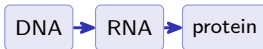


Gene Expression and Regulation

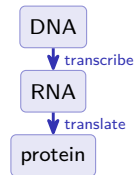
AP Biology ■ Unit 6

AP Biology



What we will cover

- 1 DNA and RNA structure
- 2 Replication
- 3 Transcription
- 4 Translation
- 5 Regulation
- 6 Mutations and biotechnology



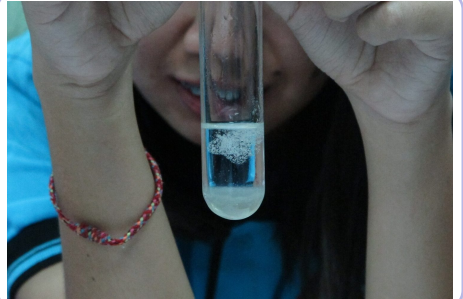


DNA and RNA structure

DNA is a **double helix** of **nucleotides** (sugar + phosphate + base).

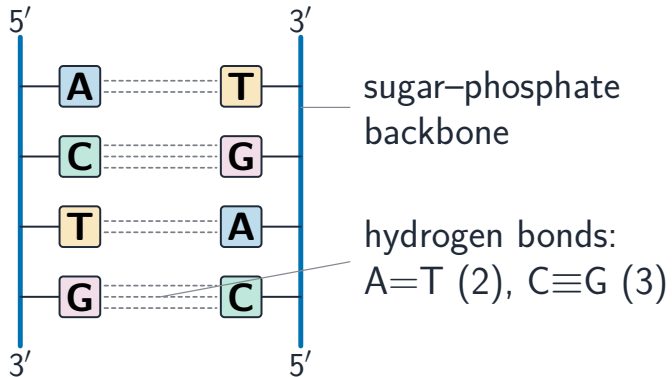
- strands are **antiparallel**
- **complementary pairing** : A–T, C–G
- RNA: ribose, single strand, U for T

One strand's **sequence** fully determines the other – the key to faithful copying.



DNA's sequence is the heritable code

DNA: two antiparallel strands held by complementary



the two strands run in opposite directions (antiparallel)

DNA: two antiparallel strands held by complementary base pairs



DNA replication

Replication is **semiconservative** : each new molecule keeps one old strand, one new.

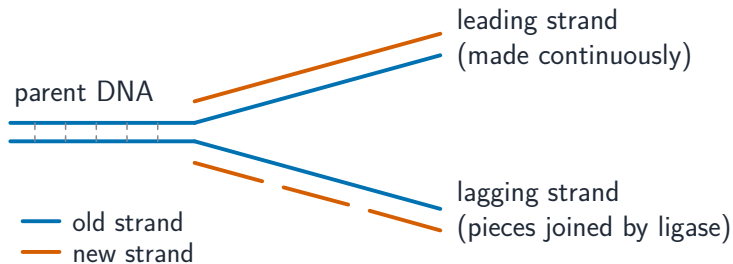
- **helicase** unzips the helix
- **DNA polymerase** DNA builds $5' \rightarrow 3'$
- **ligase** joins the pieces

Continuous **leading strand** ; piecewise **lagging strand** .



Thermal cyclers

Semi-conservative DNA replication at a replication



each new molecule = one old strand + one new strand (semi-conservative)

Semi-conservative DNA replication at a replication fork

Semiconservative replication, and the tools of biotechnology

semiconservative

the helix unwinds and each old strand templates a new one

the consequence

every daughter molecule has one old and one new strand

complementary base pairing

A with T, C with G – which is what makes each strand a template at all

PCR

copies a chosen stretch of DNA, doubling it each cycle

gel electrophoresis

separates fragments by size: shorter fragments travel further

mRNA RNA and tRNA RNA

carry the message out of the nucleus, and bring the matching amino acid to the ribosome

Meselson and Stahl's experiment is the standard evidence: after one round, all the DNA is intermediate in density – which only semiconservative replication predicts.

What replication produces, and what RNA does

semiconservative

the helix unwinds and each old strand templates a new one

the result

every daughter molecule has one old and one new strand

mRNA RNA

carries the transcribed message out of the nucleus to the ribosome

tRNA RNA

brings the amino acid matching each codon

PCR

copies a chosen stretch of DNA, doubling it each cycle

gel electrophoresis

separates fragments by size – shorter ones travel further

Meselson and Stahl's result is the evidence: after one round all the DNA is of intermediate density, which only semiconservative replication predicts.

The three RNAs, spelled out

messenger RNA (mRNA)

transcribed from the template strand, it carries the message out of the nucleus

transfer RNA (tRNA)

brings the amino acid matching each codon, using its own anticodon

ribosomal RNA (rRNA)

with protein, it builds the ribosome itself and catalyses the peptide bond

replication is semiconservatively

done – each daughter molecule keeps one old strand

why that phrasing

“conservative” would mean one wholly old and one wholly new molecule, which is what the experiment ruled out

the evidence

Meselson and Stahl: after one round all the DNA is of intermediate density

Learn the full names as well as the abbreviations – the exam uses “messenger RNA” and “transfer RNA” in its stems, and expects them back.

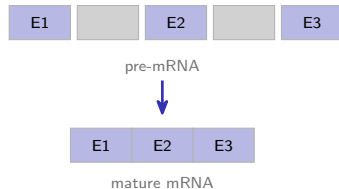


Transcription and RNA processing

Transcription : RNA polymerase RNA copies one DNA strand into **mRNA** RNA (U replaces T).

- add a **cap** and **poly-A tail**
- **splicing** removes **introns** , joins **exons**

Alternative splicing lets one gene make several proteins.



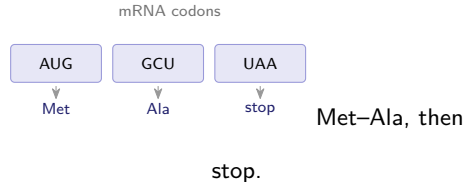


Translation

A **ribosome** reads mRNA three bases at a time. Each **codon** names one amino acid.

- AUG = **start** (Met);
UAA/UAG/UGA = **stop**
- **tRNA** RNA **anticodon** delivers the amino acid

The **genetic code** is nearly universal
– evidence of a **common ancestor** .





Regulation of gene expression

Every cell shares one genome – **differential gene expression** makes them differ:

Promoter + factors
transcription factors
switch a gene on/off

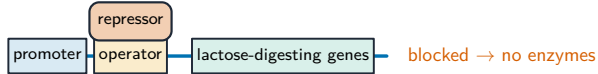
Operon
bacteria control re-
lated genes as a group

**Epigenetics – DNA methy-
lation** DNA silences a gene
without changing the sequence

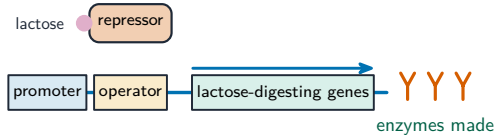
Hox genes are master switches that lay out the body plan.

Regulation of gene expression, in detail

no lactose

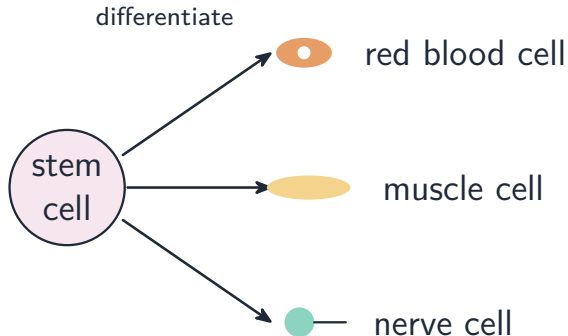


lactose present



The lac operon switches genes on only when lactose is present

Gene Expression and Cell Specialization



A stem cell differentiates into specialised cell types

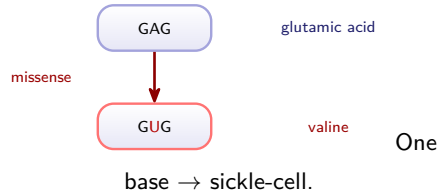


Mutations

A **mutation** is any change in DNA sequence – the ultimate source of new **variation**.

- **silent** : same amino acid
- **missense** : one amino acid changes
- **nonsense** : early stop
- **frameshift** : insert/delete shifts every codon

Germ cell mutations are inherited;
somatic ones are not.



Substitution

original

A	T	G
---	---	---

C	A	T
---	---	---

T	A	C
---	---	---

substitution

A	A	G
---	---	---

C	A	T
---	---	---

T	A	C
---	---	---

deletion

A	T	G
---	---	---

A	T	T
---	---	---

A	C
---	---

insertion

A	T	G
---	---	---

G	C	A
---	---	---

T	T	A
---	---	---

C

red = changed base; shaded = shifted by a frameshift (deletion or insertion)

Substitution, deletion, and insertion mutations

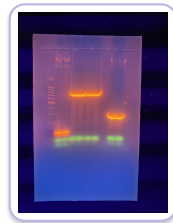


Biotechnology

Tools to study, copy, and move genes:

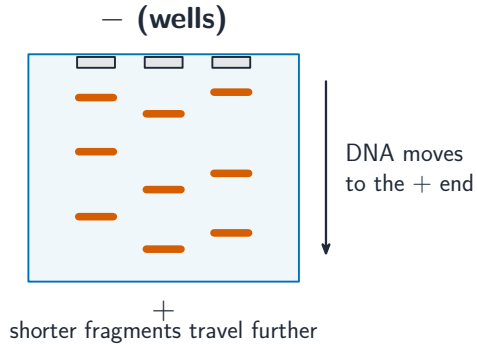
- **gel electrophoresis** sorts DNA by size
- **PCR amplifies** a target
- **restriction enzymes** and cloning **move genes** between organisms
- **CRISPR** **edits** a sequence in place
- **genetic engineering** makes a **GMO**

They enable genetic testing, engineered organisms and medical treatments.



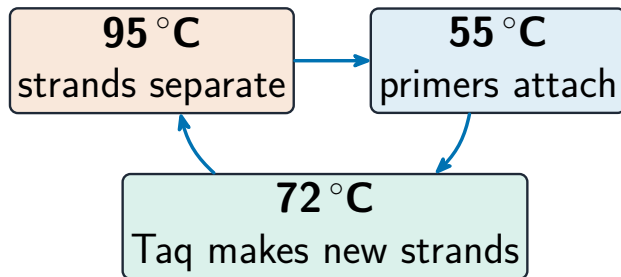
Gels sort DNA; PCR amplifies a target

Gel electrophoresis separates DNA fragments – one



Gel electrophoresis separates DNA fragments by length

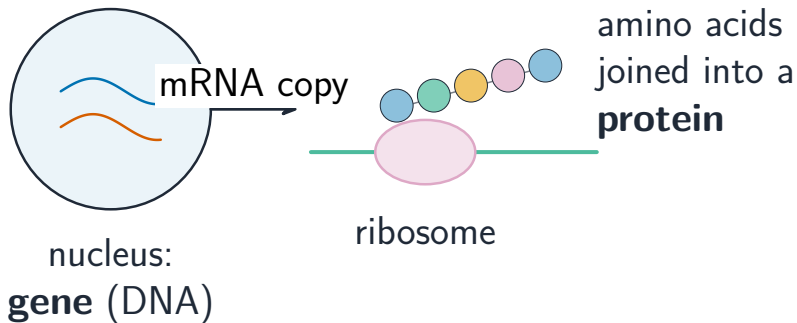
Gel electrophoresis separates DNA fragments – two



each cycle **doubles** the DNA → millions of copies

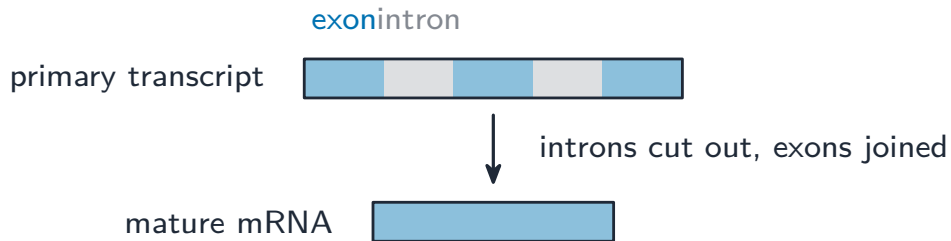
The polymerase chain reaction doubles the DNA each cycle

Translation, continued



mRNA is read by a ribosome to build a protein from amino acids

Transcription and RNA Processing, continued



Introns are removed and exons joined to make mature mRNA

Worked example – template to polypeptide

A template DNA strand 3'-TAC GGA TTC-5' is transcribed and translated. What polypeptide results?

- mRNA: 5'-AUG CCU AAG-3'.
- Codons: AUG = Met (start), CCU = Pro, AAG = Lys – so **Met-Pro-Lys**.
- Changing the *third* base of a codon often gives the same amino acid, because the code is **degenerate**.

That degeneracy softens the effect of many point mutations – and it is why silent mutations exist at all.

Exam tips

- Know the **central dogma** DNA → RNA → protein: transcription makes mRNA, translation reads it in three-base **codons** at the ribosome.
- Remember RNA is single-stranded and uses **U** instead of T; replication is **semiconservative**.
- Every cell has the **same DNA** – cells differ because they express **different genes** (differential gene expression).
- A **mutation** is a change in the DNA sequence and may be harmful, neutral, or beneficial (the raw material for selection).
- Link biotech tools to their jobs: PCR copies DNA; gel electrophoresis separates fragments by size.



Unit 6 – key takeaways

1

Central dogma

DNA $\rightarrow$ RNA $\rightarrow$ protein; A–T,
C–G pairing

2

Copy & read

semiconservative replication;
codons on a ribosome

3

Regulation

transcription factors, operons,
epigenetic methylation

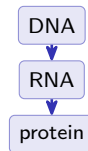
4

Change & tools

point/frameshift mutations; PCR,
gels, GMOs

Check yourself

- 1 What base pairs with adenine in DNA? in RNA?
- 2 Why is replication called semiconservative?
- 3 How many bases make one codon?
- 4 Which mutation shifts every later codon?



Answers 1. T (DNA), U (RNA) 2. each new molecule keeps one old strand 3. three
4. frameshift