evolution = change in **allele frequencies** in the **gene pool** over generations
- **six points**: mutation · recombination (→ **variation**) · gene flow · drift (**movement, chance**) · isolation (**splits**) · natural selection (**sorts**)

i. Mutation

- random; most harmful or neutral; a few useful; raw material of evolution
- **Hugo de Vries**: evening primrose (*Oenothera lamarckiana*), ~1900; *Mutationstheorie* (1901–1903): new species by sudden jumps
- **chromosomal mutation**: seen under microscope
  - structure: **deletion**, **duplication**, **inversion**, **translocation**
  - number: **aneuploidy** (one more or fewer; extra 21 → **Down syndrome**); **polyploidy** (whole extra sets; new plant species in one step; bread wheat: 6 sets)
- **gene (point) mutation**: DNA sequence in a gene
  - **substitution**, **insertion**, **deletion** of bases
  - sickle-cell anemia: one A → T; glutamic acid → valine in hemoglobin
  - insertion, deletion → **frameshift**: every later "word" wrong; worse than substitution



Changes in chromosome structure: deletion, duplication, inversion, translocation.

Chromosomal mutation	Gene mutation
structure or number of chromosomes	DNA sequence of one gene
seen under microscope	not seen
many genes	one gene
Down syndrome; bread wheat	sickle-cell anemia

ii. Genetic recombination

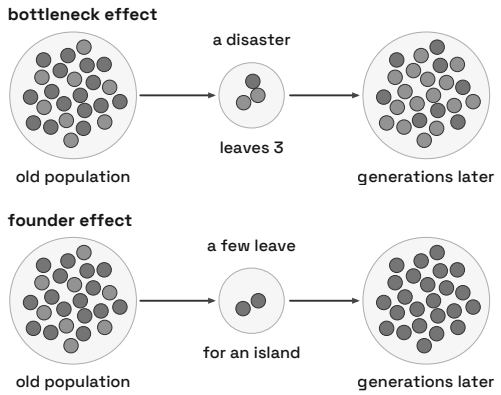
- by:
  - **crossing over** in meiosis
  - **independent assortment**: 23 pairs → $2^{23} \approx 8.4$ million kinds of gamete
  - **random fertilization** (fusion of gametes)
- no new alleles; **new combinations** → main source of variation within a population; selection acts on it

iii. Gene migration (gene flow)

- migrants breed in a new population → **new alleles**, changed frequencies
- keeps neighboring populations **alike** (no split into species)

iv. Genetic drift

- which individuals breed, which alleles reach gametes: partly luck
- large population: chances even out; **small**: allele lost or fixed by chance
- **bottleneck effect**: disaster → few survivors, a **chance sample**; alleles lost; **low diversity** → less able to adapt
  - northern elephant seal: a few dozen (1890s) → 200,000+, almost all alike
  - cheetah: bottleneck ~10,000 years ago; skin grafts not rejected
- **founder effect**: few individuals found a new population → only their alleles
  - Amish (Pennsylvania): ~200 founders, 1700s; **Ellis–van Creveld syndrome** (dwarfism, extra fingers) far commoner



Bottleneck effect (top) and founder effect (bottom).

v. Isolation

- isolated populations change separately (mutation, selection, drift) → may become species
- **geographical isolation**: physical barrier (mountain, river, sea, desert, glacier) → allopatric speciation; Himalaya: Indian vs Tibetan sides
- **reproductive isolation**: no fertile young between species living together; keeps species distinct
  - **premating** (prezygotic):
    - habitat (ecological)
    - seasonal (temporal)
    - behavioral (ethological): songs, dances
    - mechanical: organs, flower parts don't fit
    - gametic: sperm can't fertilize eggs
  - **postmating** (postzygotic):
    - **hybrid inviability**: hybrid dies
    - **hybrid sterility**: **mule** (horse 64 + donkey 62 → 63; can't pair in meiosis)
    - **hybrid breakdown**: hybrids' young weak or sterile

vi. Natural selection

- = **differential reproduction**: better adapted (physically, physiologically, in behavior) leave **more young**
- their alleles commoner; changes allele frequencies **in a direction**
- only process that makes organisms **fit** their way of life

COMMON MISTAKES

✗ Fittest = strongest
✓ leaves the **most young** in its surroundings.

✗ DDT caused resistance in mosquitoes
✓ DDT **selected** mosquitoes already resistant.

✗ Soot turned pale moths black
✓ black form existed; birds ate the **pale** ones.

✗ Darwin couldn't explain vestigial organs
✓ he did: no longer kept by selection, they shrink; give the **five** criticisms above.

✗ Darwin's finches' beaks = founder effect
✓ beaks: **natural selection**; founder effect: the **Amish**.

✗ Recombination makes new alleles
✓ only **mutation**; recombination makes new **combinations**.

✗ Struggle for existence is Lamarck's
✓ **Darwin's**; use and disuse is Lamarck's.