DP Biology – D1.3

Mutation

- How do mutations in genes arise?
- What effects do gene mutations have?

SL statements D1.3.1–7. Textbook pp. 637–642. Gene editing is at HL.
Image: a barley field. Many crop varieties carry useful mutations. Public Domain Images.



Objectives for each class

Class	Statements	By the end of the class, you can...
1	D1.3.1–3	Distinguish substitutions, insertions and deletions, and explain their effects, using HTT and CCR5
2	D1.3.4–5	Outline what causes mutations, and explain what is meant by randomness
3	D1.3.6–7	Compare mutations in germ cells with those in somatic cells, and explain their role in variation

Overview of this chapter

Part	Statements	What it covers
Types of change	D1.3.1	Substitutions, insertions and deletions
Effects	D1.3.2–3	SNPs, frameshifts, HTT and CCR5
Causes	D1.3.4–5	Mutagens, errors and randomness
Consequences	D1.3.6	Germ cells, somatic cells and cancer
Long term	D1.3.7	The source of all genetic variation

Three types of gene mutation

D1.3.1

- A **gene mutation** is a change to the base sequence of a gene

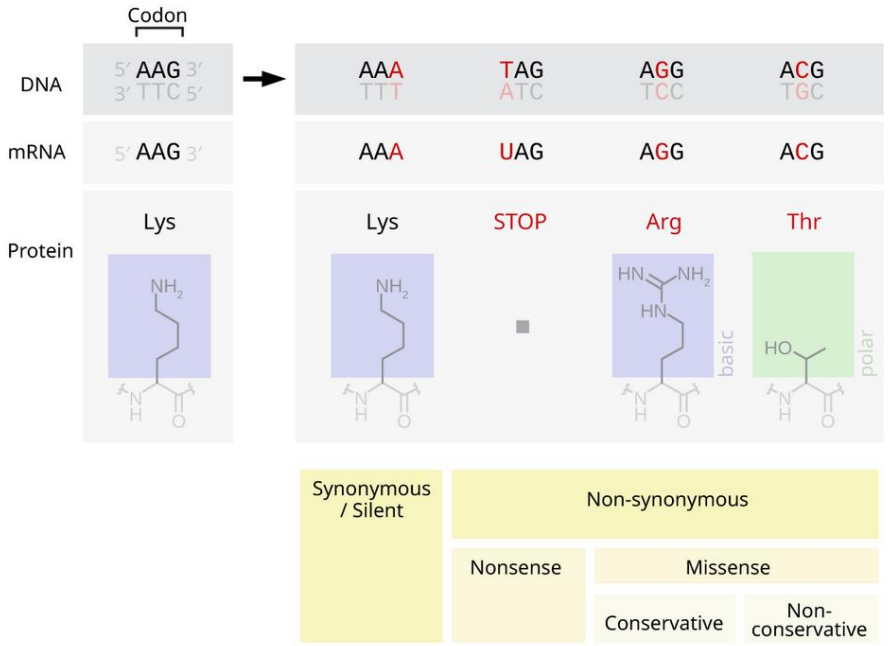
Type	Sequence	What has changed
Original	A T G C A T G G C	The starting sequence
Substitution	A T G C **C** T G G C	One base is replaced by another
Insertion	A T G C **G** A T G G C	An extra base is added
Deletion	A T G C T G G C	A base is lost

Common mistake

A gene mutation changes a base sequence. It is different from a change in chromosome number, and also from a change in the amino acid, which may or may not follow.

What a base substitution can do

D1.3.2



Effect	Example	Result
Silent	GCU to GCC	Same amino acid, because the code is degenerate
Missense	GAG to GUG	One amino acid changes
Nonsense	UAC to UAA	A stop codon ends the polypeptide early

Point mutations and their effects. Jonsta247, CC BY-SA 4.0.

- A **single-nucleotide polymorphism (SNP)** is a position where a single base varies between individuals, and results from a substitution

Key idea

Most substitutions change one amino acid at most. Sickle cell anaemia (D1.2.11) shows that even this can matter.

Insertions and deletions: frameshifts

D1.3.3

	Codons of mRNA	Amino acids
Original	AUG CAU GGC UUA	Met – His – Gly – Leu
One base deleted	AUG CUG GCU UA...	Met – Leu – Ala ...
Three bases deleted	AUG GGC UUA	Met – Gly – Leu

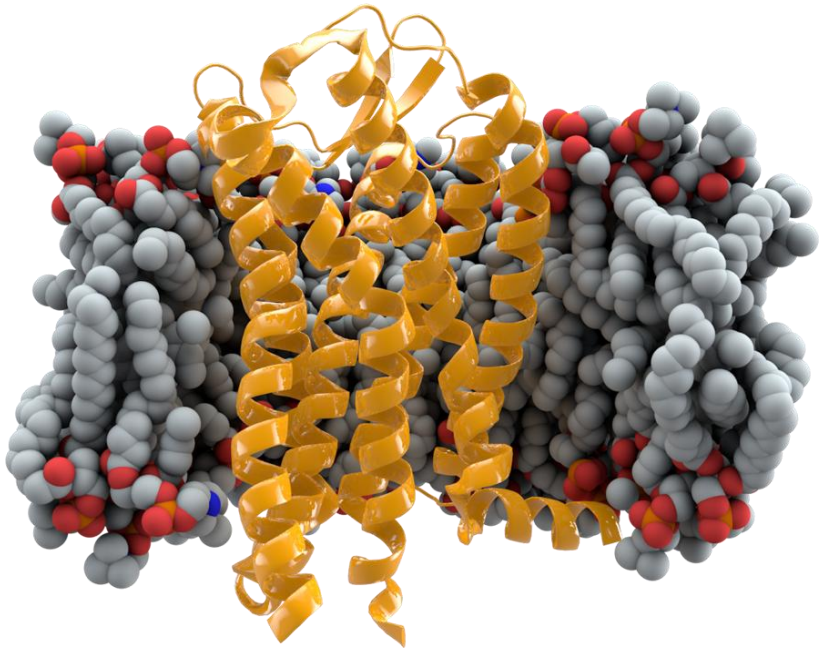
- Bases are read in threes, so losing or adding one base shifts every codon that follows: a **frameshift**
- The polypeptide usually stops working
- Adding or losing three bases keeps the frame, but still adds or removes amino acids

Activity

Delete the first base of the second codon: AUG CAU GGC. Write the new codons, and use a table to deduce the effect.

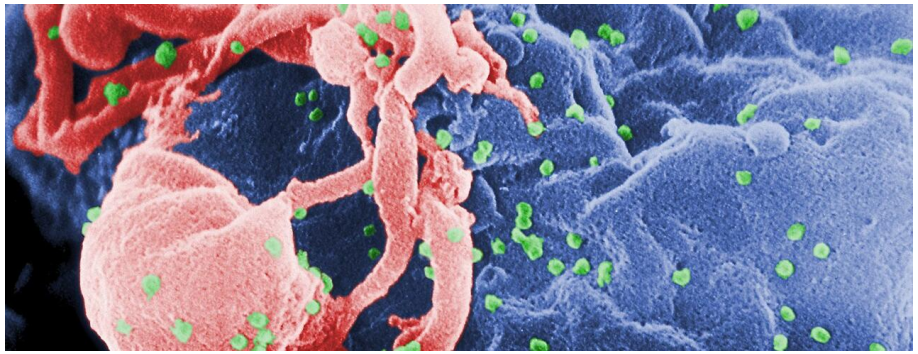
A deletion: delta 32 in the CCR5 gene

D1.3.3



CCR5 in a cell membrane. Thomas Splettstoesser, CC BY-SA 3.0.

- **CCR5** is a receptor found on some white blood cells
- Delta 32 is a **deletion of 32 bases**, which causes a frameshift
- The receptor no longer reaches the cell surface in working form
- Most HIV strains use CCR5 to enter cells
- So people with two copies have strong resistance to these strains



HIV budding from a cell. C. Goldsmith, public domain.

Key idea

This is a rare case in which losing a working protein gives an advantage.

An insertion: repeats in the HTT gene

D1.3.3

CAG repeats in HTT	Effect	Why
Up to about 35	Typical protein	Normal range
36–39	May develop the disease	Partial effect
40 or more	Huntington's disease develops	Longer chain of glutamines in the protein

- Extra copies of a **three-base** sequence are inserted, so the reading frame is kept
- The altered protein damages neurons, usually starting in middle age

Common mistake

A trinucleotide insertion is not a frameshift. The polypeptide is longer, and it still loses its normal function, because of what the extra amino acids do to it.

What causes gene mutations

D1.3.4





Tobacco smoke (C. E. Vipin, CC BY-SA 2.0); radiation symbol (public domain).

Cause	Examples
Chemical mutagens	Substances in tobacco smoke, benzene, asbestos, diesel exhaust
Mutagenic radiation	Short-wave UV, X-rays, gamma rays, alpha particles
Replication errors	DNA polymerase occasionally adds the wrong base
Repair errors	Damage to DNA is mended with a wrong sequence

Key idea

A **mutagen** raises the mutation rate. Radiation is mutagenic when it has enough energy to cause chemical changes in DNA.

Mutation is random

D1.3.5

- Mutations can occur **anywhere** in the base sequences of a genome
- Some bases have a higher probability of mutating than others, so random does not mean equally likely
- No natural mechanism is known for changing a particular base in order to change a trait

Common mistake

Organisms do not mutate because they need to. Antibiotics do not cause bacteria to develop resistance mutations: they kill those without such mutations.

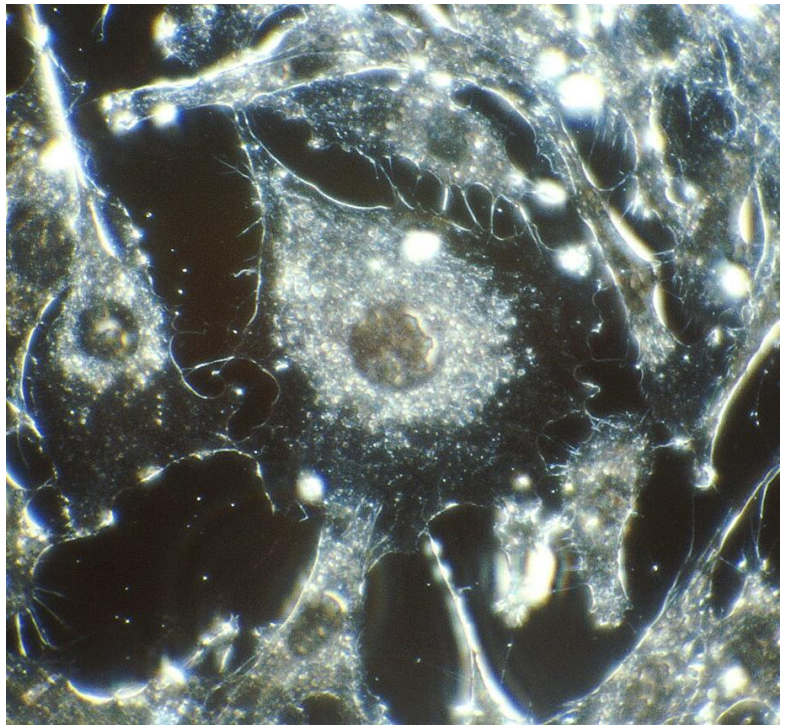
Discussion

A mutation in a stretch of DNA that does not code for anything usually has no effect at all. Why does this mean that many mutations are never noticed?

Germ cells and somatic cells

D1.3.6

	Germ cells	Somatic cells
Which cells	Give rise to gametes	All other body cells
Inherited?	Yes, by offspring	No
Effect	May be in every cell of the offspring	Only in cells descended from the mutated cell
Main risk	Genetic disease	Cancer



Cancer cells. Dr. Cecil Fox, public domain.

Cancer

A tumour forms when mutations in genes that control cell division cause uncontrolled division. Usually several mutations are required, and so risk rises with age and exposure to mutagens.

The source of all genetic variation

D1.3.7



Peppered moths: colour forms arose by mutation. Chiswick Chap, CC BY-SA 3.0.

- A new **allele** arises only by mutation
- Meiosis and fertilization mix alleles, but they do not create new ones
- Most mutations are harmful or neutral for an individual
- Without them, there would be nothing for natural selection to act on

Key idea

What can be harmful to an individual is, across long periods of time, essential for a species. Evolution depends on this variation (D4.1).

Check that you can explain

1. Substitutions, insertions and deletions
2. Silent, missense and nonsense effects
3. What a SNP is
4. Why a frameshift is so damaging
5. The examples of HTT and CCR5
6. Chemical and radiation mutagens
7. What random means in mutation
8. Germ cells compared with somatic cells
9. Why mutation matters for evolution

Exit activity: 5 minutes

On your own and without notes. Hand this in as you leave.

1. Explain why a substitution may have no effect on a polypeptide.
2. Explain why deleting one base usually does more harm than substituting one base.
3. State one chemical mutagen and one form of mutagenic radiation.

Image credits

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Point mutations-en.png – Jonsta247 – CC BY-SA 4.0

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