MDCAT Biology Unit 1: Acellular life, study guide with practice MCQs

What MDCAT asks

Unit 1 covers viruses: what a virus is made of, why it is not a cell, how viruses are sorted into groups, how a bacteriophage multiplies by the lytic and lysogenic cycles, and how HIV replicates as a retrovirus and causes AIDS. The two subtopics carry roughly equal weight in the PMDC curriculum and together make up about 2 to 3 of the 81 Biology questions in a typical paper, so a student should expect two or three questions on this unit. Questions are usually one-idea recall or one-step reasoning: a virus-to-feature match, a step in a replication cycle, or a fact about HIV transmission.

B1.1 Viruses: structure and classification

B1.1.1 Structure of a virus and why viruses are called acellular

The word virus means poison. A virus is a tiny particle that can multiply only inside a living cell. It is not made of cells and is not itself a cell, so it is called **acellular**. A bacterium, however small, has a membrane, cytoplasm, ribosomes, enzymes and its own metabolism, and can grow on a nutrient medium. A virus has none of these. Outside a host it is an inert particle; inside a host it is an **obligate intracellular parasite** that borrows the ribosomes, enzymes, ATP and raw materials of the cell to make copies of itself.

Most viruses measure about 20 nm to 250 nm, so they pass through filters that hold back bacteria and are seen only with the electron microscope. They carry genes and reproduce inside a host, yet can be crystallised and have no metabolism or cell structure, so they sit on the border between living and non-living.

A complete, infective virus particle is called a **virion**. Every virion has two essential parts:

- **Nucleic acid core.** Either DNA or RNA, never both; single- or double-stranded. It carries the few genes needed to make new virus particles.
- **Capsid.** A protein coat that protects the nucleic acid and helps the virus attach to its host. It is built from many identical protein subunits called **capsomeres**. Capsid plus nucleic acid is the **nucleocapsid**.

Some viruses have a third part:

- **Envelope.** A membrane around the nucleocapsid, taken from the host cell membrane as the virus buds out. The lipid is host-derived, but the glycoprotein spikes set in it are coded by viral genes and bind to receptors on the next host cell. Viruses without an envelope are called naked.

Learn the terms as a set: one **capsomere** is one subunit; many capsomeres form one **capsid**; capsid plus nucleic acid is the **nucleocapsid**; nucleocapsid plus envelope (if any) is the **virion**. Two simpler acellular agents: a **viroid** is naked RNA with no capsid, and a **prion** is infectious protein with no nucleic acid.

B1.1.2 Classification of viruses

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Viruses are grouped in four main ways; MDCAT usually asks you to match a named virus to its group.

1. By nucleic acid. DNA virus or RNA virus; the genome may be single-stranded (ss) or double-stranded (ds). Most DNA viruses are dsDNA and most RNA viruses are ssRNA. Retroviruses such as HIV are RNA viruses that copy their RNA into DNA inside the host.

2. By capsid symmetry. The capsomeres can be arranged in three patterns:

- **Helical:** capsomeres wind in a spiral around the nucleic acid, giving a hollow rod. Tobacco mosaic virus (TMV) is the classic example: a rigid rod of about 2 130 identical capsomeres around one strand of RNA.
- **Polyhedral (icosahedral):** a roughly spherical shell with 20 identical triangular faces and 12 corners. Poliovirus, adenovirus and the capsid of herpes virus are icosahedral.
- **Complex:** the T_4 bacteriophage has a polyhedral head on a helical tail, so it combines both patterns. Poxviruses such as smallpox are also called complex.

3. By host. Bacteriophages (phages) infect bacteria; **plant viruses** infect plants (TMV); **animal viruses** infect animals, including humans (influenza, polio, HIV). A virus infects only cells carrying the receptor it recognises, which is why a phage cannot infect a human cell and HIV attacks only CD4 cells.

4. By disease. Respiratory (influenza, common cold), nervous system (polio, rabies), skin (smallpox, chickenpox, herpes, measles), liver (hepatitis viruses), immune system (HIV).

Virus	Nucleic acid	Capsid symmetry	Envelope	Host and disease
T_4 bacteriophage	dsDNA	Complex (head + tail)	Naked	*Escherichia coli*; lyses the bacterium
Tobacco mosaic virus	ssRNA	Helical rod	Naked	Tobacco and related plants; mosaic pattern on leaves
Poliovirus	ssRNA	Icosahedral	Naked	Humans; poliomyelitis (paralysis)
Adenovirus	dsDNA	Icosahedral	Naked	Humans; respiratory and eye infections
Herpes virus	dsDNA	Icosahedral	Enveloped	Humans; cold sores, chickenpox and shingles
Influenza virus	ssRNA	Helical (inside envelope)	Enveloped	Humans; flu
HIV	ssRNA (retrovirus)	Cone-shaped core	Enveloped	Human helper T cells; AIDS
Smallpox (variola) virus	dsDNA	Complex	Enveloped	Humans; smallpox, now eradicated

The two groupings MDCAT asks most often:

Grouping	Examples
DNA viruses	Smallpox, herpes, chickenpox, adenovirus, hepatitis B, T_4 phage

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RNA viruses	Polio, influenza, measles, mumps, rabies, hepatitis A, HIV, tobacco mosaic virus
Enveloped viruses	Influenza, HIV, herpes, measles, mumps, rabies, hepatitis B
Naked viruses	Poliovirus, adenovirus, tobacco mosaic virus, T_4 phage

The T_4 phage comes up in both subtopics. It has a polyhedral **head** holding dsDNA, a **collar**, a hollow **tail** in a contractile **sheath**, a **base plate** and six **tail fibres**. The fibres attach to receptor sites on the wall of *E. coli*; the sheath contracts, and the DNA passes down the hollow tail into the cell.

MDCAT trap: one nucleic acid, many capsomeres

Two mistakes lose the most marks here. The first is picking an option that says a virus contains both DNA and RNA. A cell contains both; a virus never does. A particle described with DNA, RNA and ribosomes is a cell, however small. The second is swapping capsid and capsomere: the capsomere is the building block, the capsid is the finished coat, and one capsid is made of many capsomeres. Watch also for the envelope: not every virus has one, it comes from the host membrane, and its spikes are viral proteins, not host proteins.

Worked example

Question: An agent from the sap of a diseased plant passes through a bacterial filter, cannot be grown on a nutrient medium, and contains protein and single-stranded RNA but no DNA, ribosomes or lipid. Under the electron microscope it is a rigid rod. Identify it.

Step 1: Passing through a bacterial filter shows only that it is very small.

Step 2: No growth on a nutrient medium means no metabolism of its own: an obligate intracellular parasite, not a bacterium.

Step 3: Protein plus one kind of nucleic acid and no ribosomes is the signature of a virus. A viroid would have RNA only; a prion protein only.

Step 4: No lipid means no envelope (naked); a rigid rod means helical symmetry.

Answer: a naked, helical, single-stranded RNA plant virus. The description matches tobacco mosaic virus.

B1.2 Viral replication and disease

B1.2.1 The lytic and lysogenic cycles of a bacteriophage

A bacteriophage cannot grow or divide. It multiplies by making the bacterium build new phages from the phage DNA, in one of two ways.

The lytic cycle (studied in the T_4 phage of *E. coli*) ends in the death and bursting of the bacterium. Its stages are:

1. **Attachment (adsorption).** The tail fibres bind to specific receptor sites on the bacterial wall; this match makes each phage specific to its host.
2. **Penetration.** Lysozyme carried in the phage tail digests a small hole in the wall, the sheath contracts, and the phage DNA is injected into the cytoplasm. The protein coat (head, tail, fibres)

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stays outside as an empty ghost.

3. **Replication (synthesis).** Phage genes take over; the bacterial DNA is shut down and broken into nucleotides, and the host's enzymes, ribosomes, ATP and nucleotides copy the phage DNA many times and make capsid proteins, tail proteins and lysozyme.
4. **Assembly (maturation).** Heads are packed with DNA, tails and fibres are added, and complete virions form.
5. **Lysis and release.** Phage-coded lysozyme weakens the wall from inside, the cell bursts, and a few hundred new phages escape to infect neighbouring bacteria. In T_4 the cycle takes about half an hour.

A phage that follows only the lytic cycle is a **virulent phage**; T_4 is virulent.

The lysogenic cycle is the quiet alternative. After attachment and penetration, the phage DNA does not take over the cell. It inserts itself into the bacterial chromosome and becomes a **prophage**, which is copied with the chromosome each time the bacterium divides, so every daughter cell inherits it. The host is not harmed and is said to be **lysogenic**. A phage that can follow either cycle is a **temperate phage**; phage lambda (λ) of *E. coli* is the standard example. The prophage may stay silent for many generations, but when the bacterium is stressed, for example by ultraviolet light or certain chemicals, the prophage is cut out of the chromosome (induction) and starts a lytic cycle that ends in lysis.

Feature	Lytic cycle	Linked lysogenic cycle
Type of phage	Virulent (T_4) or temperate	Temperate only (lambda)
Fate of phage DNA	Stays free in the cytoplasm and is copied at once	Inserted into the bacterial chromosome as a prophage
Host cell	Taken over, then lysed and killed	Survives, divides normally and passes the prophage to daughter cells
New phages made	Yes, a few hundred per cell	Not until the prophage is induced into a lytic cycle
Time course	Minutes	Many bacterial generations
Trigger to lyse	None needed	Stress such as UV light or chemicals induces the prophage

B1.2.2 HIV: replication as a retrovirus, transmission, symptoms and prevention of AIDS

Structure. The human immunodeficiency virus (HIV) is an enveloped RNA virus. Its envelope carries glycoprotein spikes (gp120) that bind to the CD4 receptor. Inside, a cone-shaped protein core holds two identical single-stranded RNA molecules and the enzyme **reverse transcriptase**. Because this enzyme copies RNA into DNA, the reverse of the usual flow of information, HIV is a **retrovirus**.

Target cell. HIV infects cells carrying the CD4 receptor, chiefly the **helper T lymphocytes** and also macrophages. Helper T cells coordinate the immune system, activating B cells to make antibodies and activating killer T cells, so losing them cripples both arms of the immune response.

Replication in a helper T cell:

1. **Attachment.** gp120 on the envelope binds to CD4 on the T cell.
2. **Entry.** The envelope fuses with the cell membrane; the core enters and releases the RNA and

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enzymes.

3. **Reverse transcription.** Reverse transcriptase makes a DNA copy of the viral RNA, then a second strand, giving double-stranded viral DNA.
4. **Integration.** The viral DNA enters the nucleus and is inserted into a host chromosome as a **provirus**. Like a prophage, it may lie dormant for years and is copied whenever the cell divides.
5. **Transcription and translation.** Host RNA polymerase transcribes the provirus into viral RNA; some becomes new genomes, the rest is translated on host ribosomes into viral proteins.
6. **Assembly and budding.** New cores assemble under the membrane and bud out, taking a piece of membrane as their envelope. Repeated budding and immune attack destroy the helper T cell.

From infection to AIDS. A few weeks after infection many people have a short flu-like illness, then feel well. The virus is not gone: it multiplies steadily, the body makes antibodies (the person is now HIV-positive on a blood test), and the helper T cell count falls slowly over years. During this long symptom-free period the person looks healthy but can infect others. When the helper T cell count falls below about 200 cells per mm^3 of blood the immune system can no longer hold back ordinary microbes. The person now has **AIDS** (acquired immunodeficiency syndrome): persistent fever, weight loss, swollen lymph nodes, chronic diarrhoea, and **opportunistic infections** such as tuberculosis, *Pneumocystis* pneumonia, fungal infections of the mouth and gut, and cancers such as Kaposi's sarcoma. Death comes from these infections, not from HIV directly. Untreated, the gap from infection to AIDS is commonly around 8 to 10 years.

Transmission. HIV is carried in blood, semen, vaginal fluid and breast milk. It is fragile outside the body and cannot cross intact skin, so it spreads only when these fluids reach the blood or mucous membranes of another person.

Spreads HIV	Does not spread HIV
Unprotected sexual contact with an infected person	Shaking hands, hugging, touching
Transfusion of infected, unscreened blood or blood products	Sharing food, utensils, cups, toilets or swimming pools
Sharing needles, syringes, razors or unsterilised surgical and dental instruments	Coughing, sneezing, sweat, tears or saliva
Mother to child across the placenta, during birth, or in breast milk	Mosquito or other insect bites

Diagnosis. A blood test (ELISA) detects antibodies to HIV. Antibodies take some weeks to appear, so a very recent infection can be missed (the window period).

Prevention and treatment. There is at present no cure and no vaccine. Prevention rests on screening all donated blood, sterile disposable needles and instruments, never sharing needles or razors, safe sexual behaviour and condom use, and treating infected pregnant mothers to protect the baby. **Antiretroviral drugs**, for example the reverse transcriptase inhibitor zidovudine (AZT) given in combination, do not remove the provirus but block the enzymes HIV needs, keep the virus count low, protect helper T cells and let an infected person live a near-normal life.

> **MDCAT trap: what enters, and who can infect**

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First trap: only the DNA of a bacteriophage passes into the bacterium; head, tail and fibres stay outside. An option saying "the phage enters the cell" is wrong. By contrast, when HIV infects a T cell the whole core, RNA and reverse transcriptase included, enters the cytoplasm, because the host has no enzyme that copies RNA into DNA. Keep the two cases apart. Second trap: HIV-positive and AIDS are not the same. A person is HIV-positive from the time antibodies appear, may have no symptoms for years, and can pass the virus on throughout that time; "no symptoms, cannot transmit" is a distractor. Lastly, prophage is to a bacterium what provirus is to a T cell: viral DNA inserted in the host chromosome.

Worked example

Question: A culture holds 10 000 bacteria. One virulent phage infects one bacterium; each infected cell releases 150 phages when it lyses, and every new phage infects a fresh cell at once. (a) After one lytic cycle, how many bacteria are lysed and how many phages exist? (b) Could this phage instead have been carried silently through several bacterial divisions?

Step 1 (a): One infected bacterium lyses, releasing 150 phages: 1 bacterium lysed, 150 phages.

Step 2: In a second cycle those 150 phages would infect 150 bacteria and release 150 × 150 = 22 500 phages, more than the whole culture. This exponential rise is why a phage clears a bacterial lawn within hours.

Step 3 (b): No. A virulent phage follows only the lytic cycle. Silent carriage as a prophage is the lysogenic cycle, open only to a temperate phage such as lambda.

Answer: (a) 1 bacterium lysed, 150 phages; (b) no, because the phage is virulent, not temperate.

Practice MCQs

1. Which statement about the genetic material of a virus is correct?
   A. Every virion contains both DNA and RNA.
   B. A virion contains either DNA or RNA, never both.
   C. All viruses contain double-stranded DNA.
   D. Viruses contain only RNA because they have no nucleus.
2. Which virus is correctly matched with its features?
   A. Tobacco mosaic virus: icosahedral capsid with an envelope.
   B. Poliovirus: enveloped DNA virus.
   C. T_4 bacteriophage: helical RNA virus.
   D. Influenza virus: enveloped RNA virus.
3. A human virus has a 20-faced capsid, no envelope and a single-stranded RNA genome, and causes paralysis. It is most likely:
   A. poliovirus.
   B. herpes virus.
   C. adenovirus.
   D. rabies virus.
4. Particles from a diseased leaf pass through a bacteria-proof filter, contain protein and single-stranded RNA but no ribosomes, and will not grow on nutrient agar. The best conclusion is that the particles are:

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A. very small bacteria that need a richer medium.
B. viroids, because they contain RNA.
C. viruses, because they need a living host cell to multiply.
D. fungal spores that have lost their cell walls.

5. During the lytic cycle of the T_4 phage, which part of the phage enters the bacterium?
   A. The whole virion.
   B. The DNA only.
   C. The capsid only.
   D. The DNA together with the tail fibres.
6. A bacteriophage that may follow either the lytic or the lysogenic cycle is called a:
   A. temperate phage.
   B. virulent phage.
   C. prophage.
   D. provirus.
7. A culture of lysogenic *E. coli* growing normally is briefly exposed to ultraviolet light. Within an hour the cloudy culture clears. The best explanation is that:
   A. UV light killed the bacteria directly and no phage was involved.
   B. UV light made the bacteria shed the prophage harmlessly.
   C. UV light damaged the bacterial walls so that they lysed.
   D. UV light induced the prophage to leave the chromosome and start a lytic cycle.
8. The enzyme reverse transcriptase carried by HIV:
   A. copies host DNA into viral RNA.
   B. inserts viral DNA into the host chromosome.
   C. makes a DNA copy of the viral RNA.
   D. cuts the host cell membrane during budding.
9. Which of the following would NOT transmit HIV from an infected person to a healthy one?
   A. Sharing a meal and drinking cups.
   B. Transfusion of unscreened blood.
   C. Breast-feeding by an infected mother.
   D. Sharing an injection needle.
10. Why does the immune system collapse in AIDS?
    A. HIV destroys red blood cells, so the tissues lack oxygen.
    B. HIV digests antibodies directly in the blood.
    C. HIV infects every type of body cell.
    D. HIV destroys helper T cells, which activate B cells and killer T cells.

1. B. A virus has one kind of nucleic acid, DNA or RNA; only cells have both. DNA viruses exist, so D is wrong; many viral genomes are single-stranded, so C is wrong.

2. D. Influenza is an enveloped RNA virus. TMV is a naked helical RNA virus, poliovirus is a naked RNA virus, and T_4 is a complex DNA phage.

3. A. Poliovirus is a naked icosahedral ssRNA virus that attacks motor neurons and causes paralysis. Herpes and adenovirus are DNA viruses; rabies virus is enveloped.

4. C. Protein plus one nucleic acid, no ribosomes and no growth on a lifeless medium is the definition of a virus. A viroid has RNA with no protein, and bacteria and fungal spores have

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ribosomes.

5. B. Lysozyme opens the wall, the sheath contracts and only the DNA is injected; the protein coat stays outside the cell.

6. A. Temperate phages such as lambda can enter either cycle; a virulent phage is lytic only. Prophage and provirus are states of viral DNA, not kinds of phage.

7. D. UV light is a classic inducer: it makes the prophage excise from the chromosome, replicate and lyse the cells, so the culture clears. Lysogenic bacteria are otherwise healthy.

8. C. Reverse transcription is RNA → DNA, the reverse of normal transcription. Integration is done by integrase, not by reverse transcriptase.

9. A. HIV is not carried in food or saliva in infectious amounts and does not cross intact skin. Blood, needles and breast milk are all recognised routes.

10. D. Helper T cells coordinate both antibody production and cell-mediated immunity; when HIV depletes them, opportunistic infections take hold. HIV does not infect red cells or all cells, and it does not digest antibodies.

Before the test: 12 facts to recite

1. A virus is acellular: no cytoplasm, no ribosomes, no metabolism; it multiplies only inside a living host cell as an obligate intracellular parasite.
2. Virion = nucleic acid + capsid (+ envelope in some viruses); capsid = many capsomeres; nucleocapsid = capsid + nucleic acid.
3. One virus has either DNA or RNA, never both; most viruses measure about 20 to 250 nm and pass through bacterial filters.
4. Capsid symmetry: helical (TMV), icosahedral with 20 faces (polio, adenovirus), complex (T_4 phage, poxviruses).
5. DNA viruses: smallpox, herpes, hepatitis B, T_4. RNA viruses: polio, influenza, measles, mumps, rabies, HIV, TMV.
6. Enveloped: influenza, HIV, herpes. Naked: poliovirus, TMV, T_4. The envelope comes from the host membrane; its spikes are viral glycoproteins.
7. Lytic cycle order: attachment (adsorption) → penetration → replication → assembly → lysis; only the phage DNA enters, and lysozyme makes the hole.
8. Virulent phage (T_4) = lytic only; temperate phage (lambda) = lytic or lysogenic; prophage = phage DNA inserted in the bacterial chromosome; the host is lysogenic.
9. A prophage is copied with the chromosome at every division and can be induced by UV light or chemicals to start a lytic cycle.
10. HIV is an enveloped retrovirus with two ssRNA strands and reverse transcriptase; it binds CD4 on helper T cells, copies RNA → DNA, and integrates as a provirus.
11. HIV spreads by unprotected sex, infected blood and shared needles, and from mother to child; not by touch, food, coughing or mosquitoes. A symptom-free carrier can still infect others.
12. AIDS = helper T cells destroyed → opportunistic infections; no cure, no vaccine; antiretroviral drugs slow the virus; prevent with screened blood, sterile needles and safe behaviour.

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