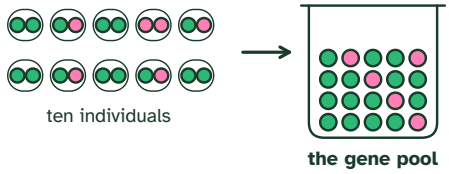
AP BIOLOGY | UNIT 7 | TOPICS 7.4, 7.5 AND 7.11 | REVISION ON TWO PAGES

Evolution, *counted*

What to know, what to draw and what to say. Nothing else.

THE ONE IDEA

Evolution is a change in allele frequencies. Mutation, drift and gene flow move them by chance; Hardy-Weinberg says what no change looks like.



14 of 20 copies: A = 0.7

6 of 20 copies: a = 0.3

add to 1

Count each heterozygote once for each allele. Ten individuals, twenty copies.

7.4.C START HERE

Count the *alleles*, not the animals

- A **gene pool** is every allele that the members of a population carry. A diploid population of N individuals holds **2N copies** of each gene.
- An **allele frequency** is one allele's share of those copies, from 0 to 1. For two alleles the frequencies add to 1. A **genotype frequency** is something else: the share of individuals with one genotype.
- **A change in allele frequencies** over generations is **evidence that a population is evolving**, whatever caused it.

200
copies in 100 diploid mice: 30 BB, 50 Bb, 20 bb

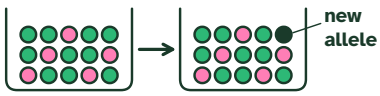
0.55
frequency of B: (2 × 30 + 50) ÷ 200

0.45
frequency of b: (2 × 20 + 50) ÷ 200

7.4.A 7.4.B NEW ALLELES

Mutation

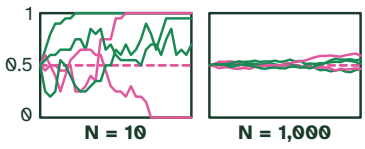
- Mutation is a **random process** that adds new genetic variation. It is the **only source of new alleles**.
- New alleles give **new phenotypes** for natural selection to act on.
- It is random with respect to need: bacteria that grow on an antibiotic plate carried resistance **before** they met the drug.
- For one gene it is rare, so alone it changes frequencies slowly.



7.4.A 7.4.B CHANCE

Genetic *drift*

- **Genetic drift** is a change in allele frequencies by chance, a **nonselective process**: which individuals breed, and which allele each passes on.
- Its effect **depends on population size**: largest in small populations. It can **lose an allele** or fix one, and let a small population **diverge**.



7.4.A TWO KINDS OF DRIFT

Bottlenecks and *founders*

- **Bottleneck effect**: cut to a few for at least one generation. **Founder effect**: a few start a new population.
- Numbers recover; **lost alleles do not**.

BOTTLENECK
Elephant seals
About 20 in the 1890s, over 200,000 now; variation still very low.

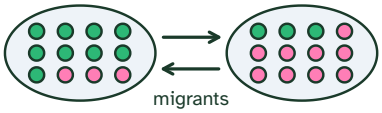
BOTTLENECK
Black robin
5 birds in 1980, one breeding female; all descend from her.

FOUNDER
Old Order Amish
A recessive syndrome far commoner, from one couple of the 1740s.

7.4.A 7.4.B ALLELES THAT MOVE

Gene flow keeps populations *alike*

- **Migration** can result in **gene flow**: alleles added to or removed from a population, but only when migrants **breed**.
- It changes frequencies when migrants' frequencies differ, and so it **prevents divergence** into separate species.
- **Examples:** prairie chickens brought into Illinois from 1992; a wildlife overpass.



7.4.A 7.4.C THE FOUR, TOGETHER

Four ways a gene pool *changes*

PROCESS	RANDOM?	WHAT IT DOES
Mutation	**Yes**	Makes new alleles, slowly, with no regard for need.
Genetic drift	**Yes**	Moves frequencies by chance; strongest in small populations.
Gene flow	**Yes**	Mixes gene pools; makes populations more alike.
Natural selection	**No**	Favors the phenotypes that leave more offspring in that environment.

The course calls mutation, drift and migration random processes.

Hardy-Weinberg, chi-square and why *diversity* matters

7.5.A THE MODEL

A population where *nothing happens*

- **Hardy-Weinberg equilibrium** models allele frequencies in a population that is **not evolving**.
- Its conditions are **never all met**, yet it is useful as a **null hypothesis**: what you would see if nothing were acting.
- Nonrandom mating alone changes **genotype** frequencies (more homozygotes), not allele frequencies.

CONDITION	RULES OUT
B **Large population**	Genetic drift
M **No migration**	Gene flow
M **No new mutations**	New alleles
R **Random mating**	Pairing by genotype
S **No natural selection**	Unequal survival

Big Mice Must Run Slowly

7.5.A ALLELES, THEN PEOPLE

Two *equations*, two ways in

- **$p + q = 1$** is about **alleles**. **$p^2 + 2pq + q^2 = 1$** is about **genotypes**: AA, Aa, aa.
- **Have all three counts?** Count the alleles: always valid. **See only the recessive phenotype?** It is q^2, so $q = \sqrt{q^2}$; this **assumes equilibrium**.
- **Carriers:** 1 in 2,500 affected gives $q^2 = 0.0004$, $q = 0.02$, $2pq = 0.0392$, about 1 in 25.

sperm \ eggs	A p = 0.6	a 0.4
A 0.6	**AA** $p^2 = 0.36$	**Aa** 0.24
a 0.4	**Aa 0.24**	**aa** 0.16

7.5.A 7.4.C CHI-SQUARE

Is this population *evolving*?

- **Null hypothesis:** the population is in equilibrium for this gene, so any difference between observed and expected counts is **due to chance**.
- Count alleles for p and q; expect p^2N, $2pqN$ and q^2N. $\chi^2 = \Sigma(o - e)^2 \div e$.
- The course's rule: 3 classes minus one, so **2 degrees of freedom**, critical value **5.99** at $p = 0.05$. Above it, **reject**; at or below, **fail to reject**, never "accept".

200 MICE	AA	Aa	aa
Observed	90	60	50
Expected	72	96	32
$(o - e)^2 \div e$	4.5	13.5	10.125

$p = 0.6$, $q = 0.4$. $\chi^2 = 28.125 > 5.99$: reject. Too few heterozygotes

7.11.A RESILIENCE

Less *diversity*, less to select from

- A population's ability to respond to a changed environment depends on its **genetic diversity**. Diverse populations are **more resilient**: some individuals can withstand a new pressure.
- Little diversity raises the risk of **decline or extinction**. **Irish potato famine** (1845 to 1852): one clonal variety, the Lumper, fell to the water mold *Phytophthora infestans*.
- An allele **adaptive in one environment** may be **deleterious in another**. One **sickle cell** allele protects against severe malaria; two cause disease.

22 IN 1982
Condor
All 27 in captivity by 1987; 561 in 2022.

18 CAUGHT
Ferret
Nearly all descend from 7 of them.

UNDER 50
Prairie chicken
Eggs failed; birds brought in from 1992.

WATCH OUT

Five mistakes that *cost points*

- ✕ **Natural selection is not random.** Mutation, drift and migration are the random processes.
- ✕ **p is not the dominant phenotype.** p and q are allele frequencies; the dominant phenotype is $p^2 + 2pq$.
- ✕ **Recovered numbers are not recovered diversity.** Only mutation or gene flow adds alleles back.
- ✕ **Drift acts in every population,** not only tiny ones; it matters most where the population is small.
- ✕ **Gene flow needs breeding.** A migrant that leaves no offspring adds no alleles.

COVER THE SHEET

Can you *answer these?*

1. Calculate p and q for 98 GG, 84 Gg and 18 gg.
2. Explain why drift matters more in small populations.
3. Describe a bottleneck and a founder effect.
4. Predict the effect of gene flow on two populations.
5. Identify the five Hardy-Weinberg conditions.
6. Calculate 2pq when 16% show the recessive trait.
7. Justify rejecting a null hypothesis with $\chi^2 = 28.1$.
8. Explain why a clonal crop is at risk from disease.

IN THE EXAM

Write down what p and q stand for before any number, and say when you assume equilibrium. Allele frequencies changing over generations is the evidence of evolution; one count is not.

GO FURTHER

Animated figures, a dry lab and a marked Check are in the full guide online.