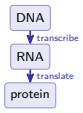
Gene Expression and Regulation

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



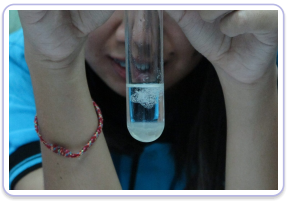
1 Structure

DNA and RNA structure

DNA 脱氧核糖核酸 is a **double helix** 双螺旋 of **nucleotides** 核苷酸 (sugar + phosphate + base).

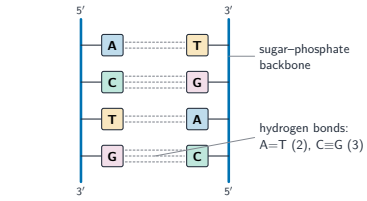
- strands are **antiparallel** 反平行的
- **complementary pairing** 互补碱基配对: A–T, C–G
- RNA: ribose, single strand, U for T

> One strand's **sequence** 序列 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

2 Replication

DNA replication

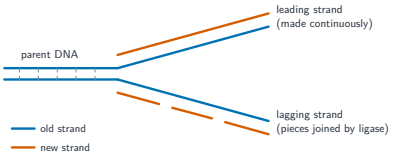
Replication 复制 is **semiconservative** 半保留的: each new molecule keeps one old strand, one new.

- **helicase** 解旋酶 unzips the helix
- **DNA polymerase** DNA 聚合酶 builds $5' \to 3'$
- **ligase** 连接酶 joins the pieces

Continuous **leading strand** 前导链; piecewise **lagging strand** 后随链.

Thermal cycler

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 半保留复制	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 碱基互补配对	A with T, C with G – which is what makes each strand a template at all
PCR 聚合酶链反应	copies a chosen stretch of DNA, doubling it each cycle
gel electrophoresis 凝胶电泳	separates fragments by size: shorter fragments travel further
mRNA 信使 RNA and tRNA 转运 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 半保留复制	helix unwinds and each old strand templates a new one
the result	every daughter molecule has one old and one new strand
mRNA 信使 RNA	carries the transcribed message out of the nucleus to the ribosome
tRNA 转运 RNA	brings the amino acid matching each codon
PCR 聚合酶链反应	copies a chosen stretch of DNA, doubling it each cycle
gel electrophoresis 凝胶电泳	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

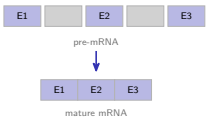
Learn the full names as well as the abbreviations – the exam uses "messenger RNA" and "transfer RNA" in its stems, and expects them back.

3 Transcription

Transcription and RNA processing

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

- add a **cap** 帽子结构 and **poly-A tail** 多聚腺苷酸尾
- **splicing** 剪接 removes **introns** 内含子, joins **exons** 外显子



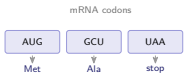
> **Alternative splicing** 可变剪接 lets one gene make several proteins.

4 Translation

Translation

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

- AUG = **start** 起始密码子 (Met); UAA/UAG/UGA = **stop** 终止密码子
- **tRNA** 转运 RNA **anticodon** 反密码子 delivers the amino acid



Met–Ala, then stop.

> The **genetic code** 遗传密码 is nearly universal – evidence of a **common ancestor** 共同祖先.

5 Regulation

Regulation of gene expression

Every cell shares one genome – **differential gene expression** 差异基因表达 makes them differ:

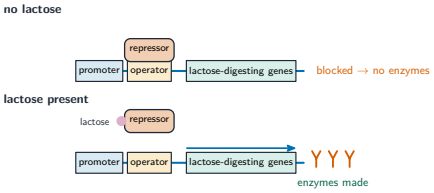
Promoter + factors
transcription factors 转录因子 switch a gene on/off

Operon
bacteria control related genes as a group

Epigenetics – DNA methylation DNA 甲基化 silences a gene without changing the sequence

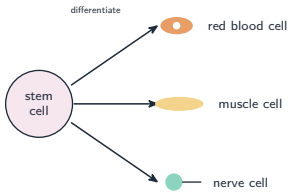
> **Hox genes** 同源异形基因 are master switches that lay out the body plan.

Regulation of gene expression, in detail



> The lac operon switches genes on only when lactose is present

Gene Expression and Cell Specialization



A stem cell differentiates into specialised cell types

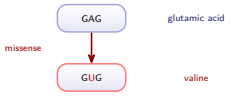
6 Mutations

Mutations

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

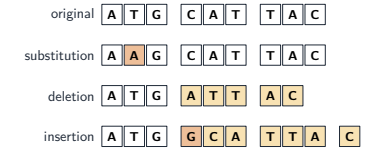
- **silent** 沉默: same amino acid
- **missense** 错义: one amino acid changes
- **nonsense** 无义: early stop
- **frameshift** 移码: insert/delete shifts every codon

Germ cell 生殖细胞 mutations are inherited; **somatic** 体细胞的 ones are not.



One base → sickle-cell.

Substitution



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

Substitution, deletion, and insertion mutations

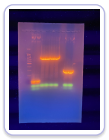
7 Biotechnology

Biotechnology

Tools to study, copy, and move genes:

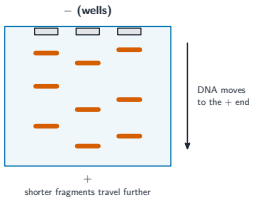
- **gel electrophoresis** 凝胶电泳 sorts DNA by size
- **PCR** 聚合酶链式反应 **amplifies** 扩增 a target
- **restriction enzymes** 限制酶 and cloning move genes between organisms
- **CRISPR** 基因编辑 edits a sequence in place
- **genetic engineering** 基因工程 makes a **GMO** 转基因生物

They enable genetic testing, engineered organisms and medical treatments.



Gels sort DNA; PCR amplifies a target

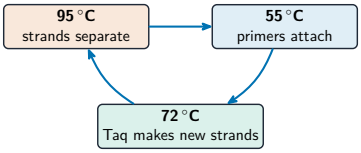
Gel electrophoresis separates DNA fragments – one



Gel electrophoresis separates DNA fragments by length

Gel electrophoresis separates DNA fragments by length

Gel electrophoresis separates DNA fragments – two

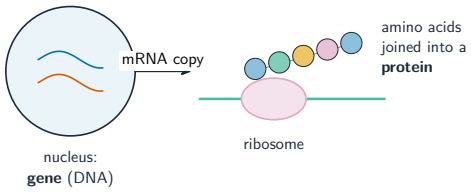


each cycle **doubles** the DNA → millions of copies

The polymerase chain reaction doubles the DNA each cycle

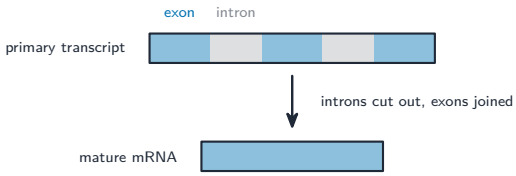
The polymerase chain reaction doubles the DNA each cycle

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.

8 Recap

Unit 6 – key takeaways

1 Central dogma
DNA → RNA → 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