LOGIC BLOOM · NEET BIOLOGY · CLASS 12

Genetics & Evolution

Molecular Basis of Inheritance · Evolution

The unit that carries more NEET marks than any other. Eleven drawn diagrams, written in points rather than paragraphs, with every key fact picked out in blue and red. Ends with a separate quick-review section of what NEET keeps asking.

13 Sections | 11 Diagrams | Quick Review Section | Trap Alerts | Fact Sheet

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Contents

1	**The Search for the Genetic Material**	*Griffith to Hershey and Chase*
2	**DNA Structure**	*every number that gets examined*
3	**Packaging DNA**	*nucleosome to chromatin*
4	**Replication**	*semiconservative, and why one strand lags*
5	**Transcription**	*and what eukaryotes add*
6	**The Genetic Code and Translation**	*64 codons and their rules*
7	**Regulation: The Lac Operon**	*a switch that reads the food supply*
8	**Genome and Fingerprinting**	*HGP numbers and VNTR*
9	**Origin of Life**	*Oparin, Haldane, Miller and Urey*
10	**Evidence for Evolution**	*homology, fossils, and melanism*
11	**Natural Selection**	*three ways it reshapes a population*
12	**Hardy-Weinberg**	*the null model, and what breaks it*
13	**Quick Review: What NEET Repeats**	*the students' request, in one place*
★	**One-Page Fact Sheet**	*every formula for revision day*

0 How to Use These Notes

- This unit is the **highest scoring** block in NEET Biology. Genetics and Evolution together carry more questions than any other unit.
- **Blue marks a defining fact**. **Red marks a trap or a number examiners love**.
- Most of the text is in points. Read the point, then study the drawing beside it.
- Sections 1 to 8 cover Molecular Basis of Inheritance. Sections 9 to 12 cover Evolution.
- Section 13 is a **separate quick-review list** of what NEET keeps coming back to. It is deliberately at the end, so you read the chapter properly first.

THINK IT THROUGH

A NOTE ON THE QUICK-REVIEW SECTION

- Several of you asked for the repeated questions to be marked beside each point.
- We have put them in a **separate section** instead, on purpose.
- If the tags sit inline, the eye jumps to them and skips everything else. You end up revising a list, not learning a chapter.
- So: read Sections 1 to 12 properly. Then use Section 13 the night before.

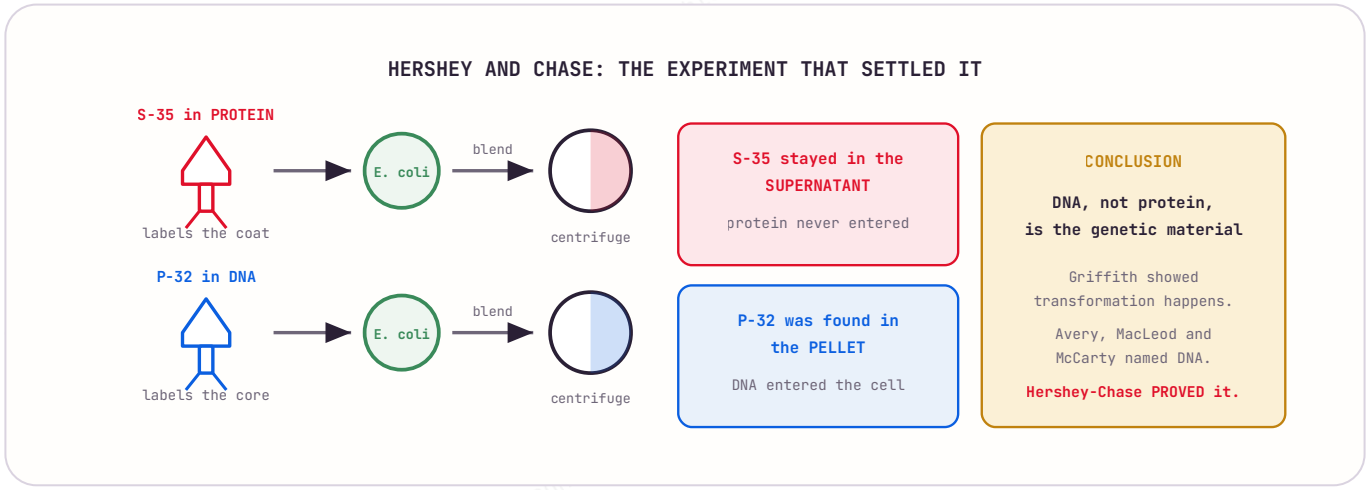
PART A

Molecular Basis of Inheritance

How the message is stored, copied and read.

1 The Search for the Genetic Material

- For a long time nobody knew whether protein or DNA carried the information.
- **Griffith (1928)** worked with two strains of pneumococcus. The **S strain** has a capsule and is virulent. The **R strain** has none and is harmless.
- He found that heat-killed S bacteria, mixed with live R bacteria, killed the mice. Something had passed across. He called this **transformation**.
- **Avery, MacLeod and McCarty (1933 to 1944)** repeated it in a test tube and destroyed each molecule in turn. Only destroying DNA stopped transformation.
- **Hershey and Chase (1952)** used bacteriophages and radioactive labels. This was the experiment that settled the argument.



Two labels, two answers. Sulfur stayed outside the cell, phosphorus went in. DNA is the genetic material.

TRAP ALERT

KNOW EXACTLY WHO PROVED WHAT

- Griffith showed that transformation **happens**. He did not name the molecule.
- Avery and his team **identified** that molecule as DNA.
- Hershey and Chase **proved** it, using phage.
- **Sulfur-35 labels protein** because protein has sulfur and DNA does not. **Phosphorus-32 labels DNA** because DNA has phosphate and protein does not.
- Swapping those two labels is the single most common error from this section.

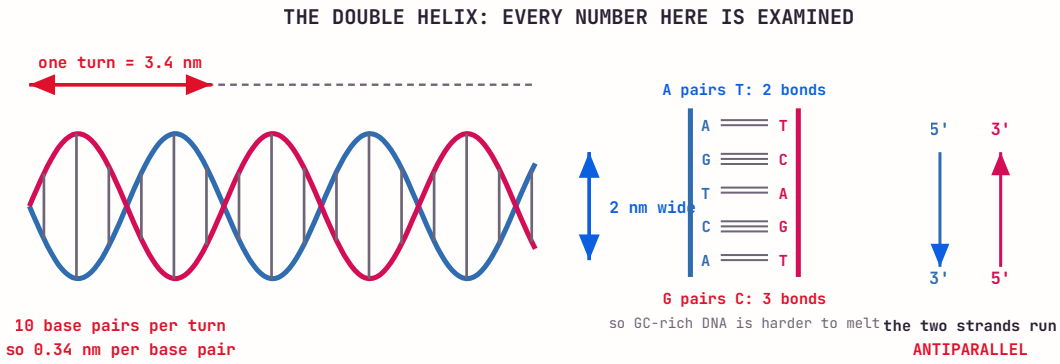
THINK IT THROUGH

WHY DNA, AND NOT RNA, BECAME THE STORE

- RNA came first and can act as a genetic material, as it does in some viruses.
- But RNA is **reactive**, so it is easily broken down.
- DNA is chemically more stable, mostly because it lacks the 2' hydroxyl group.
- So RNA kept the catalytic and messenger jobs, and DNA took over storage.

2 DNA Structure

- A nucleotide has three parts: a nitrogen base, a pentose sugar and a phosphate group.
- **Purines** are adenine and guanine, and they have two rings. **Pyrimidines** are cytosine, thymine and uracil, with one ring.
- Watson and Crick built the model in 1953, using Franklin's X-ray photograph.
- The backbone is sugar and phosphate. The bases point inward and pair across.



The B-form double helix. Learn these four numbers: 3.4 nm, 10 base pairs, 0.34 nm, 2 nm.

- **A pairs with T using two hydrogen bonds. G pairs with C using three.**
- So DNA rich in G and C takes more heat to separate. This is used in the lab all the time.
- The two strands are **antiparallel**: one runs 5' to 3', the other 3' to 5'.
- **Chargaff** found A equals T and G equals C in any double-stranded DNA. So (A + G) divided by (T + C) is always 1.

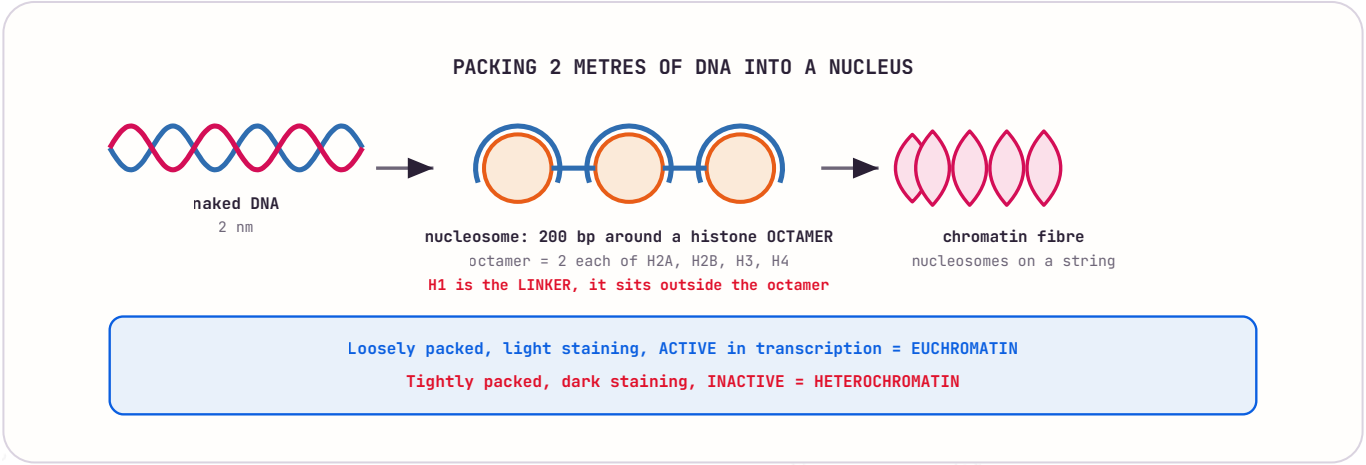
THINK IT THROUGH

A CHARGAFF QUESTION YOU CAN DO IN YOUR HEAD

- If adenine is 30% of the bases, then thymine is also 30%.
- That leaves 40% for G and C together, so each is 20%.
- Check the total: 30 + 30 + 20 + 20 = 100.
- Any question giving you one base percentage is asking for exactly this.

3 Packaging DNA

- Human DNA is about 3.3 billion base pairs long. Laid end to end that is roughly **2 metres**.
- It has to fit inside a nucleus about 10 micrometres across. So it must be packed.
- DNA wraps around a **histone octamer** to form a **nucleosome**.
- **The octamer is two each of H2A, H2B, H3 and H4**. About 200 base pairs wrap around it.
- **Histone H1 is NOT part of the octamer**. It sits outside and links one nucleosome to the next.

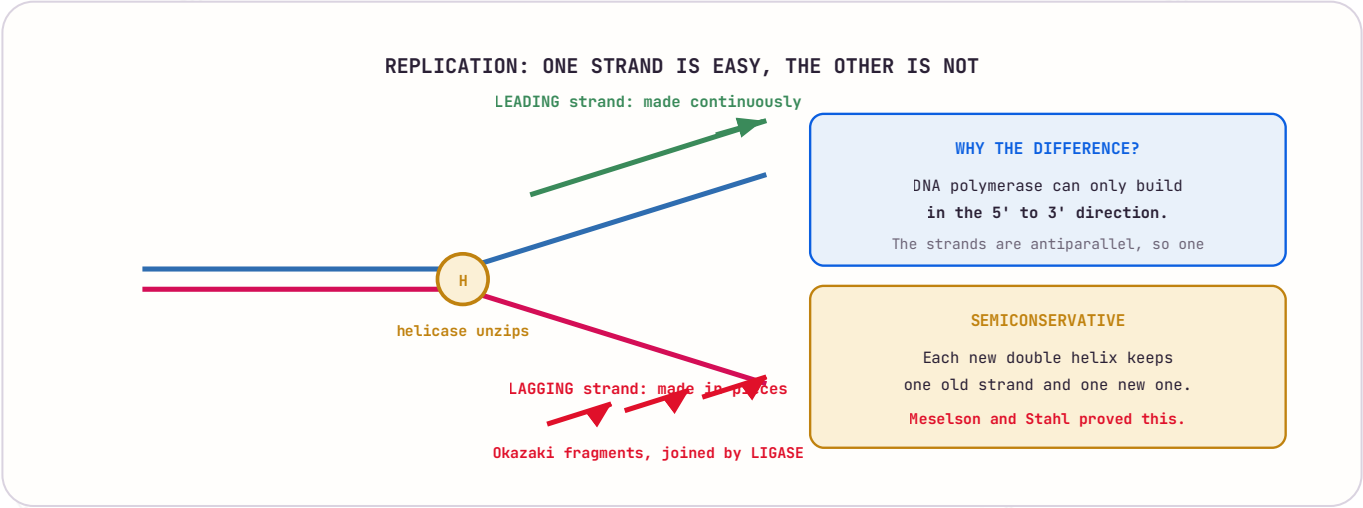


Naked DNA, then nucleosomes, then the chromatin fibre. Each step packs it tighter.

- Histones are **positively charged** because they are rich in lysine and arginine. DNA is negatively charged, so the two bind strongly.
- **Euchromatin** is loosely packed, stains light, and is **active** in transcription.
- **Heterochromatin** is tightly packed, stains dark, and is **inactive**.
- Non-histone chromosomal proteins give further levels of packing.

4 Replication

- Replication is **semiconservative**. Each new double helix keeps one old strand and one new one.
- **Meselson and Stahl (1958)** proved it using heavy nitrogen and density gradient centrifugation.
- Taylor showed the same thing in **Vicia faba**, the faba bean, using radioactive thymidine.
- Helicase unzips the two strands. DNA polymerase then builds the new ones.



One strand is built continuously. The other is built backwards in pieces, then stitched together.

- **DNA polymerase can only add nucleotides in the 5 prime to 3 prime direction**.
- Because the strands are antiparallel, only one of them can be built continuously.
- That one is the **leading strand**. The other is the **lagging strand**.
- The lagging strand is made in short pieces called **Okazaki fragments**, joined by **DNA ligase**.
- Replication starts at a specific sequence called the **origin of replication**.

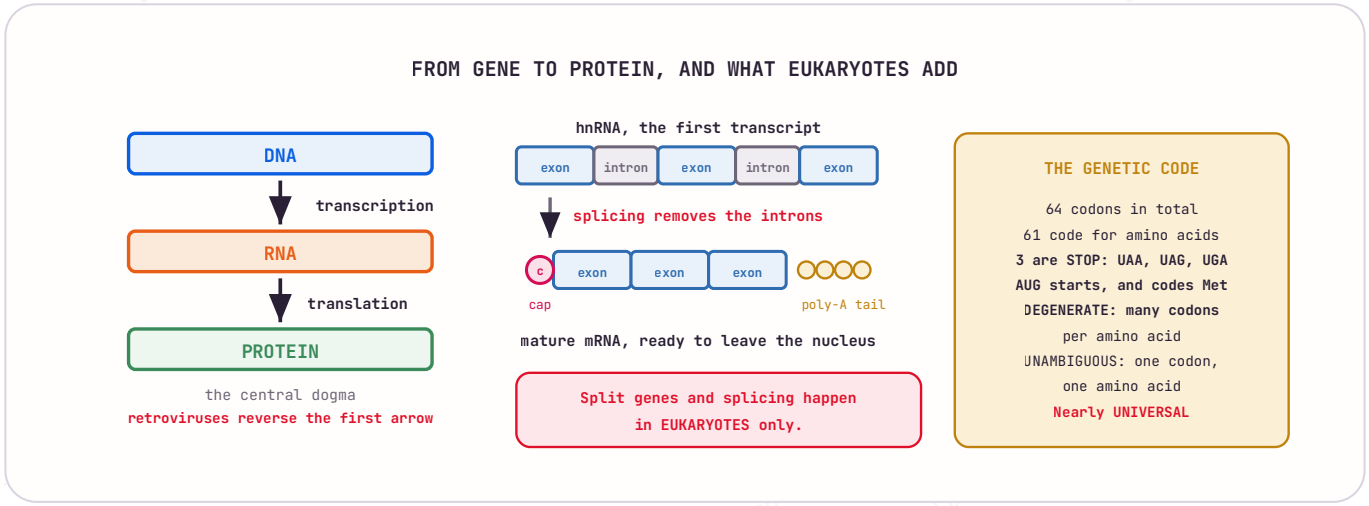
TRAP ALERT

TWO FACTS EXAMINERS PAIR TOGETHER

- Replication happens in the **S phase** of the cell cycle.
- DNA polymerase is a remarkably fast enzyme, and it also **proofreads** its own work.
- **The energy for joining nucleotides comes from the deoxyribonucleoside triphosphate itself**, not from a separate ATP molecule.
- That last point appears as a statement-based question surprisingly often.

5 Transcription and RNA Processing

- Transcription copies one strand of DNA into RNA. Only one strand is copied.
- The strand that is read is the **template strand**, running 3' to 5'.
- The other strand is the **coding strand**. It is **not** copied, but its sequence matches the RNA, with U in place of T.
- RNA polymerase does the work. In bacteria one enzyme makes all three RNA types.



DNA to RNA to protein. Eukaryotes add a step that prokaryotes do not have.

- Eukaryotes have **three RNA polymerases**. I makes rRNA, II makes hnRNA (the mRNA precursor), III makes tRNA and small RNAs.
- Eukaryotic genes are **split genes**: coding **exons** interrupted by non-coding **introns**.
- **Splicing** removes the introns and joins the exons.
- The transcript also gets a **cap** at the 5' end and a **poly-A tail** at the 3' end.
- Only after all this does it become mature mRNA and leave the nucleus.

TRAP ALERT

PROKARYOTE AGAINST EUKARYOTE

- In bacteria there is no nucleus, so transcription and translation happen at the same time and place.
- **Split genes, splicing, capping and tailing are eukaryotic only.**
- So a bacterial mRNA can be translated while it is still being made.
- Any question mentioning introns or splicing is about a eukaryote.

6 The Genetic Code and Translation

- The code is read in **triplets**. Four bases in groups of three give 4^3 = **64 codons**.
- **61 codons code for amino acids. 3 are stop codons: UAA, UAG and UGA**.
- **AUG** is the start codon, and it also codes for methionine. So it does two jobs.
- Khorana, Nirenberg and Holley worked out the code, and shared the Nobel Prize for it.

- **Degenerate**: most amino acids have more than one codon. This is not the same as ambiguous.
- **Unambiguous**: each codon specifies one amino acid only, and never two.
- **Nearly universal**: the same code works from bacteria to humans, with tiny exceptions such as in mitochondria.
- **Non-overlapping** and **comma-less**: it is read straight through, three at a time.
- **Degenerate and ambiguous are opposites**. A codon never has two meanings, but an amino acid often has several codons.

- tRNA is the **adapter**. It has an anticodon at one end and carries an amino acid at the other.
- Ribosomes are the factory. The small subunit binds mRNA, and the large one joins the amino acids.
- There is no tRNA for the stop codons, which is exactly why translation stops there.
- The mRNA has untranslated regions (UTRs) at both ends that are not translated.

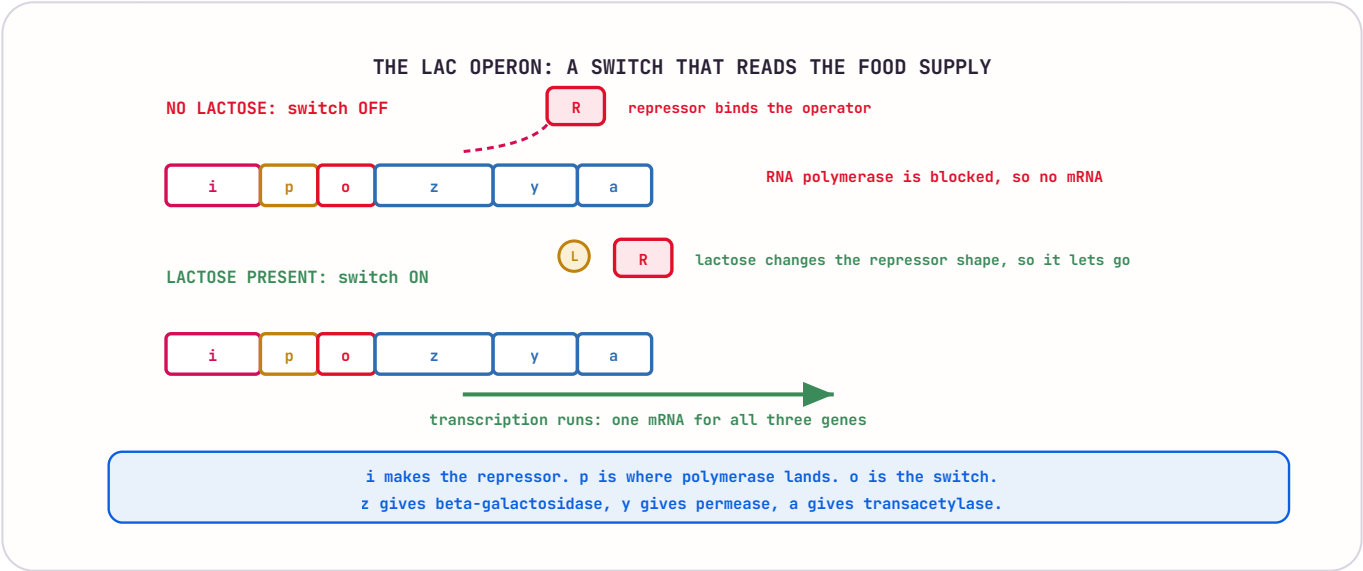
THINK IT THROUGH

HOW A MUTATION SHOWS ITS TYPE

- A change of one base that swaps one amino acid is a **point mutation**. Sickle cell anaemia is the standard example: glutamate becomes valine.
- Inserting or deleting bases in threes keeps the reading frame intact.
- **Inserting or deleting one or two bases shifts the whole reading frame** after that point, so everything downstream is wrong.
- That is why frameshift mutations are usually far more damaging.

7 Regulation: The Lac Operon

- A bacterium does not make an enzyme it does not need. It switches genes on only when the food arrives.
- Jacob and Monod described the **lac operon** in E. coli.
- An operon is a group of genes controlled together, from one promoter.
- Here lactose is the substrate, and it acts as the **inducer**.



No lactose, the repressor sits on the operator and blocks transcription. Add lactose and the block lifts.

- **i gene** makes the repressor protein. It is a regulator, not part of the operon proper.
- **p** is the promoter, where RNA polymerase binds.
- **o** is the operator, the switch that the repressor sits on.
- **z** gives beta-galactosidase, **y** gives permease, **a** gives transacetylase.
- **One mRNA is made for all three structural genes together**. That is what polycistronic means.

TRAP ALERT

THE LOGIC RUNS BACKWARDS FROM WHAT YOU EXPECT

- The repressor is made **all the time**, whether lactose is there or not.
- Lactose does not switch the gene on directly. It switches the **repressor off**.
- So this is **negative regulation**: the default state is blocked, and the inducer removes the block.
- Beta-galactosidase itself splits lactose into glucose and galactose, which is the point of the whole system.

8 Genome and DNA Fingerprinting

- The Human Genome Project ran from 1990 to 2003. The genome is about **3164.7 million base pairs**.
- It found roughly **20500 genes**, far fewer than the 80000 to 140000 people had expected.
- **Chromosome 1 has the most genes (2968). The Y chromosome has the fewest (231)**.
- About 1.4 million single base differences, called SNPs, were located.
- Less than 2% of the genome codes for protein. Much of the rest is repetitive.

- **DNA fingerprinting** was developed by Alec Jeffreys.
- It compares **VNTRs**, short sequences repeated a variable number of times.
- The number of repeats differs between people, so the banding pattern is individual.
- The steps are: isolate DNA, cut with restriction enzymes, separate by electrophoresis, blot onto a membrane, hybridise with a probe, then detect by autoradiography.
- **Identical twins are the exception**. Their fingerprints match, because their DNA does.

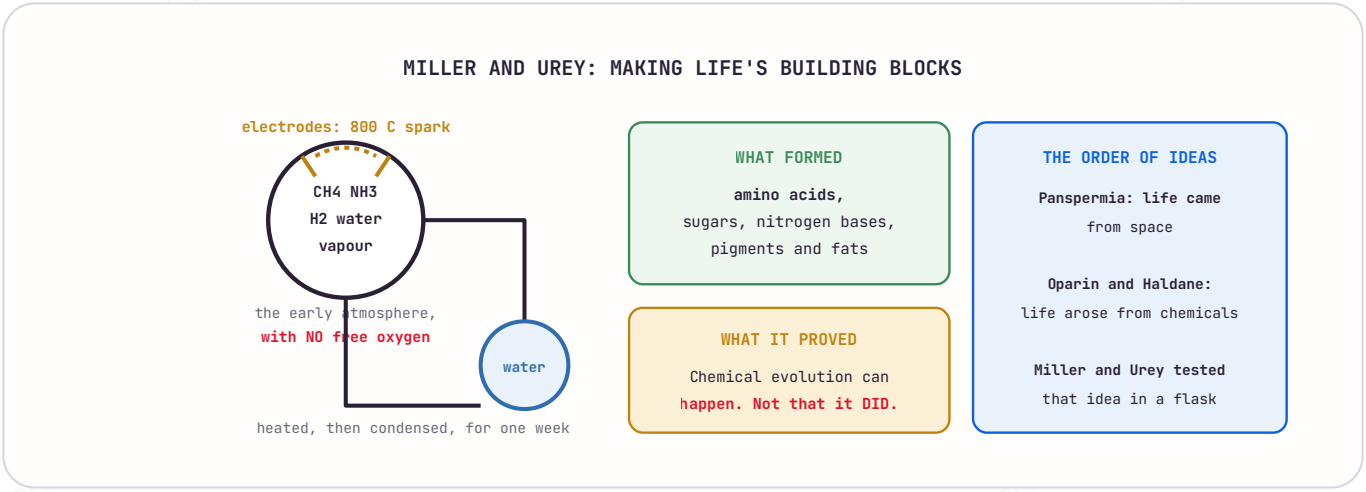
PART B

Evolution

How the variety of life came about, and how we know.

9 Origin of Life

- The universe is about 20 billion years old. The Earth formed about 4.5 billion years ago.
- Life appeared roughly 3.5 billion years ago, in water.
- **Panspermia** said life arrived from space as spores. It is mentioned, not accepted.
- **Oparin and Haldane** proposed that life arose from simple chemicals, in conditions with **no free oxygen**. This is chemical evolution.

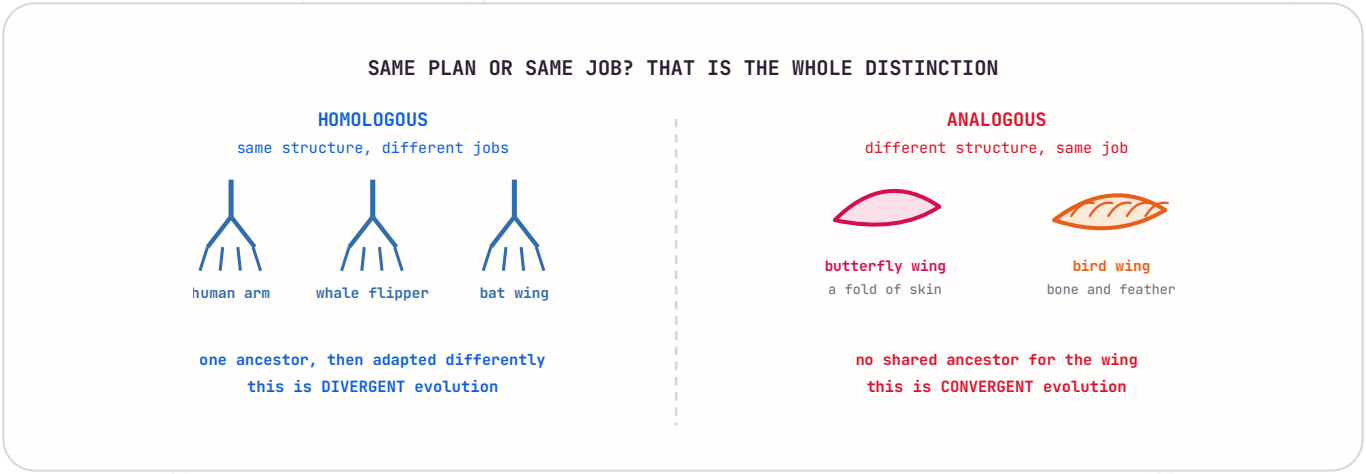


The flask that made amino acids from a mixture of gases, water and an electric spark.

- Miller and Urey used methane, ammonia, hydrogen and water vapour at 800 degrees Celsius.
- They passed an electric discharge through it for a week, to imitate lightning.
- They obtained amino acids, and later similar work gave sugars, bases, pigments and fats.
- **This showed chemical evolution CAN happen. It did not prove that it DID**. That distinction is a favourite assertion-reason question.

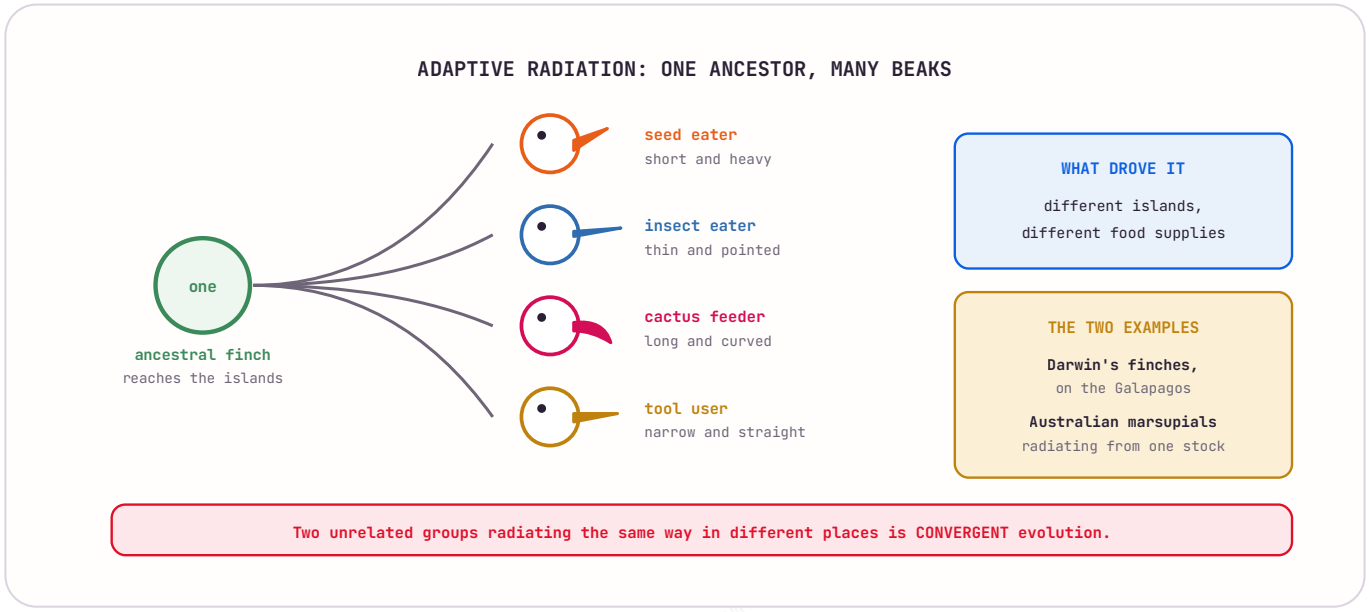
10 Evidence for Evolution

- Fossils give a direct record. The deeper the rock layer, the older the fossil in it.
- **Homologous organs** have the same basic structure but do different jobs.
- **Analogous organs** have different structures but do the same job.



Same bones doing different jobs, against different structures doing the same job.

- Homology points to a **common ancestor**, so it shows **divergent** evolution.
- Examples: the forelimbs of humans, whales, bats and cheetahs. In plants, the thorn of Bougainvillea and the tendril of Cucurbita.
- Analogy comes from a shared way of life, so it shows **convergent** evolution.
- Examples: the wings of butterflies and birds, the eyes of octopus and mammals, and the flippers of penguins and dolphins.
- In plants, the sweet potato is a root and the potato is a stem, yet both store food.



One finch, many islands, many beaks. This is adaptive radiation.

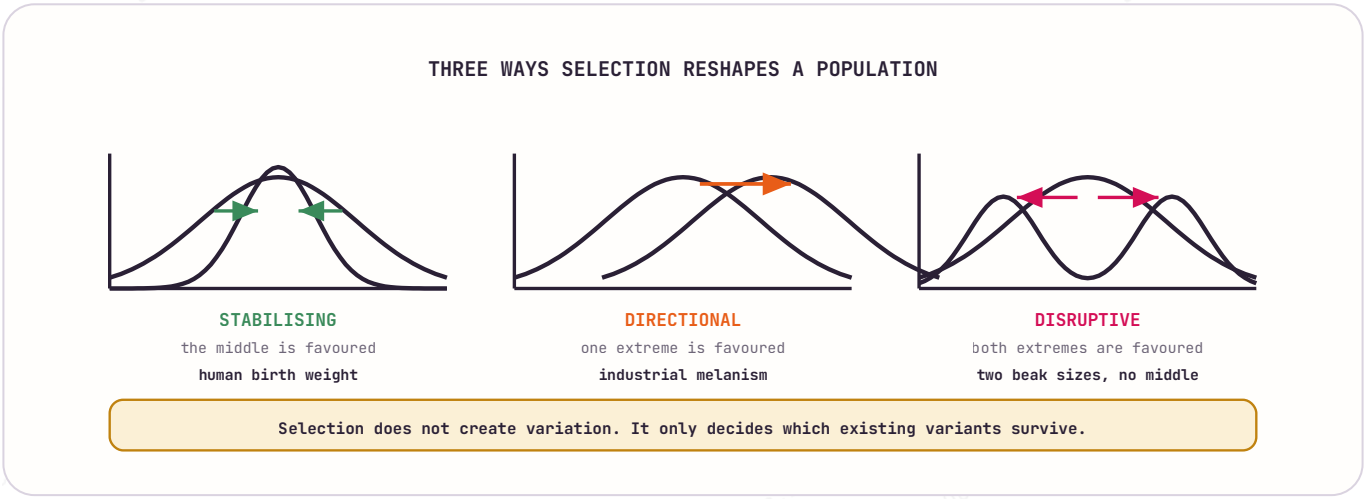
TRAP ALERT

INDUSTRIAL MELANISM, THE EVIDENCE YOU CAN DATE

- Before industry in England, the white winged moth was common and the dark moth was rare.
- After industry, soot darkened the tree trunks. Now the dark moth was better hidden.
- **The dark form became common and the white form became rare.**
- No new moth appeared. The variation was already there, and the environment changed which one survived.
- This is the clearest short example of natural selection acting in real time.

11 Natural Selection

- Darwin's two ideas were **branching descent** and **natural selection**.
- More young are produced than can survive. They vary. The ones that fit best leave more offspring.
- **Fitness** in biology means reproductive success, not strength.
- Lamarck said organs change through use and disuse, and that these changes pass on. **This was rejected**: changes to the body during life are not inherited.



The same population, three different pressures, three different outcomes.

- **Stabilising** selection favours the average and removes both extremes. Human birth weight.
- **Directional** selection favours one extreme and shifts the whole population. Industrial melanism.
- **Disruptive** selection favours both extremes and splits the population in two.
- **Selection does not create variation**. Mutation and recombination create it. Selection only decides which variants persist.

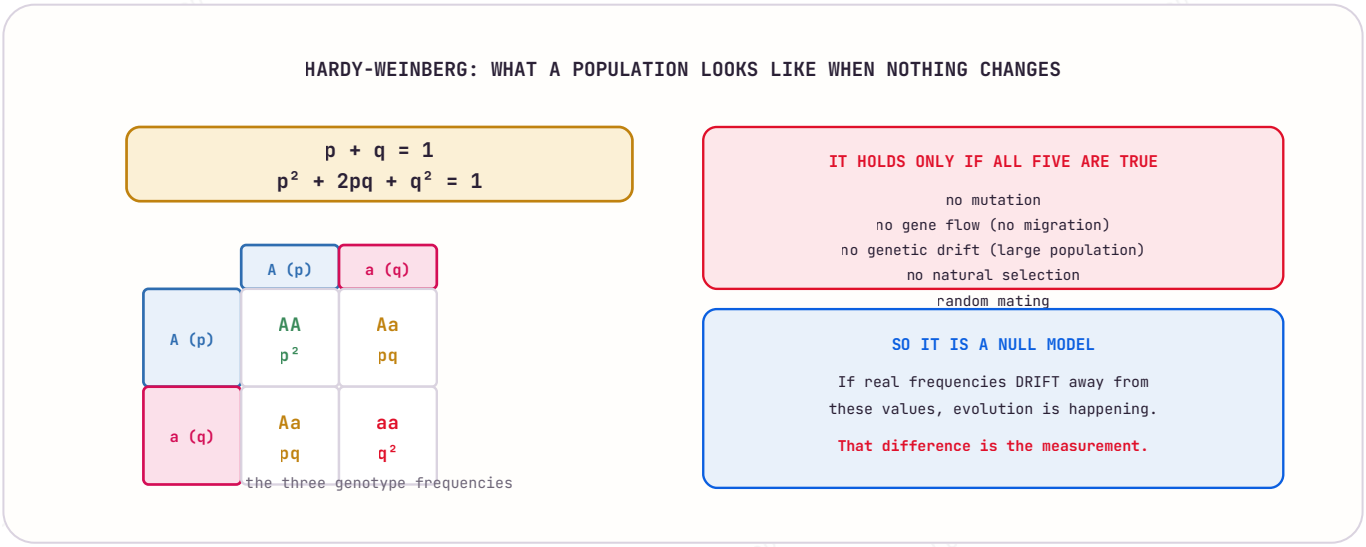
THINK IT THROUGH

WHERE VARIATION COMES FROM

- **Mutation** is the ultimate source of all new variation.
- **Recombination** during meiosis shuffles what already exists into new combinations.
- **Gene flow** brings variants in from another population.
- **Genetic drift** changes frequencies by chance alone, and it matters most in small populations.
- The founder effect is drift acting when a few individuals start a new population.

12 Hardy-Weinberg Equilibrium

- This describes a population in which allele frequencies are **not changing**.
- So it is a baseline. It tells you what to expect when no evolution is happening.
- p is the frequency of the dominant allele and q the recessive one, and $p + q = 1$.
- The genotype frequencies then follow: $p^2 + 2pq + q^2 = 1$.



The square shows where the three genotype terms come from. The list shows what must hold for it to be true.

- **Five conditions must all hold**: no mutation, no gene flow, no genetic drift, no natural selection and random mating.
- In the real world at least one is always broken. So the equilibrium is a model, not a fact.
- That is exactly why it is useful. **Any drift away from these values measures evolution**.
- Worked example: if a recessive disease affects 1 in 10000, then $q^2 = 0.0001$ and $q = 0.01$. So $p = 0.99$, and carriers are $2pq = 0.0198$, which is about 2 in 100.

TRAP ALERT

READ WHETHER THEY WANT AN ALLELE OR A GENOTYPE

- p and q are **allele** frequencies.
- p^2, $2pq$ and q^2 are **genotype** frequencies.
- **Carriers are 2pq, not q**. This mix-up is the most common error in Hardy-Weinberg numericals.
- Always start from the recessive phenotype, because that alone gives you q^2 directly.

13 Quick Review: What NEET Repeats

Several of you asked for the repeated questions to be marked. Here they are, gathered in one place rather than scattered through the notes. Cover the gold band and test yourself.

THINK IT THROUGH

HOW TO READ THE FREQUENCY LABELS

- These are grouped by **how reliably the pattern returns**, not by a single year.
- A question pattern matters more than a year number, because the wording changes but the idea does not.
- Use this the night before. It is not a substitute for the chapter.
- If you can answer all of these without looking, this unit is safe.

MOLECULAR BASIS: THE EXPERIMENTS

ALMOST EVERY YEAR — GENETIC MATERIAL

Which experiment proved that DNA, and not protein, is the genetic material, and which isotopes were used?

Hershey and Chase, using phage. S-35 labels protein, P-32 labels DNA. Only P-32 entered the cell.

REPEATS OFTEN — GENETIC MATERIAL

In Griffith's experiment, what happened when heat-killed S bacteria were mixed with live R bacteria?

The mice died and live S bacteria were recovered. This is transformation. Griffith did not identify DNA.

SEEN SEVERAL TIMES — GENETIC MATERIAL

Why is DNA a better store of information than RNA?

DNA is chemically more stable because it lacks the 2' hydroxyl group. RNA is reactive and breaks down easily.

MOLECULAR BASIS: STRUCTURE AND NUMBERS

ALMOST EVERY YEAR — DNA STRUCTURE

Give the pitch, the base pairs per turn, the rise per base pair and the diameter of B-form DNA.

3.4 nm pitch, 10 base pairs per turn, 0.34 nm per base pair, and 2 nm in diameter.

ALMOST EVERY YEAR — CHARGAFF

If adenine is 30 percent of the bases in a double-stranded DNA, what percentage is guanine?

20 percent. A = T = 30, so G and C share the remaining 40 percent equally.

REPEATS OFTEN — BASE PAIRING

How many hydrogen bonds hold A to T, and G to C?

A to T has two. G to C has three. So GC-rich DNA needs more heat to separate.

REPEATS OFTEN — PACKAGING

Which histone is not part of the nucleosome octamer?

H1. The octamer is two each of H2A, H2B, H3 and H4. H1 is the linker and sits outside.

SEEN SEVERAL TIMES — PACKAGING

Which chromatin is transcriptionally active, and how does it stain?

Euchromatin. It is loosely packed and stains light. Heterochromatin is dense, dark and inactive.

MOLECULAR BASIS: REPLICATION AND EXPRESSION

ALMOST EVERY YEAR — REPLICATION

Why is one strand made in fragments during replication?

DNA polymerase builds only 5' to 3', and the strands are antiparallel. So the lagging strand is made in Okazaki fragments, joined by ligase.

REPEATS OFTEN

REPLICATION

Who proved semiconservative replication, and in what organism was it later confirmed?

Meselson and Stahl, in E. coli. Taylor confirmed it in Vicia faba, the faba bean.

ALMOST EVERY YEAR

GENETIC CODE

How many codons are there in total, how many code for amino acids, and which are the stop codons?

64 in total, 61 code for amino acids, and UAA, UAG and UGA are stop codons. AUG starts and codes methionine.

REPEATS OFTEN

GENETIC CODE

What is meant by the code being degenerate, and how is that different from ambiguous?

Degenerate means one amino acid may have several codons. The code is never ambiguous: one codon always means one amino acid.

REPEATS OFTEN

TRANSCRIPTION

Which features of RNA processing are found only in eukaryotes?

Split genes, splicing of introns, capping at the 5' end and tailing at the 3' end.

ALMOST EVERY YEAR

LAC OPERON

In the lac operon, what does lactose actually do?

It binds the repressor and changes its shape, so the repressor releases the operator. It is negative regulation, and lactose is the inducer.

SEEN SEVERAL TIMES

LAC OPERON

Name the products of the z, y and a genes.

z gives beta-galactosidase, y gives permease, a gives transacetylase. All three come from one mRNA.

REPEATS OFTEN

GENOME

How many base pairs and how many genes did the Human Genome Project report?

About 3164.7 million base pairs and roughly 20500 genes. Chromosome 1 has the most genes, the Y the fewest.

SEEN SEVERAL TIMES

FINGERPRINTING

What is compared in DNA fingerprinting, and for whom does it fail to distinguish?

VNTRs, which are repeats present in variable numbers. It cannot distinguish identical twins.

EVOLUTION

ALMOST EVERY YEAR

ORIGIN OF LIFE

What gases did Miller and Urey use, and what did the experiment prove?

Methane, ammonia, hydrogen and water vapour, sparked at 800 degrees Celsius. It proved chemical evolution is possible, not that it actually happened.

ALMOST EVERY YEAR

EVIDENCE

Distinguish homologous and analogous organs, with one example of each.

Homologous: same structure, different function, showing divergent evolution. The forelimbs of whale and bat. Analogous: different structure, same function, showing convergent evolution. The wings of butterfly and bird.

REPEATS OFTEN

EVIDENCE

What did industrial melanism in England demonstrate?

Natural selection in real time. Soot darkened the trunks, so the dark moth was better camouflaged and became common. No new variant appeared, the environment simply changed which one survived.

REPEATS OFTEN

ADAPTIVE RADIATION

Give the two standard examples of adaptive radiation.

Darwin's finches on the Galapagos, and Australian marsupials. Both radiated from a single ancestral stock.

ALMOST EVERY YEAR

NATURAL SELECTION

Name the three types of natural selection and what each favours.

Stabilising favours the average. Directional favours one extreme. Disruptive favours both extremes and splits the population.

REPEATS OFTEN

VARIATION

Does natural selection create variation?

No. Mutation and recombination create it. Selection only decides which existing variants survive and reproduce.

ALMOST EVERY YEAR

HARDY-WEINBERG

State the five conditions required for Hardy-Weinberg equilibrium.

No mutation, no gene flow, no genetic drift, no natural selection, and random mating. All five must hold.

ALMOST EVERY YEAR

HARDY-WEINBERG

If a recessive condition affects 1 in 10000 people, what fraction of the population are carriers?

$q^2 = 0.0001$, so $q = 0.01$ and $p = 0.99$. Carriers are $2pq = 0.0198$, about 2 in 100.

SEEN SEVERAL TIMES

HUMAN EVOLUTION

Give the brain sizes of Homo habilis, Homo erectus and the Neanderthals.

Homo habilis about 650 to 800 cc, Homo erectus about 900 cc, and Neanderthals about 1400 cc.

★ Genetics & Evolution · Fact Sheet

Every formula for revision day. Print this page alone.

WHO PROVED WHAT

Griffith: transformation happens

Avery: the molecule is DNA
Hershey-Chase: proved it.

THE FOUR DNA NUMBERS

3.4 nm per turn

10 base pairs per turn
0.34 nm per bp, 2 nm wide.

BASE PAIRING

A to T: 2 hydrogen bonds

G to C: 3 hydrogen bonds
A=T and G=C (Chargaff).

NUCLEOSOME

200 bp on a histone octamer

2 each of H2A, H2B, H3, H4
H1 is the linker, outside.

REPLICATION

Semiconservative (Meselson-Stahl)

Polymerase builds 5' to 3' only
Okazaki fragments, then ligase.

EUKARYOTE EXTRAS

Split genes and splicing

5' cap and poly-A tail
Three RNA polymerases.

GENETIC CODE

64 codons, 61 code amino acids

Stop: UAA, UAG, UGA
AUG starts and codes Met.

CODE PROPERTIES

Degenerate but UNAMBIGUOUS

Non-overlapping, comma-less
Nearly universal.

LAC OPERON

i p o z y a

Lactose is the INDUCER
Negative regulation.

HUMAN GENOME

3164.7 million base pairs

About 20500 genes
Chr 1 most, Y fewest.

HOMOLOGY

Homologous: divergent

Analogous: convergent
Adaptive radiation: finches.

HARDY-WEINBERG

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

Carriers are 2pq, not q
Five conditions, all required.

Logic Bloom

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★ GENETICS STILL THE SLOWEST UNIT FOR YOU?

Play it. Then practice it.

Open Genetics and Evolution in the Logic Bloom app. Build a helix, run a replication fork, flip the lac operon on and off, then drill the repeated patterns until they are automatic. Free to start.

SCAN → PLAY · READ · PRACTICE