iBLaurel

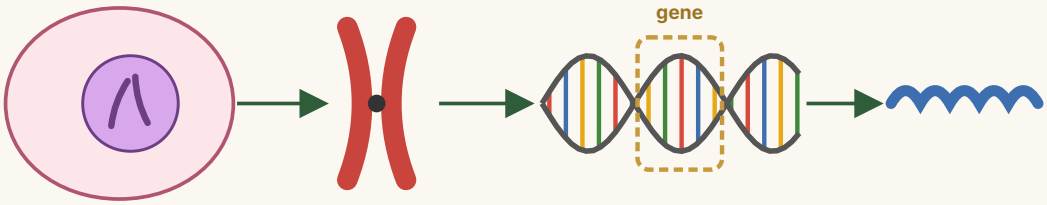
Specialist one-to-one Science, Maths & Economics tuition

AQA GCSE BIOLOGY · SPECIFICATION 4.6

Topic 6: Inheritance, Variation and Evolution

Complete revision & exam preparation guide — key points to memorise, clear diagrams, practice questions and full answers

Key-point notes | Memory hooks | Genetic diagrams | Maths skills | Exam questions + answers



Prepared by iBLaurel · Specialist one-to-one Science, Maths & Economics tuition
Suitable for Foundation and Higher tier · Combined Science (Trilogy) and Separate Biology

START HERE

Contents and how to use this guide

6.1 Sexual and asexual reproduction
6.2 Meiosis and fertilisation
6.3 Pros and cons of each (Bio)
6.4 DNA and the genome
6.5 The structure of DNA (Bio)
6.6 Protein synthesis and mutations (Bio)
6.7 Genetic inheritance: key words
6.8 Genetic diagrams and sex
6.9 Inherited disorders
6.10 Mendel and the history of genetics (Bio)
6.11 Variation
6.12 Evolution by natural selection
6.13 Darwin, Lamarck, Wallace, speciation (Bio)
6.14 Selective breeding
6.15 Genetic engineering
6.16 Cloning (Bio)
6.17 Fossils and extinction
6.18 Antibiotic-resistant bacteria
6.19 Classification
★ One-page memory sheet
✎ Summary questions
✓ Answers and mark scheme

How to use this guide

1. **Read** one section. Study the diagram and say the labels out loud.
2. **Learn the gold "Remember it" box** — short hooks that make facts stick.
3. **Cover and recall:** cover the page, write the key points and **equations** from memory, then check and correct in a different colour.
4. **Read the green "Exam tip" and red "Common mistake" boxes** — they show where marks are won and lost.
5. Finish with the **summary questions** (no notes), then mark them with the **answers**. Re-test the ones you got wrong 2–3 days later.

THE BIG IDEA OF TOPIC 6

DNA carries the code for every characteristic. **Genes** are passed on through **reproduction**, and genetic diagrams let us predict what offspring will inherit. Differences between individuals (**variation**) let **natural selection** act, so species **evolve** over time. Humans can change organisms too — by **selective breeding**, **genetic engineering** and **cloning**.

Key boxes in this guide

Box	What it means
Remember it	Memory hook, rhyme or shortcut to memorise
Exam tip	How to write the answer to get the marks
Common mistake	Errors examiners see every year
Maths skill	Calculations and graph skills you must be able to do
RP	AQA Required Practical — can be asked in the written exam
BIOLOGY ONLY	Only for Separate (Triple) Biology, not Combined Science
HIGHER TIER	Only examined on the Higher tier paper

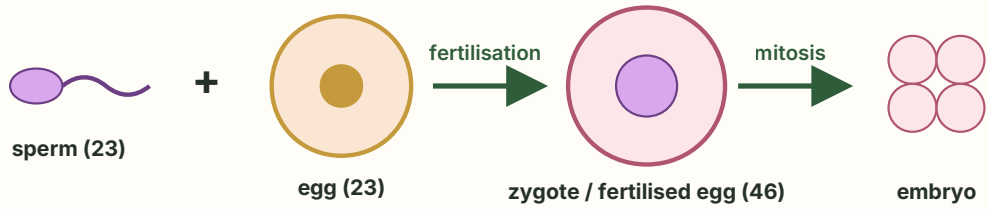
PART A

Reproduction

6.1 Sexual and asexual reproduction

AQA 4.6.1.1

	Sexual reproduction	Asexual reproduction
Parents	**Two** (male + female)	**One**
Gametes?	Yes — **fusion** of male and female gametes	No gametes, **no fusion**
Gametes in animals	**Sperm** and **egg** cells	—
Gametes in flowering plants	**Pollen** and **egg** cells	—
Cell division	Gametes made by **meiosis**	**Mitosis** only
Offspring	Mixture of genetic information → **variation**	**Genetically identical** to the parent — **clones**
Examples	Humans, most animals and plants	Bacteria, some plants (runners, bulbs), some animals



Fertilisation restores the full number of chromosomes

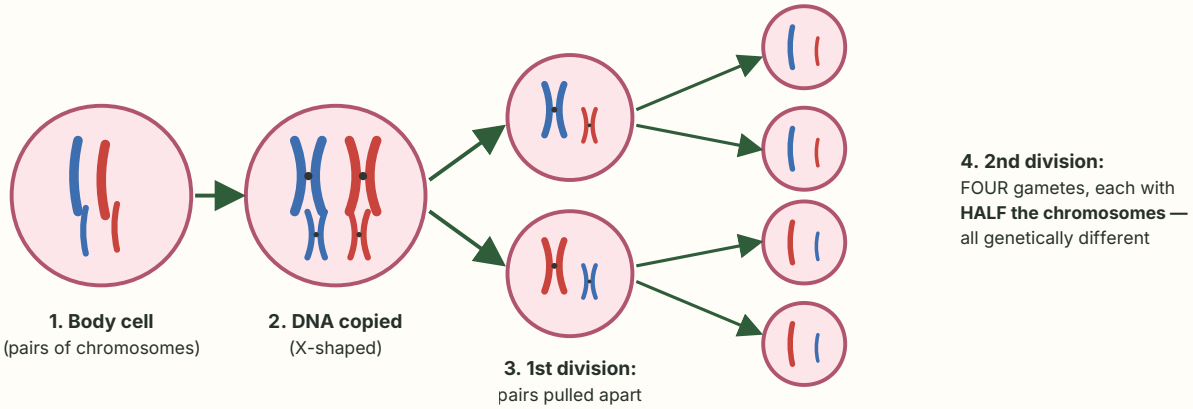
REMEMBER IT

Sexual = Shuffle (two parents, mixing, variation). **Asexual = A copy** (one parent, clones). Gametes have **23** chromosomes; body cells have **46** (23 pairs).

6.2 Meiosis and fertilisation

AQA 4.6.1.2

- **Meiosis** is the cell division that makes **gametes**. In humans it only happens in the **reproductive organs** (ovaries and testes).
- Gametes need **half** the normal number of chromosomes, so that fertilisation gives the right number.



Meiosis: one cell → four genetically different gametes

1. The cell makes **copies** of its genetic information (X-shaped chromosomes).
2. The cell divides **twice**: in the first division the **pairs** are pulled apart; in the second the **arms** of each chromosome are pulled apart.
3. The result is **four gametes**, each with a **single set** of chromosomes.
4. The gametes are all **genetically different** from each other — chromosomes are shuffled at random.

- At **fertilisation**, gametes join to restore the **normal number** of chromosomes.
- The new cell divides by **mitosis**. The number of cells increases and, as the embryo develops, cells **differentiate**.

	Mitosis	Meiosis
Used for	Growth, repair, asexual reproduction	Making gametes
Divisions	One	Two
Cells made	**2**, full set of chromosomes	**4**, half the chromosomes
Genetically	**Identical**	**Different**

REMEMBER IT

Meiosis **Makes Eggs (and sperm)**. Mi**T**osis = **T**wo identical cells; Mei**O**sis = f**O**ur different cells.

6.3 Advantages of sexual and asexual reproduction

AQA 4.6.1.3

BIOLOGY ONLY

Advantages of SEXUAL reproduction

- Produces **variation** in the offspring.
- If the environment changes, variation gives a **survival advantage** by natural selection.
- Humans can use it for **selective breeding** to increase food production.

Advantages of ASEXUAL reproduction

- Only **one parent** needed.
- More **time and energy efficient** — no need to find a mate.
- **Faster** than sexual reproduction.
- Many **identical offspring** can be produced when conditions are favourable.

Some organisms reproduce both ways:

Organism	Sexually	Asexually
Malaria parasite	In the **mosquito**	In the **human host**
Many fungi	Sexual spores → **variation** (often when conditions get worse)	Asexual **spores** → identical fungi
Many plants	**Seeds** (from flowers)	**Runners** (e.g. strawberry plants), **bulb division** (e.g. daffodils)

REMEMBER IT

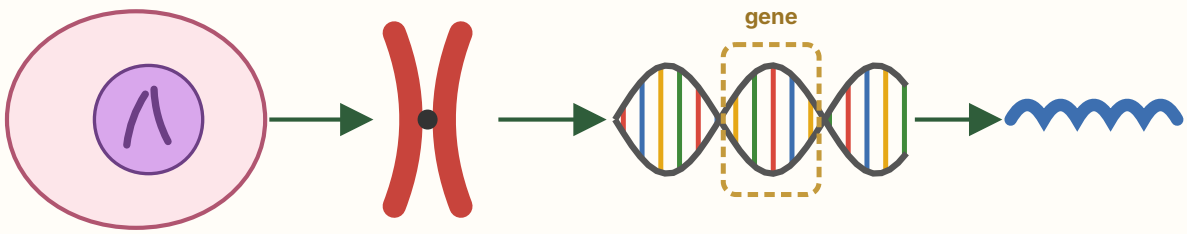
Both ways: **"My Fungi Plant"** → **M**alaria parasite, **F**ungi, **P**lants (strawberries, daffodils).

PART B

DNA and Genetics

6.4 DNA and the genome

AQA 4.6.1.4



cell → nucleus
contains chromosomes

chromosome
long coiled DNA, in pairs

DNA double helix
two strands, a polymer

protein
gene codes for its amino acids

From the nucleus to a protein

- The genetic material in the nucleus is **DNA** (deoxyribonucleic acid).
- DNA is a **polymer** made of **two strands** twisted into a **double helix**.
- DNA is found in structures called **chromosomes**.
- A **gene** is a small section of DNA on a chromosome. Each gene codes for a **particular sequence of amino acids**, to make a **specific protein**.
- The **genome** is the **entire genetic material** of an organism. The whole human genome has now been studied.

Why understanding the human genome is important:

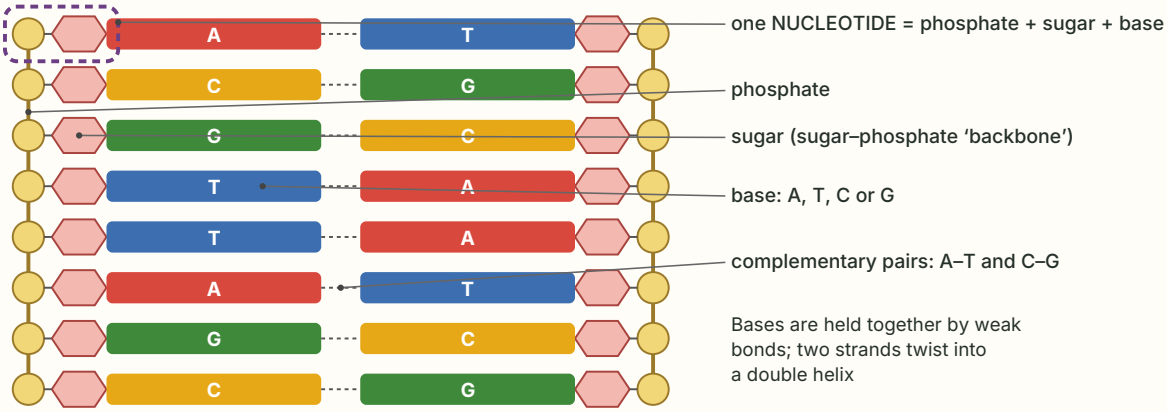
- Searching for **genes linked to different types of disease**.
- Understanding and treating **inherited disorders**.
- Tracing human **migration patterns** from the past (all modern humans came from common ancestors in Africa).

REMEMBER IT

Size order, big to small: **"Nice Cats Don't Grumble"** → **N**ucleus → **C**hromosome → **D**NA → **G**ene.
One gene → one protein.

6.5 The structure of DNA BIOLOGY ONLY

AQA 4.6.1.5



DNA is made of repeating nucleotides

- DNA is a polymer made of repeating units called **nucleotides**.
- Each nucleotide = **a sugar** + **a phosphate group** + **one of four bases** (A, C, G or T).
- The long strands are made of **alternating sugar and phosphate** sections, with a base attached to each sugar.
- On the opposite strand, **C always pairs with G** and **A always pairs with T**. These are **complementary base pairs**.
- The **order of bases** in a gene decides the order of **amino acids** in the protein.
- Each amino acid is coded for by a sequence of **three bases** in the gene.

REMEMBER IT

Base pairs: **"Apple in the Tree, Car in the Garage"** → **A–T**, **C–G**.
3 bases = 1 amino acid.

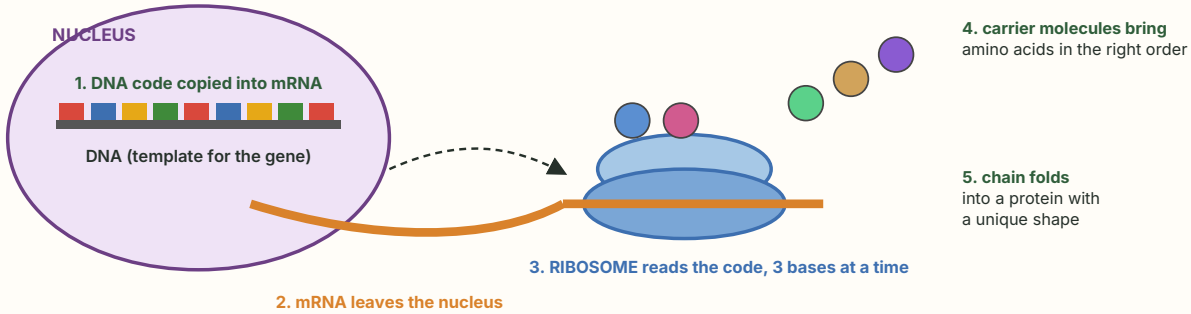
EXAM TIP

If one strand is **ATGCCA**, the complementary strand is **TACGGT**. Count the bases: if 30% of the bases are A, then 30% are T, so C + G = 40% → 20% C and 20% G.

6.6 Protein synthesis and mutations BIOLOGY ONLY

AQA 4.6.1.5

Making proteins HIGHER TIER



How a protein is made from the code in a gene

- Proteins are made on **ribosomes** in the cytoplasm, using the DNA as a **template**.

- The DNA can't leave the nucleus, so the code is copied into a molecule called **mRNA**, which travels to the ribosome.
- **Carrier molecules** bring specific **amino acids** to add to the chain in the correct order.
- When the chain is complete, it **folds** to make a protein with a **unique shape** that lets it do its job.

Protein type	Example
Enzymes	Biological catalysts, e.g. amylase
Hormones	Chemical messengers, e.g. insulin
Structural proteins	Strong proteins, e.g. **collagen** in connective tissue

Mutations

- A **mutation** is a change in the DNA base sequence. Mutations happen **continuously** (randomly).
- **Most** mutations do **not alter** the protein, or only alter it slightly so its appearance or function is not changed.
- A **few** change the protein's **shape**: an **enzyme** may no longer fit its substrate at the active site, or a **structural protein** may lose its strength.
- Not all DNA codes for proteins. **Non-coding** parts switch genes on and off, so a mutation there can change whether a gene is **expressed** HIGHER TIER.

> **REMEMBER IT**
> Protein synthesis: **"Copy, Carry, Read, Build, Fold"** → DNA copied to mRNA, carried to ribosome, read in threes, amino acids built into a chain, chain folds.

6.7 Genetic inheritance: key words

AQA 4.6.1.6

Most characteristics are the result of **several genes interacting**. A few are controlled by a **single gene**, e.g. **fur colour in mice** and **red-green colour blindness** in humans.

Word	Meaning	Example
Gamete	A sex cell (sperm or egg) with half the chromosomes	Sperm, egg, pollen
Allele	A **different version** of the same gene	B or b
Dominant	An allele that is **always expressed**, even if only one copy is present (capital letter)	B
Recessive	An allele only expressed if **two copies** are present (small letter)	b
Homozygous	Two **identical** alleles	BB or bb
Heterozygous	Two **different** alleles	Bb
Genotype	The **alleles** an organism has	Bb
Phenotype	The **characteristic** that is shown	Brown eyes

REMEMBER IT

Genotype = **Gene letters**; **Pheno**type = what you can **Physically** see.
Homo = the **same** (like homogenised); **Hetero** = **different**.
Recessive needs **two** to show — it "**recedes**" (hides) behind a dominant allele.

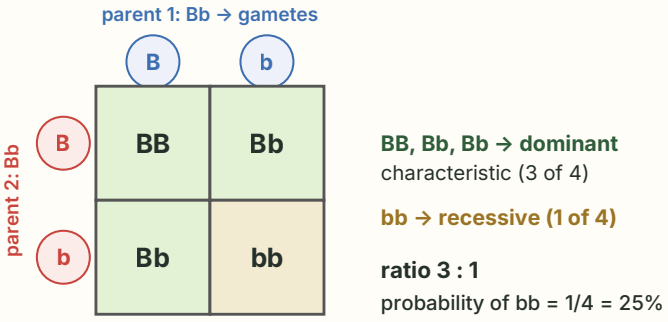
COMMON MISTAKE

Use the **same letter** for both alleles of one gene: **B** and **b** — not B and r. Choose a letter whose capital and small forms look different (e.g. B/b, not C/c or S/s).

6.8 Genetic diagrams and sex determination

AQA 4.6.1.6, 4.6.1.8

Genetic diagrams (**Punnett squares**) show the possible combinations of alleles in the offspring, and the **probability** of each.



Cross between two heterozygous parents (Bb × Bb)

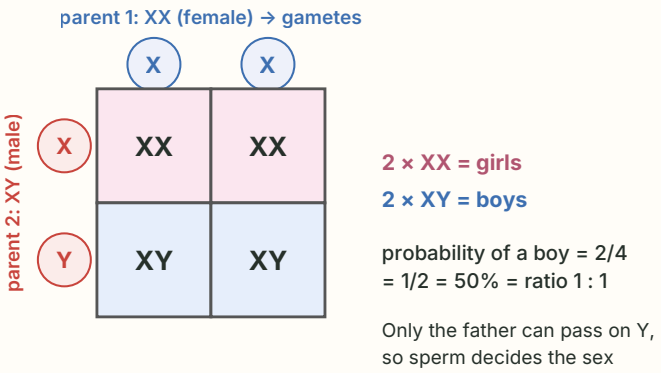
How to draw a Punnett square:

1. Write the **parents' genotypes**.
2. Split each into its **gametes** (one allele each).
3. Put one parent's gametes across the top and the other's down the side.
4. Fill in each box with the alleles from its row and column.
5. Work out the **phenotypes**, then the **ratio**, **probability** or **percentage**.

Cross	Offspring genotypes	Phenotype ratio
BB × bb	all Bb	**All** dominant
Bb × Bb	1 BB : 2 Bb : 1 bb	**3 : 1** (75% dominant, 25% recessive)
Bb × bb	2 Bb : 2 bb	**1 : 1** (50% each)

Sex determination

- Human body cells have **23 pairs** of chromosomes. **22 pairs** control characteristics only; **one pair** are the **sex chromosomes**.
- **Females** are **XX**; **males** are **XY**. The Y chromosome causes male characteristics.



There is always a 50% chance of a boy or a girl

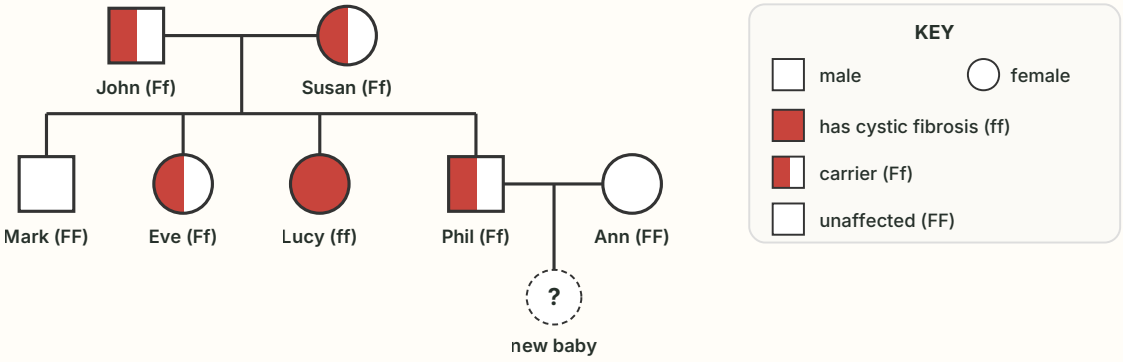
EXAM TIP

A Punnett square gives **probabilities**, not certain outcomes. A 3 : 1 ratio means each child has a **3 in 4 (75%)** chance of the dominant phenotype. Constructing your own Punnett square from scratch and using probability to make predictions is **Higher tier**; all students must be able to complete one.

6.9 Inherited disorders and family trees

AQA 4.6.1.7

	Polydactyly	Cystic fibrosis
What it is	Having **extra fingers or toes**	A disorder of **cell membranes** — thick, sticky mucus in the lungs and digestive system
Allele	**Dominant** (D)	**Recessive** (f)
Inherited if	**One parent** has it (only one allele needed)	**Both parents** pass on the allele (ff); carriers (Ff) are unaffected
Chance	Dd × dd → **50%**	Ff × Ff → **25%**



Family tree for cystic fibrosis

- Lucy has cystic fibrosis but neither parent does, so John and Susan must both be **carriers (Ff)** — the allele is recessive.
- Phil (Ff) and Ann (FF) can't have a child with CF: the baby has a **50% chance** of being a carrier and a 50% chance of being FF.

Embryo screening and gene therapy

- **Embryo screening**: during IVF a cell is removed from each embryo and its genes analysed, so embryos without the disorder can be chosen.

- **Gene therapy** may one day replace faulty alleles with healthy ones.

✓ For screening	× Against screening
Reduces suffering · treating disorders costs a lot of money · laws stop it being used for non-medical choices	Implies people with disorders are 'undesirable' → **prejudice** · could lead to 'designer babies' · **expensive** · embryos are destroyed (ethical/religious issues)

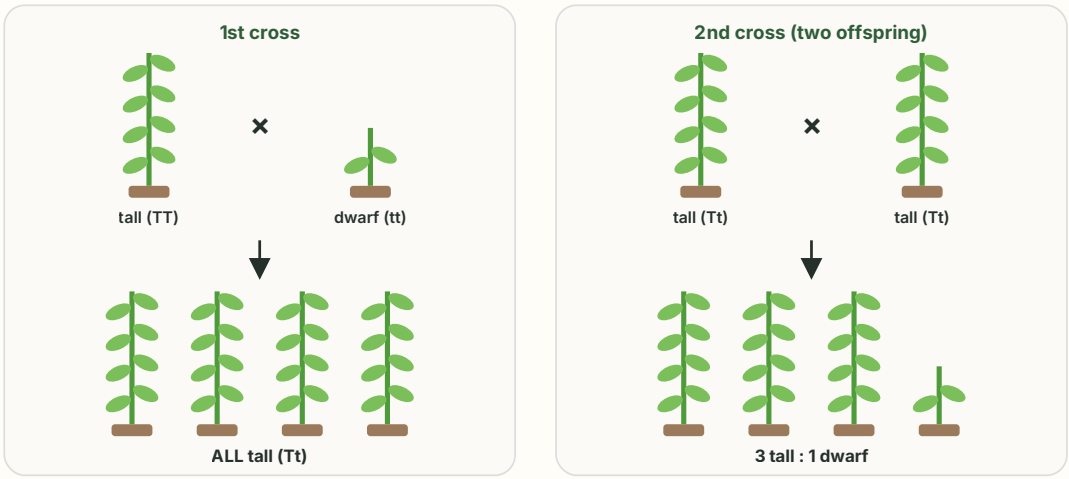
REMEMBER IT

Polydactyly = **P**owerful (dominant) — one parent is enough. **Cystic** fibrosis = **C**arriers — needs two recessive alleles.
Issues = **"ESE"**: **E**conomic, **S**ocial, **E**thical.

6.10 Mendel and the history of genetics BIOLOGY ONLY

AQA 4.6.3.1

- **Gregor Mendel** was a monk who carried out breeding experiments on **pea plants** in the mid-1800s.



Mendel's crosses of tall and dwarf pea plants

Mendel's conclusions: characteristics are determined by **'hereditary units'**; one unit is passed on from **each parent**, unchanged; units can be **dominant or recessive**.

When	Discovery
1866	Mendel published his work — but its importance wasn't recognised until **after his death** (no one knew about genes, DNA or chromosomes)
Late 1800s	Scientists observed **chromosomes** during cell division
Early 1900s	Chromosomes and Mendel's units were seen to behave in the same way → the units (**genes**) are on chromosomes
1953	The **structure of DNA** was worked out, then how genes work

REMEMBER IT

Mendel → **M**onk → **M**ini peas. Timeline: **"Peas, Chromosomes, Genes, DNA"**.

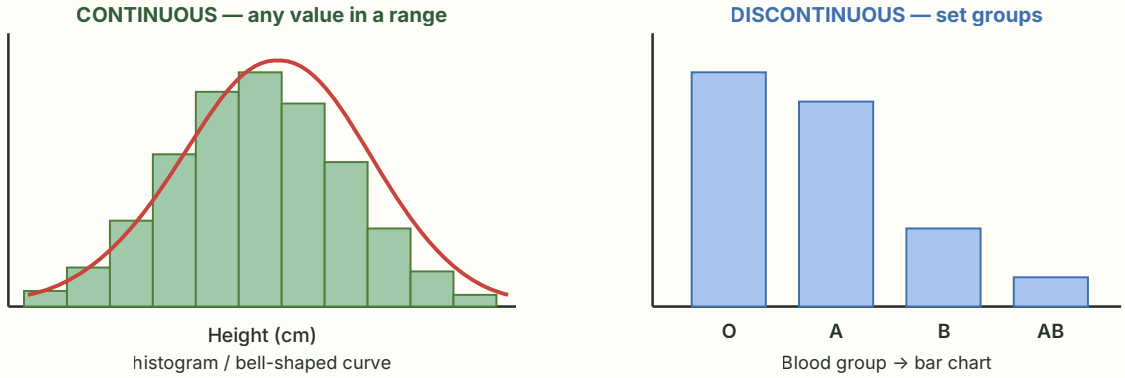
PART C

Variation and Evolution

6.11 Variation

AQA 4.6.2.1

- Differences in the characteristics of individuals in a population are called **variation**. It may be due to:
- **Genes** they inherit — **genetic causes** (e.g. eye colour, blood group).
- The **conditions** in which they develop — **environmental causes** (e.g. scars, language spoken, a plant in shade growing tall and thin).
- A **combination** of genes and environment — most characteristics (e.g. height, weight, intelligence).



Continuous and discontinuous variation

- There is usually extensive **genetic variation** within a population of a species.
- All variants arise from **mutations**. Most have **no effect** on the phenotype; some **influence** it; very few determine it.
- Mutations happen continuously. Very rarely a mutation gives a **new phenotype**; if it suits the environment, it can lead to a **relatively rapid change** in the species.

REMEMBER IT

Variation = **Genes + Environment** (most things are **both**). Identical twins are useful: any differences between them must be **environmental**.

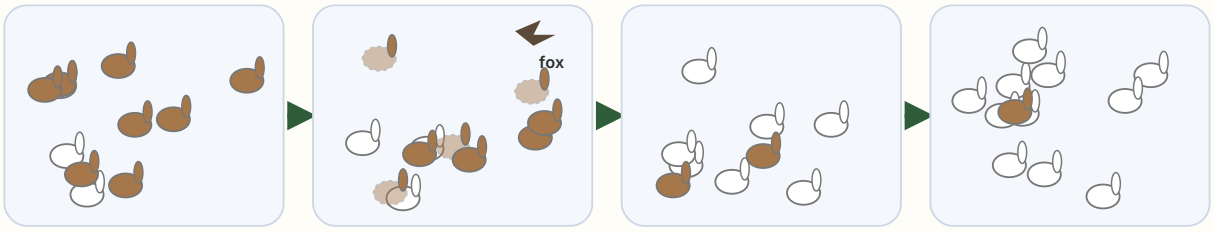
6.12 Evolution by natural selection

AQA 4.6.2.2

DEFINITION — LEARN IT

Evolution is a change in the inherited characteristics of a population over time through a process of **natural selection**, which may result in the formation of a **new species**.

- The theory states that all species of living things have evolved from **simple life forms** that first developed **more than three billion years ago**.



Natural selection in four steps

1. Individuals in a species show **variation**, caused by differences in their **genes** (from mutations).
2. Organisms **compete** for limited resources (food, mates, territory) and face predators and disease.
3. Individuals with characteristics **best suited** to the environment are more likely to **survive and breed** — 'survival of the fittest'.
4. They pass on their **alleles** to their offspring.
5. Over many generations, the useful characteristic becomes **more common** in the population.

- If two populations of one species become so different in phenotype that they can **no longer interbreed to produce fertile offspring**, they have formed **two new species**.

REMEMBER IT

Natural selection: **"VCSPM"** — **"Very Clever Squirrels Pass Messages"** → **V**ariation, **C**ompetition, **S**urvival of the best adapted, **P**ass on alleles, **M**ore common over time.

COMMON MISTAKE

Animals do **not** change **because** they need to or want to. The variation is already there (from random mutations); the environment **selects** which individuals survive.

6.13 Darwin, Lamarck, Wallace and speciation

AQA 4.6.3.2–4.6.3.4

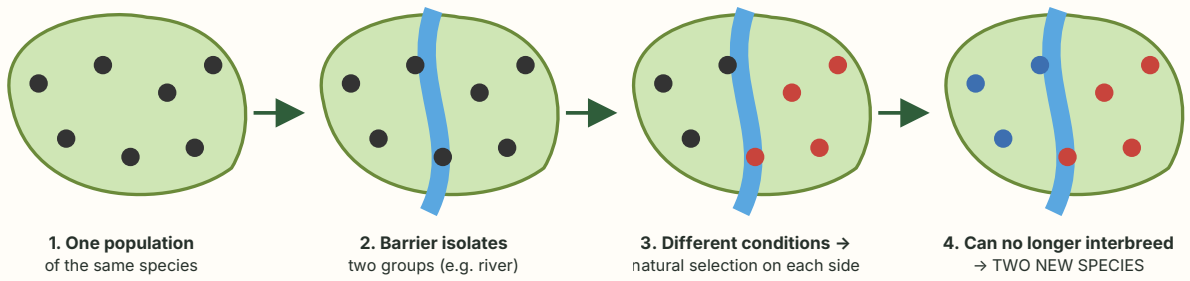
BIOLOGY ONLY

Scientist	Idea
Charles Darwin	Theory of evolution by **natural selection**, from his round-the-world voyage, experiments, discussions and knowledge of geology and fossils. Published **'On the Origin of Species' (1859)**
Jean-Baptiste Lamarck	Changes that happen to an organism **during its lifetime** can be inherited (e.g. a much-used leg gets longer, and offspring are born with longer legs). We now know this is **wrong** in most cases
Alfred Russel Wallace	Independently proposed natural selection and published with Darwin; studied **warning colouration**; best known for his work on **speciation**

Why Darwin's theory was only gradually accepted:

- It **challenged the idea that God made all living things**.
- There was **not enough evidence** at the time to convince many scientists.
- The **mechanism of inheritance** and variation was not known until 50 years later (genes).

Speciation



Speciation by isolation and natural selection

- A **species** is a group of similar organisms that can **reproduce to give fertile offspring**.
- **Isolation**: populations of a species are separated, e.g. by a **physical barrier** (floods, earthquakes, mountains).
- Conditions on each side are slightly different, so **natural selection** favours different alleles in each population.
- Eventually the populations become so different they **can't interbreed** to produce fertile offspring — they are **separate species**.

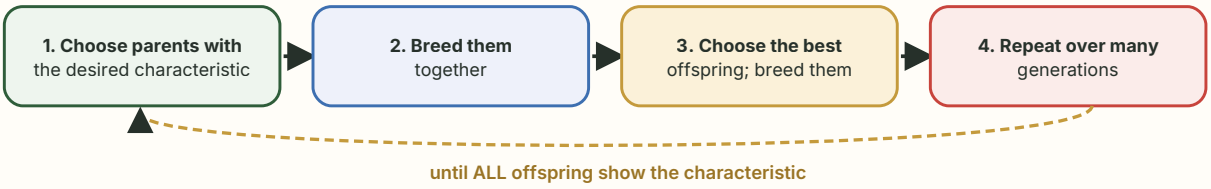
REMEMBER IT

Lamarck = **L**ifetime changes (wrong). **D**arwin = **D**ifferences already there, environment selects. **W**allace = **W**arning colours and speciation.
Speciation: **"Isolate, Select, Separate"**.

6.14 Selective breeding

AQA 4.6.2.3

- **Selective breeding** (artificial selection) is when **humans** breed plants and animals for **particular genetic characteristics**.
- Humans have done this for thousands of years — e.g. crops from wild plants and domesticated animals.



The process of selective breeding

Characteristics chosen for: disease resistance in food crops · animals that produce **more meat or milk** · domestic dogs with a **gentle nature** · **large or unusual flowers**.

Problem	Why
Inbreeding	Breeding closely related animals makes some breeds prone to **disease or inherited defects** (e.g. breathing problems in pugs)
Reduced gene pool	Fewer different alleles → if a new disease appears, there may be **no resistant individuals**, so all could be killed

REMEMBER IT

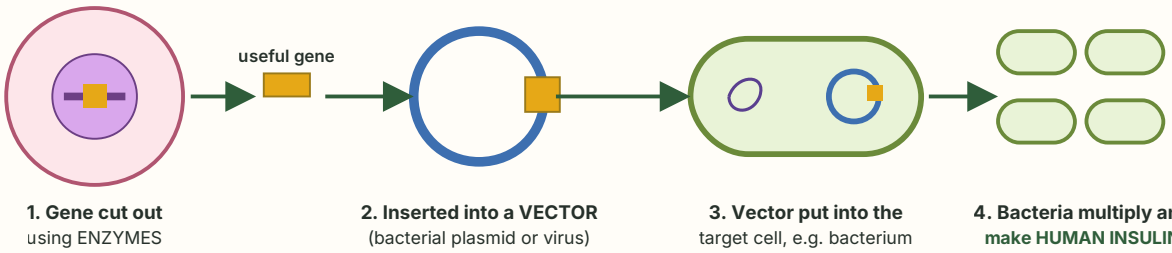
Selective breeding = **"Pick, Pair, Pick, Repeat"**. Downside: **small gene pool** → inbreeding → disease risk.

6.15 Genetic engineering

AQA 4.6.2.4

- **Genetic engineering** modifies the **genome** of an organism by introducing a **gene from another organism** to give a desired characteristic.
- **Bacterial cells** have been engineered to produce **human insulin** to treat diabetes.
- Plant crops have been **genetically modified (GM)** to be resistant to diseases, insects or herbicides, or to produce bigger, better fruits.
- Scientists are researching **gene therapy** — using genetic engineering to overcome some **inherited disorders**.

The process HIGHER TIER



Genetic engineering to make human insulin

1. **Enzymes** are used to **isolate** (cut out) the required gene.
2. The gene is inserted into a **vector**, usually a **bacterial plasmid** or a **virus**.
3. The vector is used to insert the genetic material into the required cells.
4. Genes are transferred to animals, plants or microorganisms at an **early stage of development**, so all their cells get the gene.

✓ Benefits of GM crops	× Concerns
Increase **yields** → more food · resistant to pests and disease · can add nutrients (e.g. golden rice with vitamin A)	Effect on **wild flowers and insects** (biodiversity) · effects of eating GM food on **human health** not fully explored · genes could spread to wild plants (e.g. 'superweeds')

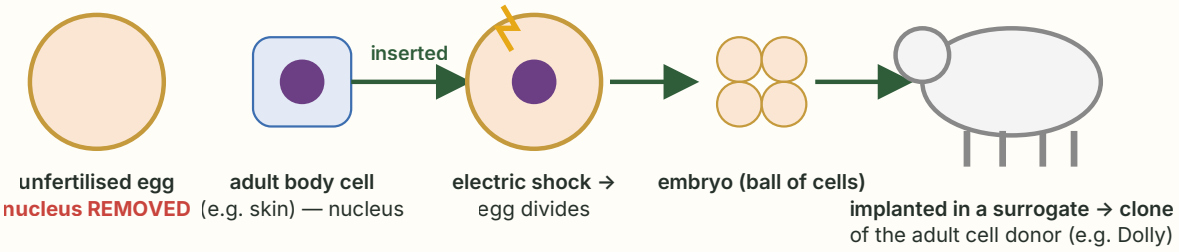
REMEMBER IT

Genetic engineering: **"Cut, Paste, Deliver"** → enzymes cut the gene, paste it into a vector, vector delivers it to the cell.

6.16 Cloning BIOLOGY ONLY

AQA 4.6.2.5

Method	How it works
Tissue culture	Small groups of cells from part of a plant are grown in a medium with hormones → new plants. Used to preserve **rare plant species** and by nurseries
Cuttings	An older, simple method: gardeners cut part of a plant and grow it into a new plant — quick and cheap
Embryo transplants	Cells are split apart from a developing **animal embryo** before they specialise; the identical embryos are transplanted into host mothers
Adult cell cloning	See diagram below — used to create **Dolly the sheep**



Adult cell cloning

1. The **nucleus is removed** from an unfertilised egg cell.
2. The nucleus from an **adult body cell** (e.g. skin) is inserted into the egg cell.
3. An **electric shock** stimulates the egg to divide and form an embryo.
4. The embryo cells contain the same genetic information as the adult skin cell. When it is a ball of cells, it is **implanted into the womb** of an adult female.

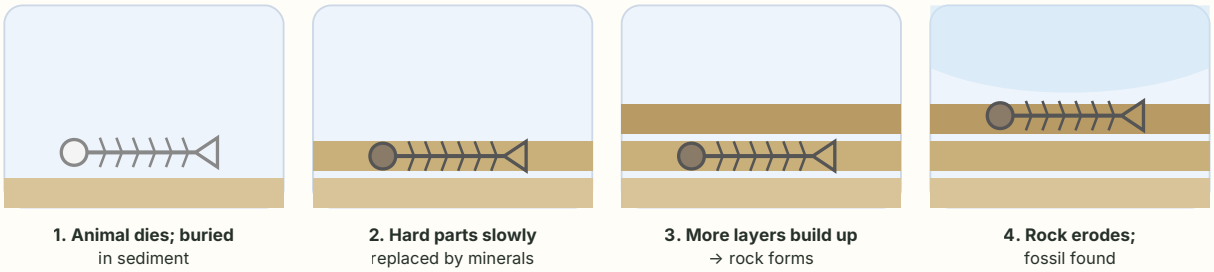
Issues: clones have a **reduced gene pool** (all vulnerable to the same disease) · cloned animals may not be as healthy · some people worry about **human cloning**. But cloning could help save **endangered species** and help research into embryos and ageing.

> **REMEMBER IT**
> Adult cell cloning: **"Empty, Insert, Shock, Implant"**. The clone is identical to the animal that gave the **body cell**, not the egg.

6.17 Fossils and extinction

AQA 4.6.3.5–4.6.3.6

- **Fossils** are the **remains of organisms** from millions of years ago, found in rocks. They give **evidence** for evolution.



How most fossils form: gradual replacement by minerals

How fossils form	Details
Gradual replacement by minerals (most fossils)	Hard parts like bones, shells and teeth are slowly replaced by minerals, forming rock in the same shape
Casts and impressions	Traces such as **footprints, burrows** and **root pathways** are pressed into soft material that hardens
Preservation where there is no decay	Conditions needed for decay are absent: **amber** and tar pits (no oxygen or moisture), **glaciers** (too cold), **peat bogs** (too acidic)

- We can't be certain **how life began**: many early forms were **soft-bodied** and left few traces, and many fossils were destroyed by **geological activity**. So the fossil record is **incomplete**.

Extinction

A species is **extinct** when there are **no remaining individuals**. Causes:

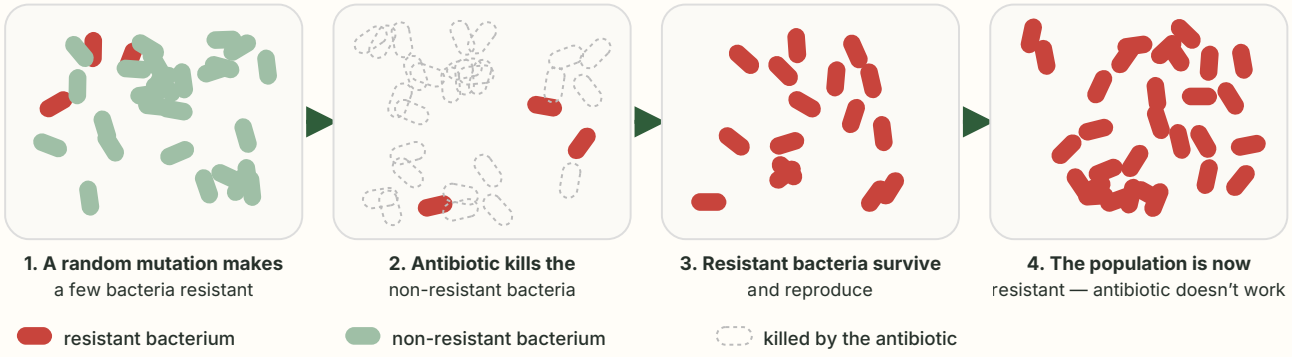
- The **environment changes** too quickly (e.g. habitat destruction).
- A new **predator** kills them all (e.g. humans hunting them).
- A new **disease** kills them all.
- They can't **compete** with another species for food.
- A **catastrophic event** (e.g. a volcanic eruption or asteroid collision).

> **REMEMBER IT**
> Fossils form when **decay can't happen**: no oxygen, too cold, too acidic. Extinction causes: **"Every Predator Destroys Cute Creatures"** → **E**nvironment, **P**redators, **D**isease, **C**ompetition, **C**atastrophe.

6.18 Antibiotic-resistant bacteria

AQA 4.6.3.7

- Bacteria can evolve **rapidly** because they **reproduce** very quickly — this is **evidence for evolution** we can watch happening.



How antibiotic resistance spreads by natural selection

- **Mutations** in bacteria produce new **strains**. Some might be **resistant** to antibiotics, so they aren't killed.
- The resistant bacteria **survive and reproduce**, so the resistant strain spreads.
- People aren't **immune** to the new strain and there is **no effective treatment**, e.g. **MRSA**.

To reduce the rate of resistance developing
Doctors should **not prescribe antibiotics** for non-serious or **viral** infections
Patients should **complete the full course**, so all bacteria are killed and none survive to mutate
Restrict the use of antibiotics in **farming**

- Developing **new antibiotics** is costly and slow, so it is unlikely to keep up with new resistant strains.

REMEMBER IT

Resistance = **natural selection in fast-forward**: **Mutate → Survive → Multiply**.

6.19 Classification

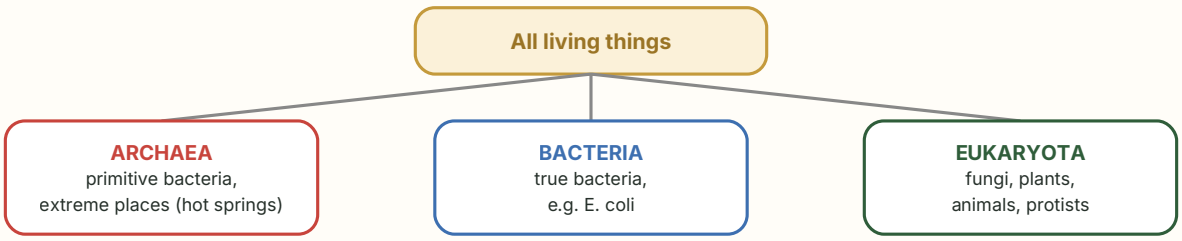
AQA 4.6.4

- **Carl Linnaeus** classified living things based on their **structure and characteristics**, into groups of decreasing size:



The Linnaean system

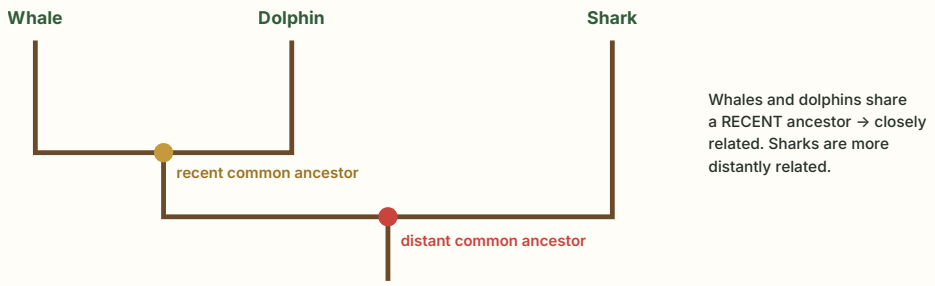
- Organisms are named using the **binomial system**: **genus + species**, e.g. *Homo sapiens*. Scientists everywhere use the same name.
- Better **microscopes** and understanding of **biochemical processes** led to new models of classification.



Carl Woese's THREE-DOMAIN system (1990) — based on chemical analysis (e.g. RNA)

The three-domain system

- **Carl Woese** proposed the **three-domain system**, using evidence from chemical analysis. It showed some species are not as closely related as first thought.
- **Archaea** (primitive bacteria, often in extreme places) · **Bacteria** (true bacteria) · **Eukaryota** (protists, fungi, plants and animals).



An evolutionary tree

- **Evolutionary trees** show how scientists think organisms are related. They use **classification data** for living organisms and the **fossil record** for extinct ones.

REMEMBER IT

Ranks: **"King Philip Came Over For Good Soup"** → Kingdom, Phylum, Class, Order, Family, Genus, Species.
Domains: **"ABE"** → **A**rchaea, **B**acteria, **E**ukaryota.

★ LAST-MINUTE

One-page memory sheet

Topic	Must-know facts
Reproduction	Sexual: 2 parents, gametes fuse (meiosis), variation. Asexual: 1 parent, mitosis, clones. Bio: sexual → variation/survival; asexual → fast, no mate. Both: malaria parasite, fungi, plants.
Meiosis	DNA copied, two divisions → 4 genetically different gametes, half the chromosomes. Fertilisation restores 46; then mitosis + differentiation.
DNA + genome	Polymer, two strands, double helix, in chromosomes. Gene codes for amino acid sequence → protein. Genome uses: disease genes, inherited disorders, migration.
DNA structure (Bio)	Nucleotide = sugar + phosphate + base. A–T, C–G. 3 bases = 1 amino acid. HT: mRNA → ribosome; carrier molecules bring amino acids; folds.
Mutations	Random, continuous. Most no effect; some change protein shape (enzyme active site, structural strength). Non-coding mutations affect expression (HT).
Key words	Allele, dominant, recessive, homozygous, heterozygous, genotype, phenotype. Single-gene: mouse fur colour, red-green colour blindness.
Genetic crosses	BB × bb → all dominant. Bb × Bb → 3 : 1. Bb × bb → 1 : 1. Sex: XX female, XY male; 50% boy.
Disorders	Polydactyly: dominant. Cystic fibrosis: recessive, cell membranes, carriers. Embryo screening: economic, social, ethical issues.
Mendel (Bio)	Pea plants; hereditary units; dominant/recessive; not recognised till after death. Chromosomes (late 1800s), genes on chromosomes (1900s), DNA structure (1953).
Variation	Genetic, environmental or both. Mutations → new variants; rarely new phenotype.
Natural selection	Variation → competition → best adapted survive + breed → pass on alleles → more common. New species when can't produce fertile offspring.
Darwin etc. (Bio)	Darwin (Origin of Species 1859) — slow acceptance: religion, little evidence, no genes. Lamarck: acquired characteristics. Wallace: speciation, warning colours. Speciation: isolation + natural selection.
Selective breeding	Choose parents, breed, repeat. Disease resistance, meat/milk, gentle dogs, flowers. Inbreeding, small gene pool.
Genetic engineering	Gene from one organism into another: insulin bacteria, GM crops, gene therapy. HT: enzymes cut, vector (plasmid/virus), early stage. Concerns: wildlife, health.
Cloning (Bio)	Tissue culture, cuttings, embryo transplants, adult cell cloning (remove egg nucleus, insert body-cell nucleus, shock, implant — Dolly).
Fossils + extinction	Mineral replacement, casts/impressions, no decay (amber, ice, peat). Record incomplete. Extinction: environment, predator, disease, competition, catastrophe.
Resistant bacteria	Mutation → resistant strain survives + spreads (MRSA). Don't over-prescribe; finish course; less use in farming.
Classification	Kingdom → Species; binomial (genus + species). Woese: Archaea, Bacteria, Eukaryota. Evolutionary trees.

PRACTICE

Summary questions

Try every question **without notes**. Tick each one you get fully right; redo the rest in 2–3 days. Answers are in the next section. Questions marked **(Bio)** are for Separate Biology only; **(HT)** are Higher tier only.

Section A — Quick recall (1–2 marks each)

1. Name the male and female gametes in animals.
2. Name the gametes in flowering plants.
3. Which type of reproduction produces genetically identical offspring?
4. Which type of cell division produces gametes?
5. How many gametes are produced from one cell in meiosis?
6. How many chromosomes are in a human gamete?
7. (Bio) Give two advantages of asexual reproduction.
8. (Bio) Describe how strawberry plants reproduce asexually.
9. What is DNA made of?
10. What is a gene?
11. What is a genome?
12. Give one reason why understanding the human genome is important.
13. (Bio) What three parts make up a nucleotide?
14. (Bio) Which bases pair together in DNA?
15. (Bio) How many bases code for one amino acid?
16. (Bio, HT) Where in the cell are proteins made?
17. (Bio) Give one way a mutation could affect the function of an enzyme.
18. What is an allele?
19. What does homozygous mean?
20. What is the difference between genotype and phenotype?
21. Give one human characteristic controlled by a single gene.
22. What are the sex chromosomes of a human male?
23. What is the probability that a baby will be a girl?
24. Is the allele for polydactyly dominant or recessive?
25. What is a carrier of cystic fibrosis?
26. Give one argument against embryo screening.
27. (Bio) What did Mendel call the ‘units’ that are now known as genes?
28. What are the two causes of variation?
29. What is evolution?
30. When are two populations said to be different species?
31. (Bio) What was Lamarck’s theory?
32. (Bio) Give two reasons why Darwin’s theory was not accepted at first.
33. What is selective breeding?

34. Give one problem with selective breeding.
35. What is genetic engineering?
36. (HT) Name two vectors used in genetic engineering.
37. (Bio) Name two methods of cloning plants.
38. Give two ways fossils can be formed.
39. Give two causes of extinction.
40. Name the three domains in Woese's system.
41. What are the two parts of a binomial name?

Section B — Exam-style questions

42. Describe how meiosis produces gametes. [4 marks]
43. Explain why sexual reproduction leads to variation in the offspring. [2 marks]
44. (Bio) Explain the advantages of sexual reproduction for a species. [3 marks]
45. (Bio) Explain how the order of bases in DNA determines the protein made. [3 marks]
46. (Bio, HT) Describe how a protein is made using the code in a gene. [4 marks]
47. (Bio) Explain how a mutation could stop a structural protein such as collagen working. [3 marks]
48. Two mice heterozygous for fur colour (Bb) are crossed. Black (B) is dominant to brown (b). Use a genetic diagram to find the probability of a brown offspring. [4 marks]
49. Use a genetic diagram to show why there is an equal chance of a baby being male or female. [3 marks]
50. Two parents who do not have cystic fibrosis have a child with cystic fibrosis. Explain how this is possible. [3 marks]
51. Evaluate the use of embryo screening to prevent inherited disorders. [6 marks]
52. Explain how natural selection could lead to a population of white rabbits in a snowy habitat. [5 marks]
53. (Bio) Describe how two populations of one species could become two separate species. [4 marks]
54. A farmer wants a herd of cows that produce a lot of milk. Describe how she could use selective breeding. [4 marks]
55. (HT) Describe how bacteria can be genetically engineered to produce human insulin. [4 marks]
56. Give one benefit and one concern about GM crops. [2 marks]
57. (Bio) Describe how an animal can be cloned by adult cell cloning. [5 marks]
58. Explain why scientists cannot be certain about how life began on Earth. [2 marks]
59. Explain why it is important that patients finish their course of antibiotics. [3 marks]

Section C — Maths and genetics skills

60. A Bb plant is crossed with a bb plant. What fraction of the offspring will show the recessive phenotype? [1 mark]
61. A cross gave 312 tall and 104 dwarf pea plants. Calculate the ratio in its simplest form. [2 marks]
62. In a DNA sample, 28% of the bases are adenine. Calculate the percentage of cytosine. [2 marks]
63. A gene has 1500 bases. How many amino acids does it code for? [1 mark]
64. A couple have a 1 in 4 chance of a child with cystic fibrosis. Express this as a percentage and a decimal. [2 marks]
65. A population of 2400 moths contained 360 dark moths. Calculate the percentage of dark moths. [2 marks]

ANSWERS

Answers and mark scheme

Section A — Quick recall

1. **Name the male and female gametes in animals.**
   Sperm and egg cells.
2. **Name the gametes in flowering plants.**
   Pollen and egg cells.
3. **Which type of reproduction produces genetically identical offspring?**
   Asexual reproduction.
4. **Which type of cell division produces gametes?**
   Meiosis.
5. **How many gametes are produced from one cell in meiosis?**
   Four.
6. **How many chromosomes are in a human gamete?**
   23.
7. **(Bio) Give two advantages of asexual reproduction.**
   Only one parent needed; faster; more time/energy efficient; many identical offspring in favourable conditions (any two).
8. **(Bio) Describe how strawberry plants reproduce asexually.**
   By runners — stems that grow sideways and form new identical plants.
9. **What is DNA made of?**
   Two strands forming a double helix (a polymer).
10. **What is a gene?**
    A small section of DNA on a chromosome that codes for a particular sequence of amino acids, to make a specific protein.
11. **What is a genome?**
    The entire genetic material of an organism.
12. **Give one reason why understanding the human genome is important.**
    Finding genes linked to disease; understanding/treating inherited disorders; tracing human migration (any one).
13. **(Bio) What three parts make up a nucleotide?**
    A sugar, a phosphate group and one of four bases.
14. **(Bio) Which bases pair together in DNA?**
    A with T, and C with G.
15. **(Bio) How many bases code for one amino acid?**
    Three.
16. **(Bio, HT) Where in the cell are proteins made?**
    On ribosomes in the cytoplasm.
17. **(Bio) Give one way a mutation could affect the function of an enzyme.**
    Changes the shape of the active site, so the substrate no longer fits.
18. **What is an allele?**
    A different version of the same gene.

19. **What does homozygous mean?**
    Having two identical alleles of a gene (e.g. BB or bb).
20. **What is the difference between genotype and phenotype?**
    Genotype = the alleles present; phenotype = the characteristic shown.
21. **Give one human characteristic controlled by a single gene.**
    Red-green colour blindness.
22. **What are the sex chromosomes of a human male?**
    XY.
23. **What is the probability that a baby will be a girl?**
    1/2 (50%).
24. **Is the allele for polydactyly dominant or recessive?**
    Dominant.
25. **What is a carrier of cystic fibrosis?**
    A person with one recessive allele (Ff) — they don't have the disorder but can pass the allele on.
26. **Give one argument against embryo screening.**
    Prejudice against people with disorders; 'designer babies'; expensive; embryos destroyed (any one).
27. **(Bio) What did Mendel call the 'units' that are now known as genes?**
    Hereditary units.
28. **What are the two causes of variation?**
    Genes and the environment (or a combination).
29. **What is evolution?**
    A change in the inherited characteristics of a population over time through natural selection, which may result in a new species.
30. **When are two populations said to be different species?**
    When they can no longer interbreed to produce fertile offspring.
31. **(Bio) What was Lamarck's theory?**
    Changes acquired during an organism's lifetime can be inherited by its offspring.
32. **(Bio) Give two reasons why Darwin's theory was not accepted at first.**
    It challenged the idea that God created all life; not enough evidence; the mechanism of inheritance was unknown (any two).
33. **What is selective breeding?**
    When humans breed plants and animals for particular genetic characteristics.
34. **Give one problem with selective breeding.**
    Inbreeding → disease/inherited defects; reduced gene pool (any one).
35. **What is genetic engineering?**
    Modifying an organism's genome by introducing a gene from another organism to give a desired characteristic.
36. **(HT) Name two vectors used in genetic engineering.**
    Bacterial plasmids and viruses.
37. **(Bio) Name two methods of cloning plants.**
    Tissue culture and cuttings.
38. **Give two ways fossils can be formed.**
    Gradual replacement by minerals; casts and impressions; preservation where decay can't happen (any two).
39. **Give two causes of extinction.**
    Environmental change; new predator; new disease; competition; catastrophic event (any two).

40. **Name the three domains in Woese's system.**
Archaea, Bacteria, Eukaryota.

41. **What are the two parts of a binomial name?**
Genus and species.

Section B — Exam-style questions

42. **Describe how meiosis produces gametes.** [4]
    - The cell copies its genetic information / DNA (1)
    - The cell divides twice (1)
    - to form four gametes (1)
    - each with a single set of chromosomes / half the number, all genetically different (1)

43. **Explain why sexual reproduction leads to variation in the offspring.** [2]
    - Offspring inherit a mixture of genetic information from two parents (1)
    - Meiosis produces gametes that are all genetically different (1)

44. **(Bio) Explain the advantages of sexual reproduction for a species.** [3]
    - It produces variation (1)
    - If the environment changes, some individuals may be better adapted and survive (1) — natural selection
    - Humans can use it in selective breeding to increase food production (1)

45. **(Bio) Explain how the order of bases in DNA determines the protein made.** [3]
    - Each set of three bases codes for one amino acid (1)
    - The order of bases determines the order of amino acids (1)
    - which determines how the chain folds and the protein's shape/function (1)

46. **(Bio, HT) Describe how a protein is made using the code in a gene.** [4]
    - DNA code is copied into mRNA (template), which leaves the nucleus (1)
    - mRNA attaches to a ribosome (1)
    - Carrier molecules bring specific amino acids, which are added in the order coded by the bases (1)
    - The completed chain folds into a protein with a unique shape (1)

47. **(Bio) Explain how a mutation could stop a structural protein such as collagen working.** [3]
    - The mutation changes the base sequence (1)
    - so the amino acid sequence changes, and the protein folds into a different shape (1)
    - so it may lose its strength / no longer support tissues (1)

48. **Two mice heterozygous for fur colour (Bb) are crossed. Black (B) is dominant to brown (b). Use a genetic diagram to find the probability of a brown offspring.** [4]
    - Gametes: B and b from each parent (1)
    - Correct Punnett square: BB, Bb, Bb, bb (1)
    - Phenotypes: 3 black : 1 brown (1)
    - Probability of brown = 1/4 / 25% / 0.25 (1)

49. **Use a genetic diagram to show why there is an equal chance of a baby being male or female.** [3]
    - Mother XX gives X eggs; father XY gives X or Y sperm (1)
    - Punnett square: XX, XX, XY, XY (1)
    - 2 of 4 are XY → 50% chance of a boy (1)

50. **Two parents who do not have cystic fibrosis have a child with cystic fibrosis. Explain how this is possible.** [3]
    - Cystic fibrosis is caused by a recessive allele (1)
    - Both parents must be carriers / heterozygous (Ff) (1)
    - Each passed on the recessive allele, so the child is ff (1) — a 25% chance

51. **Evaluate the use of embryo screening to prevent inherited disorders.** [6]
    - **For:** reduces suffering; reduces long-term cost of treating disorders; parents can make informed choices; laws prevent use for non-medical reasons
    - **Against:** may suggest people with disorders are 'undesirable' (prejudice); could lead to designer babies; expensive; embryos destroyed — ethical/religious objections; screening can be wrong
    - **Conclusion** with a justified judgement
    - *Level marking: balanced economic, social and ethical points + justified conclusion for 5–6 marks.*

52. **Explain how natural selection could lead to a population of white rabbits in a snowy habitat.** [5]
    - Rabbits show variation in fur colour due to genes/mutation (1)
    - Brown rabbits are more easily seen by predators and are eaten (1)
    - White rabbits are camouflaged so are more likely to survive (1)
    - and reproduce, passing on the alleles for white fur (1)
    - Over many generations, white fur becomes more common in the population (1)

53. **(Bio) Describe how two populations of one species could become two separate species.** [4]
    - The populations become isolated, e.g. by a physical barrier (1)
    - Conditions on each side are different; each population has genetic variation (1)
    - Natural selection favours different alleles in each population (1)
    - Eventually they are so different they can't interbreed to produce fertile offspring (1)

54. **A farmer wants a herd of cows that produce a lot of milk. Describe how she could use selective breeding.** [4]
    - Select a cow and a bull with the highest milk yield (or from high-yield mothers) (1)
    - Breed them together (1)
    - Select the offspring with the highest milk yield and breed them (1)
    - Repeat over many generations until all offspring produce a lot of milk (1)

55. **(HT) Describe how bacteria can be genetically engineered to produce human insulin.** [4]
    - The human insulin gene is cut out using enzymes (1)
    - The gene is inserted into a vector, e.g. a bacterial plasmid (1)
    - The plasmid is put into a bacterium (1)
    - The bacteria multiply and produce insulin, which is collected (1)

56. **Give one benefit and one concern about GM crops.** [2]
    - Benefit: higher yields / pest or disease resistance / extra nutrients (1)
    - Concern: effects on wild flowers and insects / human health not fully known / genes spreading to wild plants (1)

57. **(Bio) Describe how an animal can be cloned by adult cell cloning.** [5]
    - Nucleus removed from an unfertilised egg cell (1)
    - Nucleus from an adult body cell inserted into the egg cell (1)
    - Electric shock stimulates the egg to divide (1)
    - forms an embryo with the same genetic information as the adult cell (1)
    - Embryo implanted into the womb of an adult female (1)
58. **Explain why scientists cannot be certain about how life began on Earth.** [2]
    - Early life forms were soft-bodied, so left few fossils (1)
    - Many fossils have been destroyed by geological activity, so the record is incomplete (1)
59. **Explain why it is important that patients finish their course of antibiotics.** [3]
    - All the bacteria are killed (1)
    - so none survive to mutate (1)
    - reducing the chance of antibiotic-resistant strains developing/spreading (1)

Section C — Maths and genetics skills

60. **A Bb plant is crossed with a bb plant. What fraction of the offspring will show the recessive phenotype?** [1]
    1/2 (50%)
61. **A cross gave 312 tall and 104 dwarf pea plants. Calculate the ratio in its simplest form.** [2]
    312 ÷ 104 = 3 (1) → ratio **3 : 1** (1)
62. **In a DNA sample, 28% of the bases are adenine. Calculate the percentage of cytosine.** [2]
    T = 28%, so A + T = 56% (1) → C + G = 44% → C = **22%** (1)
63. **A gene has 1500 bases. How many amino acids does it code for?** [1]
    1500 ÷ 3 = **500 amino acids**
64. **A couple have a 1 in 4 chance of a child with cystic fibrosis. Express this as a percentage and a decimal.** [2]
    25% (1); **0.25** (1)
65. **A population of 2400 moths contained 360 dark moths. Calculate the percentage of dark moths.** [2]
    360 ÷ 2400 × 100 (1) = **15%** (1)

FINAL EXAM ADVICE

Use the **key words** examiners look for: *meiosis, gamete, fertilisation, nucleotide, complementary base pairs, allele, dominant, recessive, homozygous, heterozygous, genotype, phenotype, carrier, mutation, natural selection, speciation, selective breeding, vector, plasmid, clone, fossil, extinct, binomial, domain*. In genetic diagram questions always show the **gametes**, the **Punnett square** and the final **ratio or probability**.

© iBLaurel — Innovative Learning Support Ltd. Notes, diagrams and questions written for iBLaurel students. Aligned to the AQA GCSE Biology (8461) specification, section 4.6.