DP Biology – A2.3 (HL only)

Viruses

- How do viruses manage with so few genes?
- How do viruses differ from one another?

HL statements A2.3.1–6. Textbook pp. 88–99.

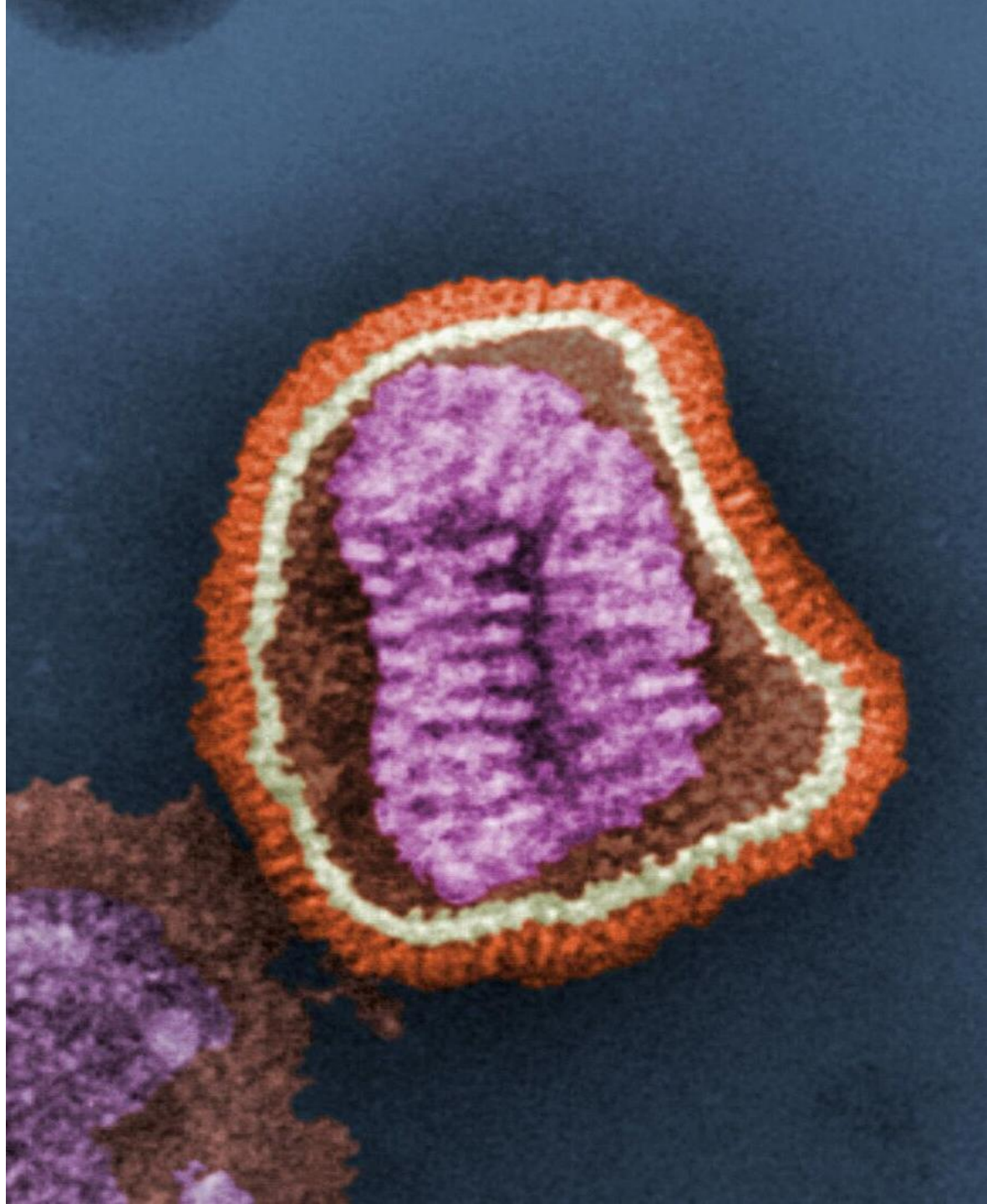


Image: an influenza virus particle (TEM, coloured). C. Goldsmith, CDC, public domain.

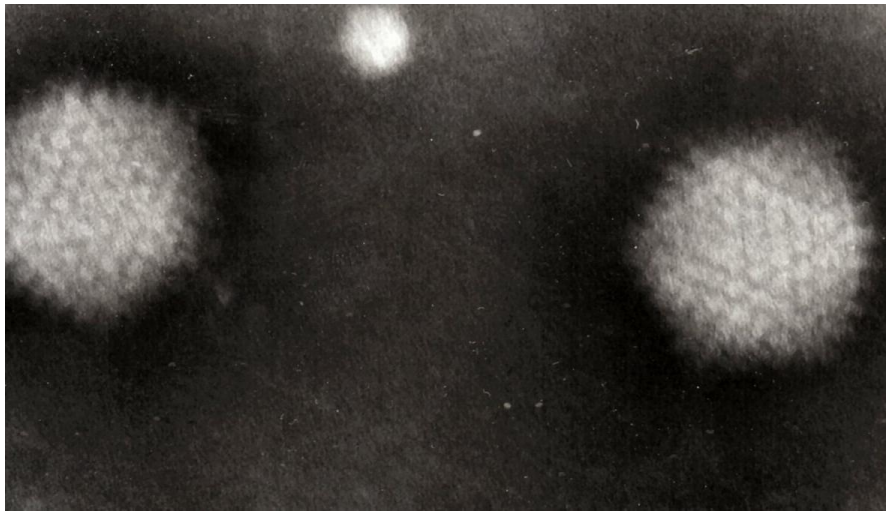
Objectives for each class

Class	Statements	By the end of the class, you can...
1	A2.3.1–2	Describe the features all viruses share, and the diversity of their genomes, capsids and envelopes
2	A2.3.3–4	Compare the lytic and lysogenic cycles of bacteriophage lambda
3	A2.3.5–6	Evaluate hypotheses for the origins of viruses, and explain rapid evolution in influenza and HIV

Features shared by all viruses

A2.3.1

Feature	Detail
Small, fixed size	About 20 to 400 nm; viruses are assembled, not grown
Nucleic acid	DNA or RNA as genetic material, never both
Protein capsid	A coat of protein subunits (capsomeres) around the genome
No cytoplasm	No ribosomes and no metabolism of their own
Few or no enzymes	They use the enzymes and ribosomes of the host



Adenovirus particles (TEM). GrahamColm, CC BY 3.0.

Common mistake

A virus is not a cell. It has no nucleus or nucleoid, only a genome inside a capsid. It is an obligate parasite: it can only reproduce inside a host cell.

Viruses compared with bacteria

A2.3.1

	Virus	Bacterium
Cellular?	No	Yes
Diameter	About 0.02 to 0.4 μm	About 1 to 5 μm
Nucleic acid	DNA or RNA	Both DNA and RNA
Ribosomes	None	70S
Outer surface	Protein capsid; some have an envelope	Cell wall of peptidoglycan
Reproduction	Assembled inside a host cell	Binary fission

Viruses were predicted before they were seen: infected sap still caused disease after filtering out bacteria.

Diversity of viral genomes

A2.3.2

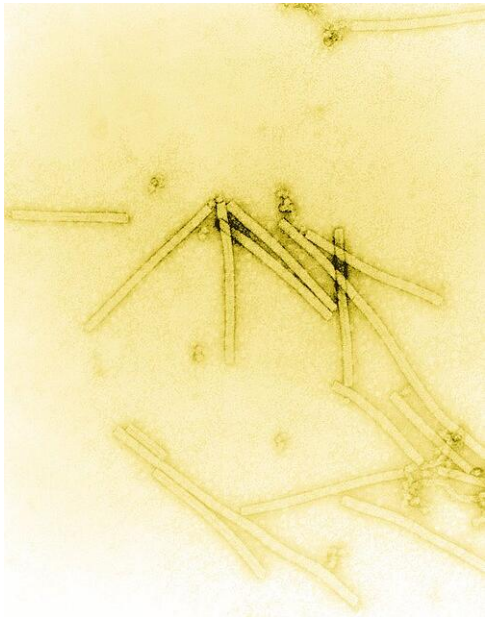
Genome	Example	Notes
Double-stranded DNA	Bacteriophage lambda	Linear in the virion; circularizes inside the host
Single-stranded RNA, positive sense	SARS-CoV-2 (coronavirus)	Acts directly as mRNA on host ribosomes
Single-stranded RNA, negative sense	Influenza	Must first be copied into mRNA; 8 separate segments
Single-stranded RNA, retrovirus	HIV	Reverse transcriptase copies RNA into DNA, which joins the host genome

Key idea

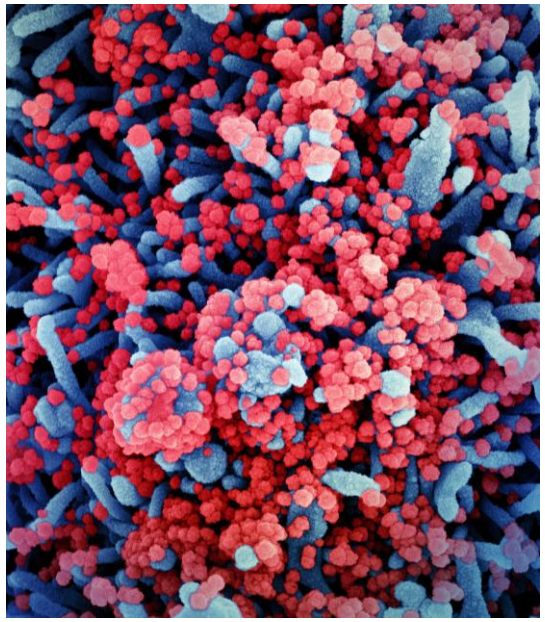
Genomes can be DNA or RNA, single- or double-stranded, linear or circular, in one piece or in segments. Small genomes replicate fast.

Capsids and envelopes

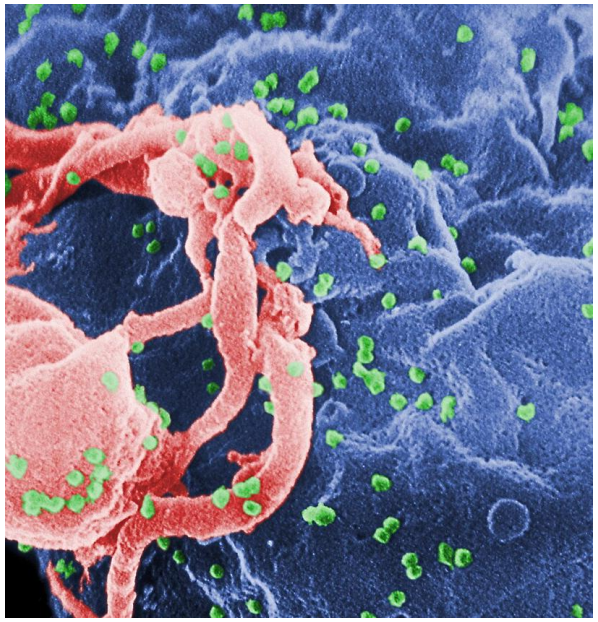
A2.3.2



TMV rods (TEM). Public domain.



SARS-CoV-2 on a cell (SEM). NIH, public domain.



HIV budding from a cell. CDC, public domain.

- Capsid shapes: **helical** (TMV), **icosahedral** (adenovirus), **complex** (phages)
- An **envelope** is host membrane with viral glycoproteins

	Enveloped	Not enveloped
Examples	HIV, coronaviruses, influenza	Bacteriophage lambda, TMV, adenovirus
How it forms	The virus takes membrane as it buds out of the host cell	Released when the cell bursts

Comparing three viruses

A2.3.2

	Bacteriophage lambda	SARS-CoV-2	HIV
Nucleic acid			
Single or double stranded			
Envelope?			
Host cell			
One distinctive feature			

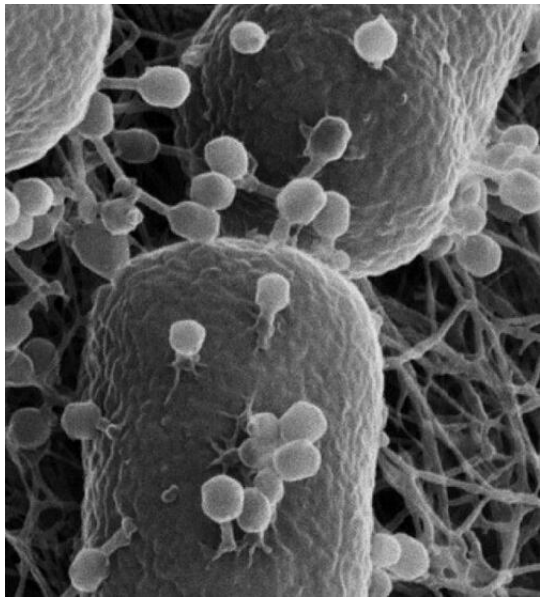
Activity

Complete the table in pairs, using the previous slides and the textbook. Then suggest which feature most limits the host range of each virus.

The lytic cycle of phage lambda

A2.3.3

Attachment: tail fibre binds a receptor on E. coli → Entry: DNA injected; capsid stays outside → Replication: host enzymes copy phage DNA; host DNA broken down → Synthesis and assembly: host ribosomes make capsid proteins → Lysis: enzymes break the wall; about 100 new phages released



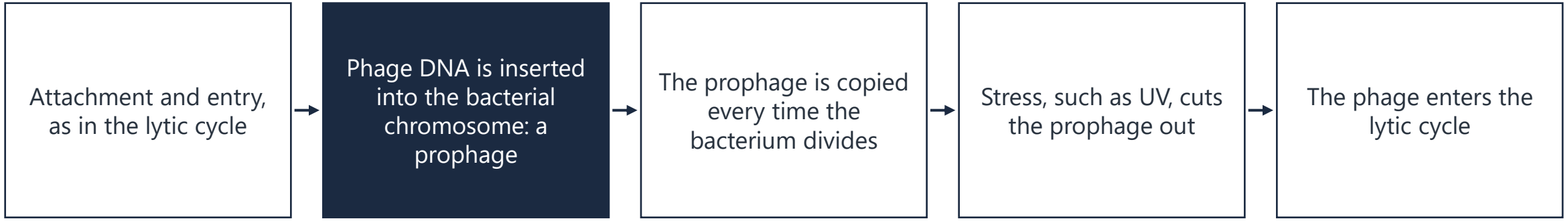
E. coli with phages attached. McGenity et al., CC BY-SA 4.0.

Using the host

The phage has no ribosomes or metabolism. It relies on the host for energy (ATP), nucleotides and amino acids, enzymes, and ribosomes for protein synthesis. The host cell dies. Phages that only use this cycle are called virulent. Discuss: what are the advantages and disadvantages of the lytic cycle for the virus?

The lysogenic cycle of phage lambda

A2.3.4



	Lytic	Lysogenic
Phage DNA	Separate from host DNA	Integrated as a prophage
Host cell	Killed quickly	Survives and divides
Number of copies	Many new phages at once	One copy in every daughter cell
Favoured when	Bacteria grow well	Bacteria grow poorly

Which cycle is better for the virus?

A2.3.4

	Advantages	Disadvantages
Lytic, for the virus		
Lysogenic, for the virus		
Lysogenic, for the host		

Hint

Think about speed, number of new viruses, survival when hosts are scarce, and whether the host can still spread the virus when it divides.

Where did viruses come from?

A2.3.5

Hypothesis	Idea	Fits
Progressive (escaped genes)	Mobile genetic elements, such as transposons, gained a coat and the ability to move between cells	Retroviruses
Regressive (reduction)	Viruses are remnants of cells that lost genes as they became parasites	Large DNA viruses
Virus first	Viruses arose from self-replicating RNA before cells, and later infected them	The RNA world idea

Evidence for several origins

No single gene is shared by all viruses, so they are unlikely to have one common ancestor. Their shared features, such as a capsid and small size, are probably convergent evolution: similar adaptations to the same parasitic way of life. Viruses do use the same genetic code as their hosts.

Why some viruses evolve so fast

A2.3.6

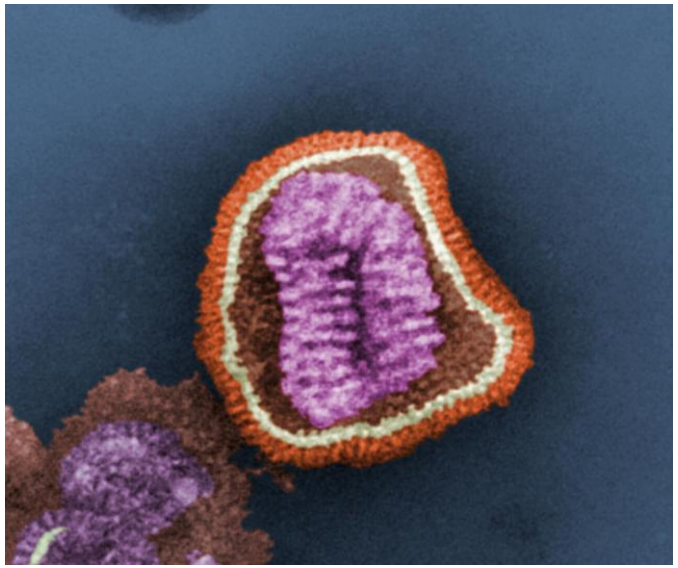
Factor	Effect
Short generation time	New viruses in hours, so many generations a year
Huge numbers	Billions of copies in one infected host, so rare mutations still occur often
No proofreading	RNA replicase and reverse transcriptase do not correct errors, so mutation rate is high
Strong selection	Immune responses and drugs select variants that escape them

Consequence

Vaccines and drugs can lose their effect. Flu vaccines are updated every year, and HIV is treated with combinations of drugs.

Rapid evolution: influenza

A2.3.6



Influenza virus (TEM). CDC, public domain.

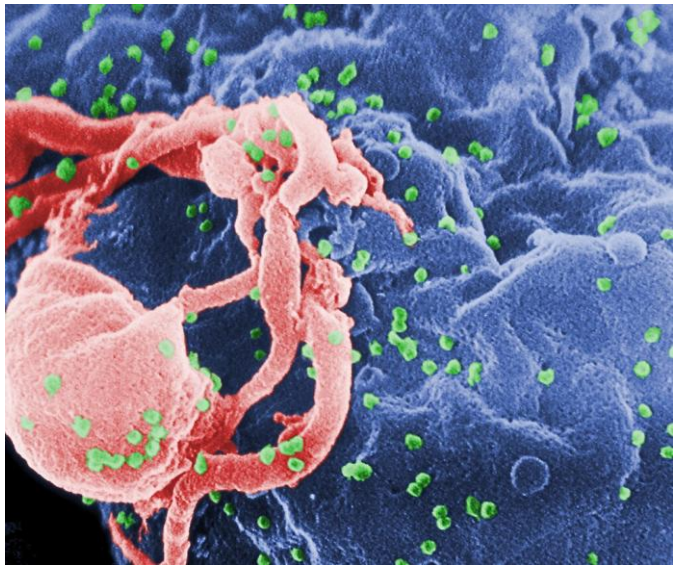
- Genome: 8 segments of negative-sense RNA, copied without proofreading
- Surface proteins: haemagglutinin (H) and neuraminidase (N) are antigens
- **Antigenic drift**: small mutations gradually change H and N, so immunity fades
- **Antigenic shift**: two strains infect one cell and swap whole segments, giving a new subtype

Pandemics

A shift can produce H and N proteins that nobody is immune to. Pigs and birds can carry several strains, so new combinations may arise there. The 1918 and 2009 pandemics were caused by new influenza A subtypes. Seasonal flu vaccines must be updated each year because of drift.

Rapid evolution: HIV

A2.3.6



HIV budding (SEM). CDC, public domain.

- A retrovirus: **reverse transcriptase** copies its RNA into DNA, which integrates into the host genome as a provirus
- Reverse transcriptase has no proofreading, so most new viruses carry a mutation
- One person can carry many variants after a few years

Consequences for treatment

Variants resistant to one drug are selected quickly. Antiretroviral therapy combines three or more drugs with different targets, so a virus would need several mutations at once to resist them all. Rapid change of envelope proteins has also made an HIV vaccine very hard to develop.

Check that you can explain

1. The five features shared by all viruses
2. How viral genomes, capsids and envelopes vary, with examples
3. The stages of the lytic cycle of phage lambda
4. How the lysogenic cycle differs, and when each is favoured
5. Three hypotheses for the origin of viruses, and why several origins are likely
6. Why RNA viruses and retroviruses evolve rapidly
7. Antigenic drift and shift in influenza
8. Why HIV is treated with drug combinations

Exit activity: 5 minutes

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

1. State three features that all viruses share.
2. Distinguish between the lytic and lysogenic cycles.
3. Explain why influenza vaccines are changed every year.

Image credits

Influenza virus particle color.jpg – Photo Credit: Cynthia Goldsmith Content Providers(s): CDC/ D – Public domain

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Novel Coronavirus SARS-CoV-2 (50098378372).jpg – NIH Image Gallery from Bethesda, Maryland, USA – Public domain

HIV-budding-Color.jpg – Photo Credit: C. Goldsmith Content Providers: CDC/ C. Goldsm – Public domain

Escherichia coli with phages.jpg – Terry J. McGenity, Amare Gessesse, John E. Hallsworth, Esthe – CC BY-SA 4.0

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