Genes and Inheritance

Word cloud

Genotype, Phenotype, Allele, Dominant, Recessive, Co-dominant, Multiple alleles, Test cross, Allelic frequency, Monohybrid, Dihybrid, Gene linkage, Autosomes, Sex chromosomes, X-linked, Epistasis, Gene pool

The Basics

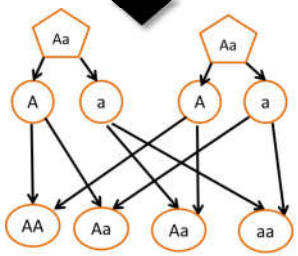
- Each parent passes one set of genes to their offspring.
- Genes have variants called alleles (two or more) which may be dominant, recessive or co-dominant.
- Mathematical rules govern inheritance of genes.
- Genes may be sex-linked.
- Some genes control whether others are expressed.
- All the alleles in a population make up a gene pool.

Genes, alleles and dominance – recap

- **Genotype**: the gene sequence of an individual.
- **Phenotype**: the characteristics caused by a gene sequence, which may be modified by the organism's environment.
- Each individual has two copies of a gene – one from each parent.
- **Alleles** are variants of a gene, with different genetic sequences.
- **Dominant** alleles – are fully expressed when one copy is present.
- **Recessive** alleles – are only expressed if two copies are present.
- For two alleles, write them in different cases – ***A*** and ***a***.

One gene: monohybrid crosses

- An individual with two of the same allele for a gene is **homozygous**.
- An individual with different alleles is **heterozygous**.
- **Example:** the diagram below shows a breeding cross between two pea plants which are **heterozygous** for gene **A**.
- Plants with allele ***A*** have yellow seeds, and plants with allele ***a*** have green seeds.
- The ratio of heterozygotes to homozygotes is 1:1, but *A* is dominant and *a* is recessive – so 75% of the offspring have the yellow seed phenotype (ratio 3:1).



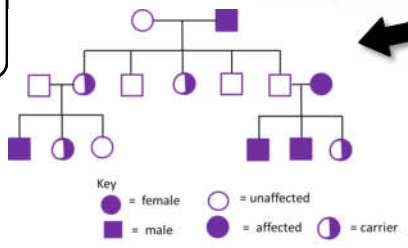
Gene linkage

If two genes are close together on a pair of homologous chromosomes, they are linked – an individual is likely to pass on the alleles which are on the same chromosome together.

Two genes: dihybrid crosses

- You can also study how two genes are inherited at once.
- The pea plant from the monohybrid cross has another gene that controls stalk length – ***T*** (dominant) creates tall stems, while ***t*** (recessive) creates short, dwarf stems.
- Two plants which are heterozygous for A and T are crossed – see the Punnett square below.
- Any of the 16 possible offspring genotypes are equally likely.
- But the ratio of phenotypes is different – 9 tall, yellow (seed); 3 tall, green; 3 short, yellow; 1 short, green (9:3:3:1).

	AT	At	aT	at
AT	AATT	AATt	AaTT	AaTt
At	AAtT	AAtt	AatT	Aatt
aT	aATT	aATt	aaTT	aaTt
at	aAtT	aAtt	aatT	aatt



Sex linkage

- 22 sets of human chromosomes are **autosomes** – the others are the **sex chromosomes**, X and Y (Y is much smaller).
- Some genes are X-linked – males only have one copy, but females have two.
- A male can have a recessive trait if he inherits just one copy of an X-linked gene.
- This Pedigree Diagram shows inheritance of an X-linked condition (haemophilia) through a family.

Co-dominance and multiple alleles

- There may be more than two alleles of a gene across a population.
- For example, human blood type – alleles are I_A, I_B, I_O.
- Sometimes, two alleles are codominant – they are both expressed.
- For blood types, I_A and I_B are co-dominant, and both are dominant over I_O.
- A person with genotype I_AI_B has blood type AB. Someone with I_BI_O has blood type B, and someone with I_OI_O has blood type O.

Epistasis

Sometimes one gene controls whether another is expressed. A gene for flower pigment won't affect a plant which doesn't produce flowers due to a mutation…

Example: for a squash, ***D*** causes white gourds, while ***d*** (recessive) is non-functional. A second gene controls colour – G (dominant) produces yellow gourds, while g (recessive) produces green gourds. However, these genes can only be expressed when the dominant D allele is not expressed.

	DG	Dg	dG	dg
DG	DDGG	DDGg	DdGG	DdGg
Dg	DDgG	DDgg	DdgG	Ddgg
dG	dDGG	dDGg	ddGG	ddGg
dg	dDgG	dDgg	ddgG	ddgg

Dihybrid cross with epistasis: 12 white gourd, 3 yellow, 1 green.

Chi-squared testing

- Genetic crosses such as dihybrid crosses may produce offspring in expected phenotypic ratios.
- However, life isn't that neat – results may be different by chance.
- Or may be complicated by some other factor, such as gene linkage, epistasis or polygenic effects.
- A chi-squared test assesses whether results are different from expected due to chance, or some other factor.

X^2 Formula

$$x^2 = \Sigma \frac{(O-E)^2}{E}$$

Where O is observed results and E is expected results.

Gene pools and allelic frequency

- A population consists of individuals from the same species, in the same place, which may interbreed.
- All the alleles present across the whole population make up the gene pool.
- Allelic frequency – for a specific gene, how common an allele of that gene is in the population. Can be used in the Hardy-Weinberg equation.

Hardy-Weinberg equation:

$$p^2 + 2pq + q^2 = 1$$

where p = dominant allele's frequency, q= recessive allele's frequency.

For a simple dominant-recessive allele relationship, q^2 will be the number of individuals with the recessive phenotype (homozygous recessive). You can use q^2 to work out q, and because there are only two alleles whose frequency must add up to 1, p = 1 – q. From p you can discover p^2 (number of homozygous dominant individuals) and 2pq (number of heterozygotes).

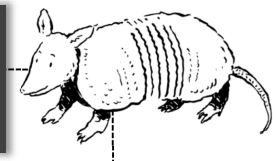
Evolution May Lead to Speciation

The Basics

- Evolution is the process by which organisms become more and more adapted for their environment.
- Variation is the measure by which organisms differ.
- Allele frequency is how often an allele appears in a population.
- Different traits might be selected according to different pressures.
- Speciation is the formation of new species.
- Artificial selection is a forced process by humans.

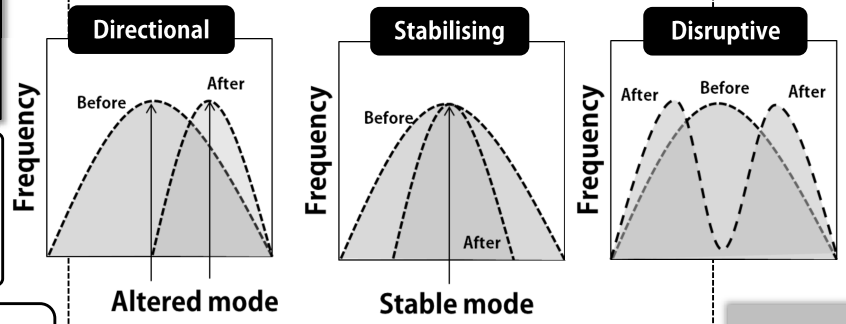
Selection pressure

Where variation exists, the population changes as a result. The changes can force an entire population to adopt the new phenotype, or for extremes of phenotype to be lost.



Same old story!

Disease resistance, breeding advantage or escaping predators.
Throughout biology, organisms with these traits have an advantage – it is these traits, and the organisms that carry them, that benefit the most in biology.



Variation

– Evolution of species depends almost entirely on variation. Variation describes the difference between one organism and another. It can describe genetic variation, or phenotypic variation.

Artificial selection

- Evolution isn't always a natural process.
- Humans often force breeding between organisms to produce beneficial new breeds. This is sometimes called **selective breeding**.

Sources of variation

- Variation occurs most commonly due to **mutation**.
- Changes in the **genome** often result in changes in the phenotype.
- These may be **advantageous** or **disadvantageous**, and might be **inherited** or cause an organism to **die** before reproducing.
- **Meiosis** is another source of variation.
- Random mixing of the chromosomes at meiosis introduces large differences in the genotype.
- The random nature of **fertilisation** also causes variation, with gametes with very different alleles mixing together.

Selection

- **Directional** selection is associated with environmental change – a phenotype on one side of the mean is favoured.
- **Stabilising** selection is associated with **stable** environments where the extreme phenotype is not beneficial.
- **Disruptive** selection describes selection towards **both extremes** in a phenotype, resulting in almost two separate populations.

Gene pool

Term used to describe the collection of all genes present in all species in a population.

Genetic drift

- Genetic drift only happens in **small populations**.
- If an individual (or a small number of individuals) happens to die **without reproducing**, the alleles they carried are **lost**.
- Similarly, if a small group of the population **reproduce more** than would be expected, then the alleles they carry **flood the gene pool**.
- The result is that the gains or losses of these individuals cause a substantial **change in the allele frequency** of the entire population – a **genetic drift** from the norm!

Speciation

- Large change in the allele frequency can lead to the formation of new species.
- New species only form when genetic differences are accumulated.
- Two individuals must become **reproductively isolated** and have very different gene pools to become different species.

So what is evolution?

Quite simply, evolution is the change in the allele frequency in a population. The allele frequency might change so substantially that individuals can no longer breed with each other; they form new species.

Differential reproductive success

- Variation can give some organisms a benefit.
- They might be bigger, stronger, or more attractive to a mate.
- Meanwhile, that same variation may be disadvantageous.
- The difference between these organisms is termed the **differential reproductive success**.

Allopatric

Species can form when they become geographically isolated, leading to different environments.
Examples include an alien species landing on an island, or a natural event, such as an earthquake or a volcano dividing a habitat.
There is no **genetic drift** between individuals, meaning variation increases as species adapt to new environments.

Sympatric

Sympatric speciation does not require geographic isolation. Here, one species gains a mutation that gives an advantage, and allows them to fill a new niche.
The ancestral population do not benefit from the new niche, and continue to thrive without the mutation, allowing both populations to drift apart.

Important

*If an allele offers an organism an advantage, it is more likely to be **inherited**. This leads to an increase in the **allele frequency**. The process that leads to this change in allele frequency is called **natural selection**.*

Word cloud

Stabilising
Allopatric
Sympatric
Gene pool
Genetic drift
Evolution
Variation
Mutation
Inheritance
Meiosis
Differential reproductive success
Allele frequency
Natural selection
Speciation
Directional
Disruptive

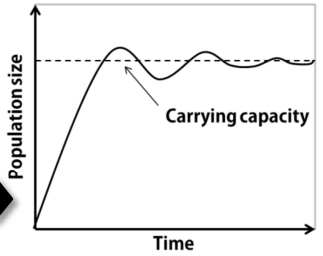
Population in Ecosystems

The Basics

- Populations are groups of individuals that can breed.
- Groups of populations are communities, which with abiotic factors make up ecosystems – they reach carrying capacity.
- Competition and predation affect ecosystems.
- Ecologists count the size of populations.
- They use quadrats, transects and marking.
- New ecosystems are formed by succession.

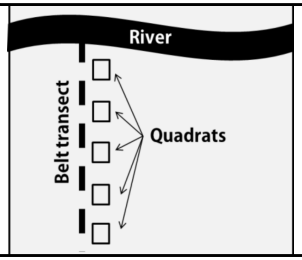
Carrying capacity

- The maximum capacity of an ecosystem.
- Every ecosystem only has a certain amount of resources.
- If the population gets too big, it crashes (lack of food, competition, disease, etc.) bringing the population back down to the carrying capacity.

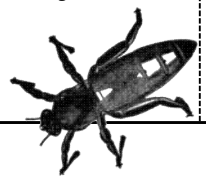


Quadrats and belt transects

- Quadrats are squares placed randomly in an area of interest.
- Count the organisms in the square for an estimate of the population in that environment.
- Belt transects are lines drawn across an environment where an abiotic factor may be present.
- Quadrats are placed along the belt, and organisms are counted along the line to estimate the effect of the abiotic factor.
- These methods are best used on **non-motile** organisms.



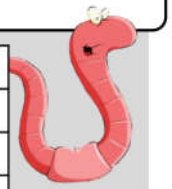
In this experiment, the effect of the river is tested, with multiple quadrats along a transect.



Populations, communities and ecosystems

- **Population** is a group of individuals of the same species in the same place.
- **Community** is a group of populations that exist in the same area.
- Both the living and non-living components of the community is the **ecosystem**.
- Ecosystems vary in size – an entire rainforest is an ecosystem, but so is a single rotten apple for bacteria, worms and decomposers.

Biotic	Abiotic
Available food	Available sunlight
Risk of predation	Wind strength
Disease prevalence	Acidity of soil
Competition	Humidity



Remember

Ecosystems are **dynamic**. They change!
Just because there were 100 ants on a sweet today, doesn't mean there will be 100 ants tomorrow!

Competition

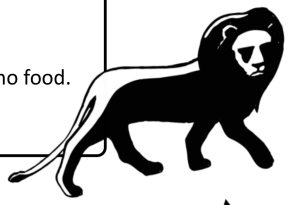
Two types of competition exist: **inter**specific and **intra**specific.

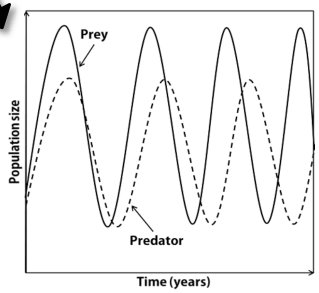
- Interspecific is competition **between different** species.
- Intraspecific is competition **within the same** species.

Species compete for food, water, light, soil, space, mates, etc.

Predation

- Predators eat prey. Prey is a living organism that is eaten.
- The population of predators depends on prey. No prey = no food.
- However, prey depend on predators.
  Too many predators = prey might be wiped out!





Random sampling

Throughout this part you'll hear of counting or estimating numbers. In biology this should always be random. Counting systematically introduces bias which limits the use of the count.

Mark-release-recapture

- Counting moving organisms using a quadrat is very difficult!
- Ecologists capture a small number of animals and mark them.
- They then release those animals back into the wild.
- After a short time, they perform another capture and recount.
- The size of the population can be estimated.

Calculation:

$$\frac{No.\ of\ marked\ in\ sample}{Total\ no.\ in\ sample} = \frac{No.\ of\ marked\ in\ population}{Total\ no.\ in\ population}$$

Assumes that:

- All animals come from the same population
- Marking doesn't make them more likely to be caught/eaten
- No animals entered or left the population
- No births or deaths happened during sampling

Biological niche

The part of the ecosystem in which a species lives is its **niche**. But also the **role** it plays in that space is its niche.
The niche of a worm might be a **rotting apple**, but its niche is also **decomposing** the apple, and also recycling nutrients, increasing availability of nutrients, improving the structure of soil and providing food for their predators.

Odd! The ecological niche of an animal may be to act as prey for another animal!

Succession and its management

- Sand is initially uninhabitable for plants, but some xerophytes, such as marram grass, can settle there. They are named **pioneer species**.
- The marram grass changes the habitat, blocking wind, forming detritus and fixing the sand to trap water.
- These changes make the habitat more suitable for new species.
- New species settle, and make the habitat even more hospitable, while making it inhospitable for the previous species.
- This is **succession** and it can lead to a **climax community**.
- Loss of biodiversity can result from succession.
- This can be **managed** by humans to protect species that are adapted to particular stages in succession.

Word cloud

Population
Community
Ecosystem
Biotic
Abiotic
Predation
Quadrat
Transect
Succession
Niche
Carrying capacity
Competition
Interspecific
Intraspecific