Unit 8 · Mendelian Genetics

STUDY NOTES

WHAT NEB'S GRADE 12 EXAM ASKS

- **CDC's grid (2078):** Genetics (Units 7–10 together): 12 of 75 marks; 1 short question (4 marks: understanding 1, application 2, higher ability 1) and 1 long question (8 marks: understanding 2, application 3, higher ability 3)
- **The paper:** Botany 37 + Zoology 38; each part: MCQs × 1 (5 Botany, 6 Zoology) · 4 short × 4 · 2 long × 8; one OR in each short and long group; 3 hours; 1 mark per expected point
- **CDC's model paper:** long: Mendel's law of independent assortment; the crosses to the F_2 with a checkerboard and the ratios (1 + 3 + 2 + 2)
- **MCQ (1 mark)**
  - gene; homozygous; phenotype
  - gametes of the F_1 of TTRR × ttrr
  - recessive reappears in F_2 (segregation)
  - Rr × rr, Tt × tt: 1 : 1
  - intermediate hybrid → incomplete dominance; red × pink *Mirabilis*: 1 red : 1 pink
- **Short and long (in parts)**
  - dominant, recessive; monohybrid vs dihybrid
  - why Mendel chose peas; law of dominance; independent assortment with a dihybrid cross
  - incomplete dominance vs dominance; AB blood group as codominance
  - TtRr selfed: chance of dwarf white; 9 : 3 : 3 : 1 → which cross, which law
  - blue-eyed pedigree; 302 tall : 99 dwarf genetic diagram; F_2 checkerboard to read

Key terms

Gene: segment of DNA for a protein or functional RNA; unit of heredity.

Allele: one form of a gene, at the same **locus** on homologous chromosomes; dominant capital (T), recessive small (t).

Homozygous: two identical alleles (TT, tt); true-breeding.

Heterozygous: two different alleles (Tt).

Dominant character: appears in F_1; **recessive**: hidden in F_1.

Hybridization: crossing genetically different organisms; **hybrid**: their offspring.

Phenotype: observable character (genotype + surroundings).

Genotype: the alleles inherited; TT and Tt, same phenotype tall.

Monohybrid cross: parents differ in one pair of characters; **dihybrid**: two pairs.

P, F_1, F_2: parents; first filial (Latin *filius*); second filial, from selfing F_1.

Punnett square (Punnett, ~1905): checkerboard of gametes; each box equally likely.

Emasculation: removing stamens before anthers ripen.

Reciprocal cross: the same cross with the sexes swapped.

Incomplete dominance: hybrid in between its parents.

Codominance: both alleles fully expressed in the hybrid.

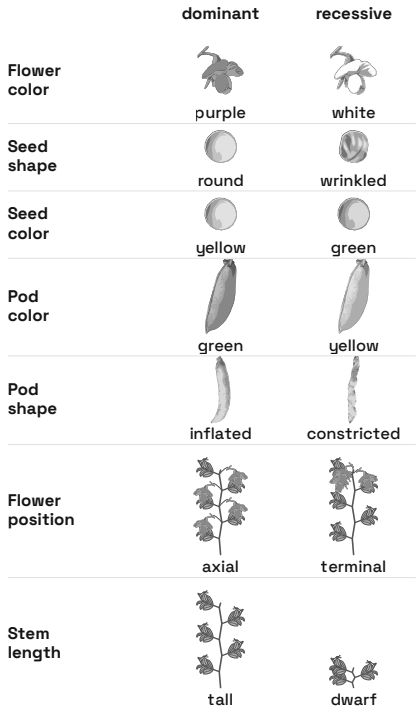
Mendel

- **Gregor Johann Mendel** (1822–1884), Augustinian monk, Brünn (now Brno); physics and maths at Vienna: he **counted**
- 1856–1863, garden pea *Pisum sativum*; 34 varieties → 22 → **7 pairs** of characters
- read to the **Natural History Society of Brünn** (1865); published 1866, *Experiments on Plant Hybrids*; abbot 1868

- rediscovered **1900**: **de Vries** (Netherlands), **Correns** (Germany), **von Tschermak** (Austria); **father of genetics**

Why peas

- clearly contrasting characters
- naturally **self-pollinating** (keel encloses stamens and pistil)
- **cross-pollination** easy by hand
- **short life cycle**
- easy to grow
- **many seeds**
- **fertile hybrids**



Mendel's seven pairs of characters.

Method

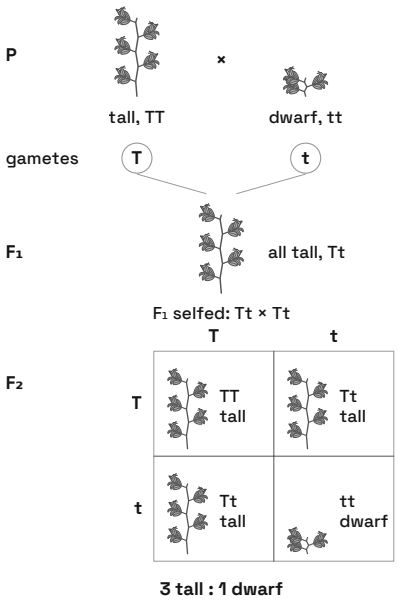
- **true-breeding parents**: selfed for generations
- **hybridization**: one pair at a time, then two
- **emasculation** → pollen of the other parent → bag
- **reciprocal cross**: same result
- **F_1 selfed** in bags → F_2; further generations to test

Monohybrid cross

Generation	Cross or result
P	tall TT × dwarf tt
gametes	all T; all t
F_1	all **Tt**, tall
F_1 selfed	Tt × Tt; gametes ½ T, ½ t
F_2	1 TT : 2 Tt : 1 tt

	♂ T	♂ t
♀ T	TT tall	Tt tall
♀ t	Tt tall	tt dwarf

- **phenotypic 3 : 1**; **genotypic 1 : 2 : 1**
- of the tall F_2, **⅓** pure (TT)
- all seven characters near 3 : 1: total 14 949 : 5010 = **2.98 : 1** (tall 787 : dwarf 277; round 5474 : wrinkled 1850)
- 302 tall : 99 dwarf ≈ 3 : 1 → Tt × Tt
- **Tt × tt** (or Rr × rr) → **1 : 1** (105 round : 99 wrinkled)
- coins: small samples stray; large ones near 3 : 1



A monohybrid cross.

Dihybrid cross

- P: tall purple **TTPP** × dwarf white **ttpp** → F_1 all **TtPp**, tall purple
- F_1 gametes: **TP, Tp, tP, tp**, ¼ each → 16 boxes

	♂ TP	♂ Tp	♂ tP	♂ tp
♀ TP	TTPP	TTPp	TtPP	TtPp
♀ Tp	TTPp	TTpp	TtPp	Ttpp
♀ tP	TtPP	TtPp	ttPP	ttPp
♀ tp	TtPp	Ttpp	ttPp	ttpp

- **phenotypic 9 : 3 : 3 : 1**: tall purple : tall white : dwarf purple : dwarf white
- **genotypic** (9 kinds): 1 TTPP : 2 TTPp : 2 TtPP : 4 TtPp : 1 TTpp : 2 Ttpp : 1 ttPP : 2 ttPp : 1 ttpp
- **new combinations**: tall white, dwarf purple
- each pair alone 3 : 1 (12 : 4); 9 : 3 : 3 : 1 = (3 : 1) × (3 : 1)

- TtRr selfed: dwarf white (ttrr) = **1/16**
- Mendel's seeds: 315 round yellow, 108 round green, 101 wrinkled yellow, 32 wrinkled green (556)
- pea flowers are **purple** (P/p); a question's R for red works the same

Mendel's laws

1. Law of dominance

- two pure contrasting parents → only one character in F_1 (dominant); other hidden (recessive)
- TT × tt → all Tt tall; t hidden, not lost

2. Law of segregation (purity of gametes)

- alleles stay together **unblended** in the hybrid, **separate** in gametes: one each
- every gamete **pure** (T or t)
- proof: **dwarf reappears** in F_2, as dwarf as the grandparent
- basis: homologous chromosomes part in **meiosis**

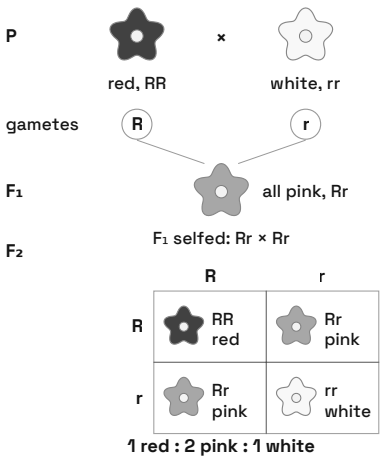
3. Law of independent assortment

- each pair of characters inherited **independently**; alleles of different genes sort at random
- proof: **new combinations** in the F_2 (9 : 3 : 3 : 1)
- holds for genes on **different chromosomes** (or far apart); near ones → **linkage** (Unit 9)
- common ≠ dominant: frequency depends on the population; eye color several genes
- brown-eyed man, blue-eyed mother: man **Bb**, mother bb; father BB or Bb; × blue-eyed woman → ½ Bb, ½ bb

Gene interaction

Incomplete dominance: neither allele dominant; hybrid **in between**

- snapdragon (*Antirrhinum*), four o'clock (*Mirabilis jalapa*), Andalusian fowl (slate-blue)
- *Mirabilis*: red RR × white rr → F_1 all **pink** Rr → F_2 red : pink : white **1 : 2 : 1**
- alleles **don't blend**: red and white come back; one R makes less pigment
- red × pink → 1 red : 1 pink



Incomplete dominance in *Mirabilis*.

Codominance: both alleles **fully** expressed side by side

- **ABO blood group**: I^A (antigen A), I^B (antigen B), i (none); I^A, I^B dominant over i, **codominant with each other**
- $I^AI^A \times I^BI^B$ → all $\mathbf{I^AI^B}$: group **AB**, both antigens
- roan cattle: red RR × white WW → red and white hairs mixed

	Complete	Incomplete	Codominance
hybrid	like dominant parent	in between	both characters
F_2 phenotypes	3 : 1	1 : 2 : 1	1 : 2 : 1
example	tall pea	pink *Mirabilis*	AB blood group

COMMON MISTAKES

✗ The F_2 genotypic ratio is 3 : 1
✓ **1 : 2 : 1**; 3 : 1 is phenotypic.

✗ Recessive alleles are lost in the F_1
✓ hidden; they **reappear** in F_2.

✗ A TtPp plant makes two kinds of gametes
✓ **four**: TP, Tp, tP, tp.

✗ Dominant characters are the commonest
✓ frequency depends on the population.

✗ Pink *Mirabilis* shows alleles blending
✓ alleles stay pure; red and white return.

✗ Codominance gives an in-between color
✓ **both** characters fully shown (AB).

✗ Independent assortment holds for all genes
✓ not for **linked** genes.