Bio Factsheet

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The Coronavirus (COVID-19)

This Biology Factsheet:

- Describes the outbreak of the latest coronavirus and explains why it spread so rapidly.
- Describes the structure of the virus.
- Explains how a virus replicates and causes cell and tissue damage.
- Reviews how patients are tested for viral infections and may be treated with new drugs and vaccines.
- Provides some common exam questions on viruses and adds information from examiners reports.

Introduction

In December 2019, the city of Wuhan in Hubei province China, became the centre of a suspected outbreak of pneumonia. At first no-one knew the cause. Chinese health authorities immediately investigated the nature of the disease and ways to control its spread. This involved:

- isolating people suspected of having the disease and monitoring their contacts.
- collecting **epidemiological** and clinical data from patients.
- identifying the genetic structure of the pathogen.
- developing diagnostic and treatment procedures including attempts to produce a vaccine.

Test Question 1: *What is epidemiology?*

The New Coronavirus Strain

In January 2020, Chinese scientists isolated a new coronavirus from the patients in Wuhan. This is now called **SARS-Cov-2** and causes the disease **COVID-19**. It is the seventh virus from this family known to infect humans.

Rapid publication of the genetic sequence of the virus helped the development of real-time, point-of-care diagnostic tests, specific for the virus. However, by the time the authorities realised the dangers of the virus, tens of thousands of potentially infected people had travelled away from Wuhan. Infected patients and deaths have now been recorded across the world. In March 2020 the World Health Organisation (WHO) declared the outbreak as a **pandemic**. A pandemic is a state where a new disease (for which people don't have immunity) spreads around the world. The WHO reacted when people who lived thousands of miles away, and had never visited China, became infected.

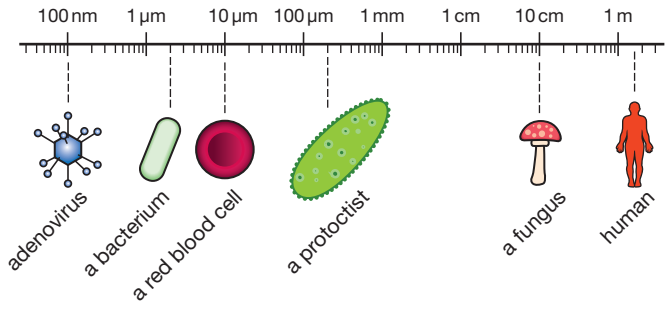
Test Question 2: *Although the Chinese health authorities tried to act quickly once they detected the disease, why was it able to spread globally?*

Viruses: The Basics

A virus is microscopic structure which is much smaller than a bacterium. The simplest viruses consist of a piece of nucleic acid (either DNA or RNA) inside a protein coat or capsid. A virus particle or virion cannot reproduce or exist outside another living cell.

Exam Hint: *Students often confuse viruses and bacteria (See **Table 1**). First, get your head around the relative sizes of different organisms.*

Figure 1 The relative sizes of microbes



Exam Hint: *Make sure that you can convert nanometres to micrometres to millimetres (and back). You must be able to express measurements as decimals or in standard form.*

Table 1 The differences between bacteria and viruses

Virus	Bacteria
Non-cellular structure/ no cytoplasm or organelles.	Cellular structure with a peptidoglycan cell wall and cytoplasm.
RNA/DNA surrounded by protein coat/capsid.	DNA not surrounded by capsid.
Can only reproduce using host cell. They are parasites.	Reproduce asexually by binary fission. Can reproduce outside host cells.
Various shapes.	Rod/cocci/spirilli shapes. Some have flagella.

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Corona Viruses

These are a group of retro-viruses. Their characteristics are:

- They contain a single-strand of RNA rather than DNA.
- There are many different types. They have been found in chickens, turkeys, bats, camels, civets, pigs, mice, dogs, and cats.
- They are **zoonotic** which means they can pass between non-human animals to humans.

Most strains of coronavirus cause mild clinical symptoms in humans. However, some are more dangerous. For example:

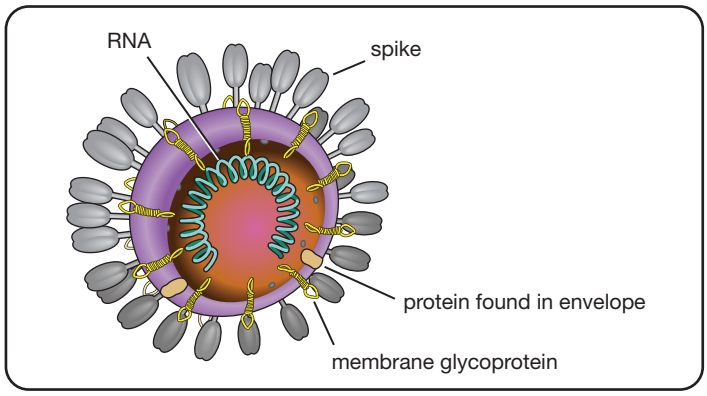
- **Severe Acute Respiratory Syndrome (SARS) coronavirus.** An outbreak in Guangdong, South China resulted in 8000 human infections and 774 deaths in 37 countries between 2002 and 2003.
- **Middle East Respiratory Syndrome (MERS) coronavirus.** An outbreak in Saudi Arabia caused more than 800 deaths in 2012.

Coronavirus itself isn't new but it has occasionally ***mutated*** to form different, increasingly pathogenic strains.

Test Question 3: *What is a pathogen?*

COVID-19

Figure 2 The basic structure of the new coronavirus (COVID-19)



This virus has:

- A single strand of RNA.
- Approximately 10 genes. The largest gene codes for the spike protein of the virus.

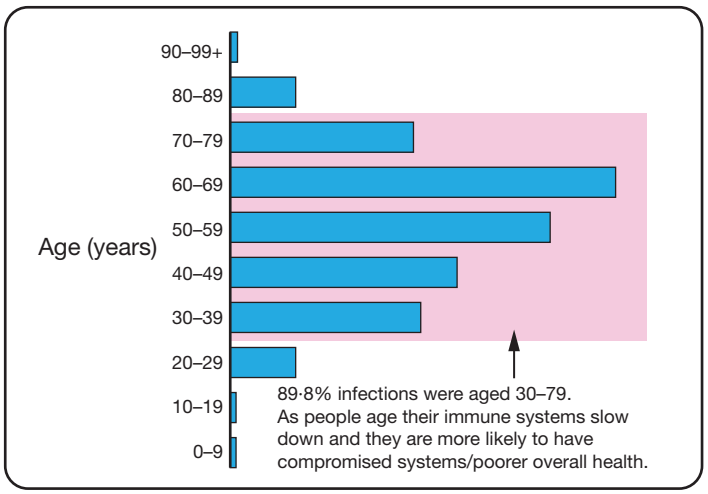
The virus uses the spikes to attach to receptors on the host's cells and the cell membrane engulfs the virus. Once inside the cell, the virus is transported to a lysosome and the two fuse together. The enzymes inside the lysosome help digest the protein coat so the viral RNA is released. The host cell uses the instructions on this RNA strand to construct viral proteins and build up new viral particles.

What happens when COVID-19 infects someone?

- The virus penetrates **goblet** and **ciliated epithelial** cells in the respiratory system. The immune system responds and tries to remove the virus.
- Newly replicated virus particles burst out of the cells. The damaged cells die. Dead tissue falls into the lungs and they become blocked. The blockage can lead to pneumonia.
- Mucus (phlegm) is usually produced to try to prevent viral entry to cells. Coughing helps move the virus and any dead cells. These would be moved by the cilia up to the throat and swallowed into the stomach where they are attacked by stomach acid. However, the cilia and goblet cells are destroyed so a **dry cough**, without much phlegm, develops.
- Inflammation of the airways irritates the nerves and then sudden movement, or a speck of dust can result in **severe coughing**. Inflammation in the lungs can make breathing more difficult. Artificial ventilation aims to give the lungs sufficient time to recover but this coronavirus replicates rapidly and can affect large parts of lung tissue.
- The person's temperature increases (**fever**) as a result of increased metabolic activity. This increases the efficiency of the immune response which can also cause damage to healthy tissue.
- More energy and resources are devoted to the immune response which results in **exhaustion/weakness**.
- Bones increase production of white blood cells causing **aching/sore bones**.

Most people with healthy immune systems will eventually produce sufficient antibodies to overcome the virus. People with weaker (compromised) immune systems and comorbidities (e.g. the elderly, those who may have certain types of cancer or transplant patients) are more at risk.

Figure 3 Infection rate by age group (Wuhan, China, February 2020)



Source: *Adapted from China CDC Weekly 2020*

Where did COVID-19 originate?

The virus originated in one or more non-human animals. It then spread to humans - making it **zoonotic**. Genetic analysis showed that the viral strain currently spreading among humans was 96% identical to that found in horseshoe bats (genus *Rhinolophus*).

Some Chinese researchers believe that the virus spread to pangolins (genus *Smutsia*) and then humans. Pangolins are an endangered species but are regularly targeted by wildlife traffickers and sometimes sold in markets. Other scientists have suggested other "missing links" e.g. the palm civet (*Paguma larvata*), a small mammal used as a food source.

The corona outbreak began at a seafood market in Wuhan which sold hundreds of different animals. Identifying the precise animal that transmitted the virus is now extremely difficult as the market has been permanently closed.

Zoonotic Organisms

Almost all bacteria and viruses that infect other animals or plants are harmless to humans. Some zoonotic organisms are potentially lethal to humans. Some of these are shown in **Table 2**.

Table 2 Examples of zoonotic pathogens

Disease affecting humans	Original host organism
COVID-19	Uncertain – bats, pangolins, civets?
Ebola	Bats, chimpanzees, monkeys
HIV	Chimpanzees
1918 flu	Birds
Lassa fever	Rats
Rift Valley fever	Livestock and mosquitoes

There are two reasons why zoonotic viruses can be so deadly:

1) Humans lack pre-existing immunity to them.

2) The viruses aren't adapted to humans.

A virus that isn't adapted to a human host may kill the person. If the person dies, the virus has failed to be transmitted so is effectively neutralised.

Exam Hint: *Do not to write things like "the virus does not want to die so it adapts to the human host". Mutation doesn't involve thought... (and viruses cannot think).*

Random mutations may allow a virus to infect a human and cause disease - but not kill the person. This means the virus has adapted to the human host.

Preventing Future Zoonotic Outbreaks

- Ban the sale of wild animals in markets?
- Compile a 'watch list' of all animals that could potentially transmit viruses to humans.
- Develop a vaccine.
- Try to alter the genetic sequence of some of the virus' genes to try to make the virus less virulent.

Testing for Viral Infections

Exam Hint: *Exam questions often focus on ELISA and PCR techniques. The ELISA test is not on every exam specification. However it can appear on any exam board's papers because it is a useful way for examiners to test candidates' ability to* ***apply*** *their knowledge of antigens, antibodies and enzyme-linked assays.*

The ELISA Test

This test detects the antibodies that a person produces when they are infected by the pathogen. By detecting these antibodies, medics can determine which individuals were infected.

In the past, tests such as ELISA only worked if the individual had already produced large numbers (billions!) of antibodies (see **Figure 4**). Such tests were also slow.

Figure 4 An outline of the ELISA test

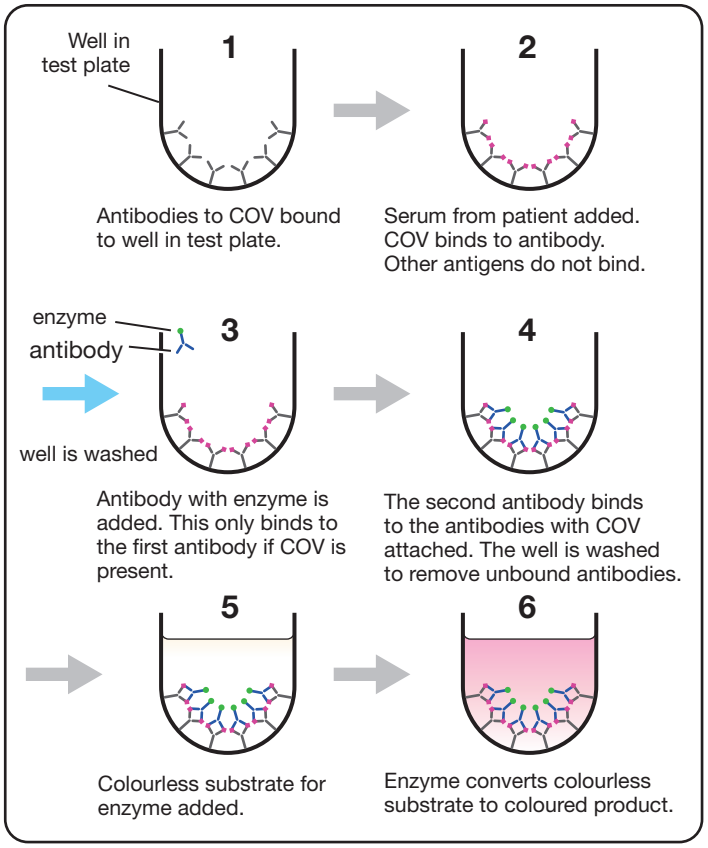


Table 3 Advantages and disadvantages of ELISA Testing

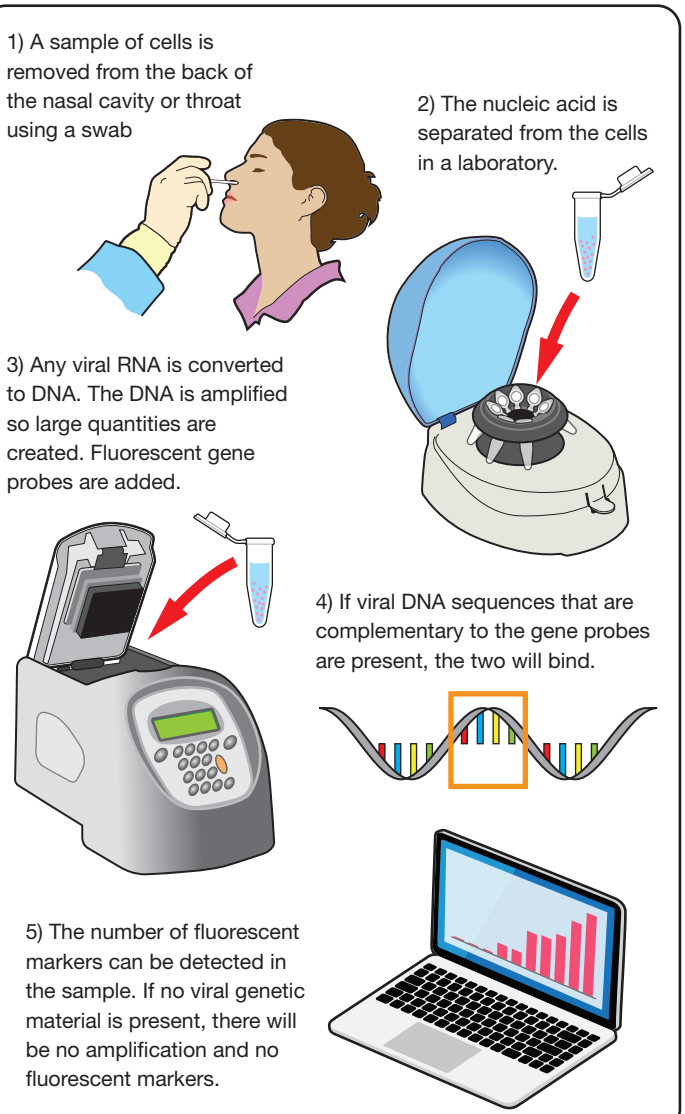
Advantages	Disadvantages
Highly sensitive: can detect antibodies at the picogram level – one trillionth of a gram (10^{-12}g).	Because detection is based upon rapid enzyme/substrate reactions, the test must be conducted very quickly.
Highly specific because of the specific antigen-antibody relationship.	Doesn't give much information about the antigen other than its presence and amount.
Easy to perform.	
Quantitative.	
Can be used to test a variety of samples, e.g. plasma, cell extracts, saliva, urine.	

Researchers studying the **Zika** virus have recently developed a microwire sensor.

This can detect as few as 10 antibody molecules in a person's blood within 20 minutes (Wang et al 2019). Proteins similar to the ones found on the Zika virus are chemically attached to microscopic gold wires. These proteins act as antigens. If antibodies to Zika are present in the patient's blood, they become attached to the proteins. This allows a **quantitative** assessment of the number of virus particles in the patient's blood.

Polymerase Chain Reaction (PCR)

Figure 5 How the PCR technique can be used to detect viral nucleic acid



Overcoming COVID-19

1) Use existing drugs and vaccines

Creating and testing new vaccines and drugs to treat infectious diseases usually takes years. One way of speeding the process up could be to investigate drugs and vaccines already developed. In March 2020 the WHO launched SOLIDARITY – a huge global trial, involving thousands of individuals. SOLIDARITY sets out to investigate the potential of treating COVID-19 patients with:

- existing anti-HIV drugs.
- a malaria treatment.
- the antiviral tried (unsuccessfully) against Ebola.

2) New vaccines

One of the most promising types of new vaccines are messenger RNA vaccines. mRNA vaccines are composed of the nucleic acid RNA, which codes for antigens on the pathogen (e.g. the protein spikes on the coronavirus). Inside the patient's cells, the RNA is translated into protein antigens which then stimulate an effective T- and B- cell immune response.

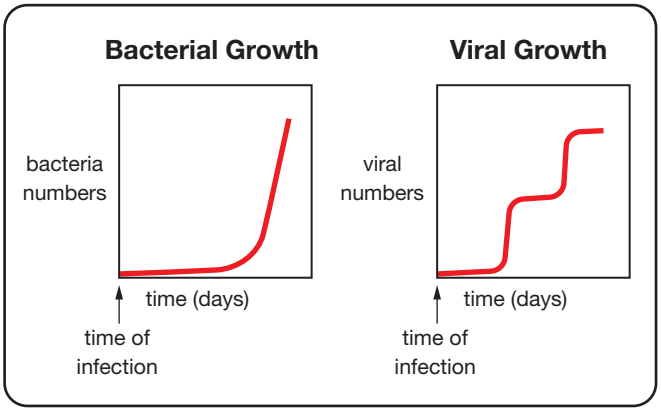
The huge advantage of mRNA vaccines is that the virus isn't introduced into the patient. This means that the patient cannot contract the virus from the vaccine itself.

Extract from Chief Examiner's Report

"Some students did not understand the key properties of an effective anti-viral drug. The drug only needs to prevent the initial entry of the virus or prevent its exit from an infected cell. It isn't necessary or cost - effective to try to coat every cell of the body with the drug."

Exam Style Questions

1) Scientists monitored and compared the growth of bacteria and viruses after they had infected a host. The graph shows the results.



a) Describe and explain the difference in the pattern of growth of the bacteria and viruses after infection of the host. (3 marks)

b) After the 2019 coronavirus outbreak the Chinese authorities implemented a series of control measures. These included:

- isolating infected people (quarantined).
- closing schools and theatres and banning public meetings.
- advising people to wash their hands regularly.

Suggest a reason for each of the measures. (3 marks)

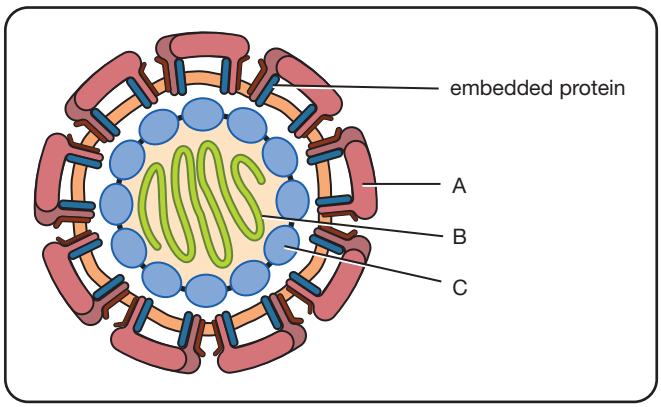
c) The Chinese authorities and the governments of many other countries banned or severely restricted international travel, suspended public transport and made health checks and quarantine compulsory.

Explain how these governments justified restricting people's freedoms in these ways (3 marks)

d) Explain why individuals who recover from an infectious disease are unlikely to get the same disease again for months or years. (2 marks)

e) Explain why viruses with high mutation rates may cause regular epidemics. (3 marks)

2) The diagram shows a simplified structure of a virus.



a) (i) Name structures A to C. (3 marks)

(ii) What is structure C composed of? (1 mark)

b) Suggest two factors that influence the rate by which a virus spreads. (2 marks)

3) The Ebola virus causes Ebola Virus Disease (EVD) which occurs in several West and Central African countries. The virus is transmitted from wild animals to humans.

a) What term describes a virus that can be transmitted from wild animals to humans? (1 mark)

b) The genes which code for some Ebola virus proteins have a high rate of mutation. Why has this made development of a vaccine more difficult? (1 mark)

Answers to Exam Questions

1) a) Bacteria reproduce exponentially;

Growth not dependent on host cell cycles;

Viruses dependent on host cell machinery/cycles;

Virus cells released when host cell ruptured so numbers remain level for periods

Cycle then repeats. (3 marks)

b) reduces contact between infected and non-infected people/ symptomless but incubating individuals;

one infected person could infect many;

virus picked up on hands less likely to enter the body

to be transmitted to another person. (3 marks)

c) Method of transmission not understood;

Severity of the pathogen was unknown;

No vaccine available;

Free movement put medical personnel at risk of infection;

by others' freedom;

risk of epidemic/pandemic. (3 marks)

d) on first infection the immune system will produce antibodies against the pathogen;

immune system/white cells/antibodies able to respond more rapidly on reinfection/ ref to memory/recognition; (2 marks)

e) surface protein may be changed by mutation;

less likely to be recognised by immune system/ antibodies;

new strain more likely to survive and reproduce/more likely to be passed on to others;

previous vaccines ineffective. (3 marks)

2) a) (i) A = Outer envelope; B = RNA strand; C = Capsid. (3 marks)

(ii) Protein (1 mark)

b) Population density (the denser the population, the faster the spread);

Population movement;

Speed of detection of symptoms;

Speed of development of effective treatment/vaccine/ quarantine. (2 marks)

3) a) Zoonotic (1 mark)

b) Viral proteins altered/vaccine unable to recognise virus; (1 mark)

Answer to Test Questions

1) Epidemiology is the study of the incidence, patterns of spread and possible control of diseases

2) • Initially, the authorities did not realise it was a new virus and didn't act quickly enough. Person-to-person spread occurs mainly via respiratory droplets produced when an infected person coughs or sneezes or when a person touches an infected surface and transfers it to their nose or mouth. Dense populations and mass transport and travel allowed the virus to spread rapidly.

• Infected people often showed no symptoms and huge numbers travelled within China and across the world before being diagnosed.

• Many countries, e.g. in Africa lacked the facilities to be able to diagnose the disease or isolate infected people.

3) A pathogen is a disease causing organism.

Acknowledgements: *This* ***Biology Factsheet*** *was researched and written by* ***Kevin Byrne*** *and published in* ***April 2020*** *by* ***Curriculum Press****.*