

C.3.2 · Defence against disease

International Baccalaureate · IB Diploma · Biology · HL

Scope and prerequisites

This handout covers selected HL topics for the course first assessed in 2025; it is not the whole syllabus.

Prerequisites: cells and membranes from B.2 and enzymes from B.1.

The examples are original and fictional: they are not real measurements or real student investigations.

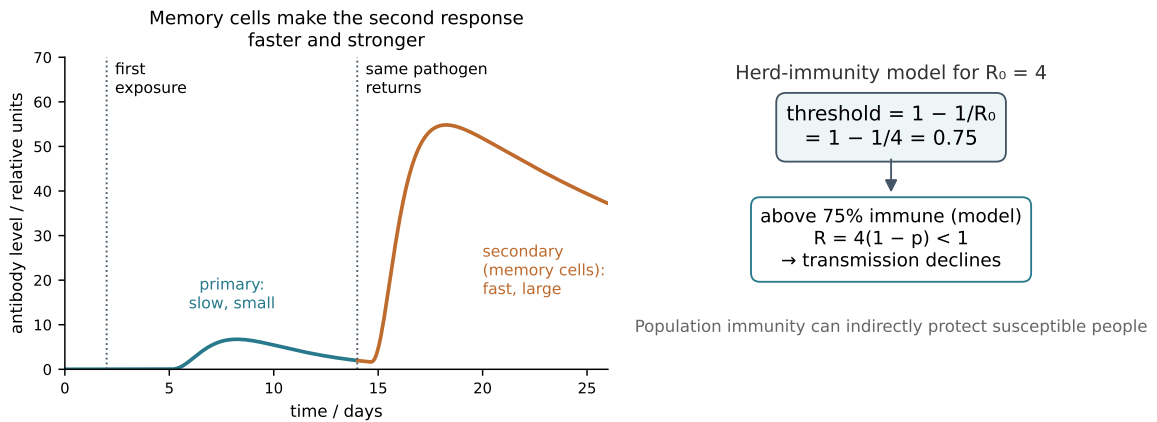
Defence against disease

■ What would explain this observation?

- Most people catch chickenpox once and never again, while a cold can return every year. What does the immune system remember, and why does it fail against the cold?

■ Build the model

- Pathogens carry **antigens** – molecular structures recognised by specific immune receptors. Phagocytes engulf and digest pathogens, while lymphocytes make **antibodies**, proteins shaped to bind one specific antigen. The first response is slow because the matching lymphocytes must be selected and multiplied.
- After the first infection, **memory cells** remain. On re-exposure they produce a faster, stronger secondary response, often destroying the pathogen before symptoms appear. **Vaccination** can prepare immune memory for later exposure. Immunity in a population can reduce transmission and indirectly protect susceptible people – **herd immunity**. Protection depends on the pathogen, population and vaccine; it does not guarantee that no infection or outbreak can occur.
- antigen: A molecular structure recognised by a specific antibody or immune receptor; antigens can come from the body itself or from outside it; antibody: A protein that binds one specific antigen; memory cell: A long-lived lymphocyte that enables a fast secondary response; vaccination: Giving a vaccine to prepare a specific immune response and memory; herd immunity: Indirect population protection when immunity reduces transmission.



Memory cells make the second response faster and larger; with $R_0 = 4$, herd immunity needs 75% immune

■ Choose evidence that can test it

- Track antibody concentration after a first and a second exposure to the same antigen: the model predicts a faster and larger second peak. A cold can return because many different viruses and strains cause colds; immunity to one need not protect against another.
- Compare outbreak sizes in populations with different vaccination coverage; above the threshold, outbreaks should fail to grow.

■ Work from known quantities

- Known: a pathogen has a basic reproduction number $R_0 = 4$, meaning four secondary cases per case on average in a fully susceptible population under this model. The threshold is $1 - 1/R_0 = 1 - 1/4 = 0.75$. With uniform mixing and complete protection, exactly 75% immune gives $R = 4 \times (1 - 0.75) = 1$. The immune proportion must exceed 75% to give $R < 1$ and declining transmission in the model.

Example:

A different pathogen has $R_0 = 2.5$. Find the herd-immunity threshold as a percentage using the same sequence: known quantities $\rightarrow$ model $\rightarrow$ relation $\rightarrow$ substitution $\rightarrow$ unit and interpretation. (Answer: $1 - 1/2.5 = 1 - 0.4 = 0.6 = 60\%$. A less contagious pathogen needs less coverage.)

■ Check the conclusion and its limits

- The threshold model assumes uniform mixing, equal susceptibility and complete protection against transmission among immune people; real populations cluster and protection can wane. If vaccination gives incomplete protection against transmission, the required vaccination proportion is higher than the immune threshold

in this simplified model.

Warn:

An antibody can bind equally well to any pathogen. This claim is false: antibodies recognise particular antigen shapes. A different antigen can escape an existing response; vaccines target chosen antigens.

Key:

Defence against disease: phagocytes engulf; lymphocytes make antigen-specific antibodies; memory cells give a faster, stronger second response. Vaccination can prepare specific immune memory. When population immunity reduces transmission, herd immunity can provide indirect protection. The simplified threshold $1 - 1/R_0$ is a model boundary, not a guarantee that everyone is protected.

■ **Write from a threshold of 80 percent**

- A pathogen has $R_0 = 5$.
- Find the herd-immunity threshold: $1 - 1/5 = 0.8$, so 80 percent immune.

■ **Write from a threshold of 50 percent**

- A milder strain has $R_0 = 2$.
- Find the threshold: $1 - 1/2 = 50$ percent – the threshold tracks $1/R_0$, falling toward zero as R_0 approaches one.

■ **Write from coverage that falls short**

- $R_0 = 4$ and vaccination covers 60 percent of the population.
- Is the threshold met? $1 - 1/4 = 75$ percent needed, so no – transmission continues in the gap.