Essential facts about

Covid-19

The disease, the responses and an uncertain future

For South African Learners, Teachers and the General Public

Commissioned by the Academy of Science of South Africa (ASSAf)

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The **Academy of Science of South Africa** (ASSAf) was inaugurated in May 1996. It was formed in response to the need for an Academy of Science consonant with the dawn of democracy in South Africa: **activist** in its mission of using science and scholarship for the **benefit of society**, with a mandate encompassing all scholarly disciplines that use an **open-minded** and **evidence-based** approach to build **knowledge**. ASSAf thus adopted in its name the term 'science' in the singular as reflecting a common way of enquiring rather than an aggregation of different disciplines. Its Members are elected on the basis of a combination of two principal criteria, **academic excellence** and **significant contributions to society**.

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CHAPTER **6**

Viruses in the Human Body

To understand what a virus is we need to see it in a broader context. Our Universe and our Earth are approximately 13.7 and 4.5 billion years old, respectively. Both living and non-living matter are made of atoms. There are many theories of how life began on Earth from non-life. The first living organisms were archaea and bacteria, which we call prokaryotes. All complex life on Earth shares a common ancestor, a eukaryotic cell that arose from bacteria on just one occasion approximately 2 billion years ago. The questions are what are viruses? Where do viruses fit into this scheme? Why do viruses spread so fast and cause so much harm? How does the body's immune system respond to a viral infection and what is the response of the medical establishment to a global pandemic such as the coronavirus pandemic we are currently experiencing? These are questions that this chapter attempts to answer.

What is Covid-19?

Covid-19 is short for coronavirus disease 2019, a viral infection that has afflicted people all over the world. When a disease spreads worldwide, it becomes known as a pandemic. An epidemic, on the other hand, is an infectious disease that has spread throughout a community at a particular time without spreading worldwide. We commonly speak, for example, of a 'flu epidemic', 'the HIV-AIDS' epidemic in sub-Saharan Africa, an 'epidemic of drug abuse' in a particular area, or we say, 'there is an epidemic of diabetes in the Indian population of KwaZulu-Natal'. The main actor in our entire story is the new SARS-CoV-2 coronavirus, the cause of the Covid-19 pandemic.

Because we are dealing with a new virus which is causing worldwide devastation, scientists throughout the world have been studying the virus in an attempt to produce a vaccine. Before trying to understand the origin and manner in which the virus infects humans to produce the clinical symptoms of the Covid disease, it is necessary to first put things into context.

Everything you look at, whether it is a rock, a virus, the air we breathe, a tree or human being, is made of atoms. Different arrangements of atoms produce different forms of matter, some alive (trees and humans) and some not (air, rocks, etc.), and some that sit somewhere in between, seemingly not living, but not non-living either. These include the viruses.

Atoms join in various combinations to form molecules, for example, two hydrogen atoms and one oxygen atom combine by covalent bonding to form water. Water is an example of a simple molecule. Atoms can also form more complex molecules (and macromolecules, which are very large and generally put together in living organisms). Imagine a delicious piece of steak. What are the components of that piece of meat? You will find that it is made up of both macromolecules and smaller molecules. The macromolecules are proteins and nucleic acids (DNA and RNA and, in this case, coronavirus is an RNA virus), or assemblies of complex lipids and carbohydrates. These are organic compounds made up largely of carbon (C), hydrogen (H), nitrogen (N), oxygen (O) and phosphorous (P) atoms. The steak will also have smaller molecules such as large amounts of water (H_2O) and any number of small organic compounds and inorganic ions such as sodium (Na+), potassium (K+), chloride (Cl-) and other ions.

Everything you look at, whether it is a rock, a virus, the air we breathe, a tree or human being, is made of atoms.

The organic and inorganic molecules are arranged to form structures called cells. On our planet, this first happened approximately four billion years ago. The earliest cellular structures were the prokaryotes (cells with no nucleus, with the genetic material floating around in the cytoplasm). We know prokaryotes very well today because, like viruses, some of them cause serious diseases in our bodies. Others, however, are beneficial to humans (for example, those living in our large intestines or on our skin). However, prokaryotes differ from viruses because they have the property of life: they are metabolically active, which facilitates their independent reproduction. Viruses are often considered non-living as they can reproduce only inside a host cell. They require the machinery of the host cell in order to produce more 'baby' viruses.

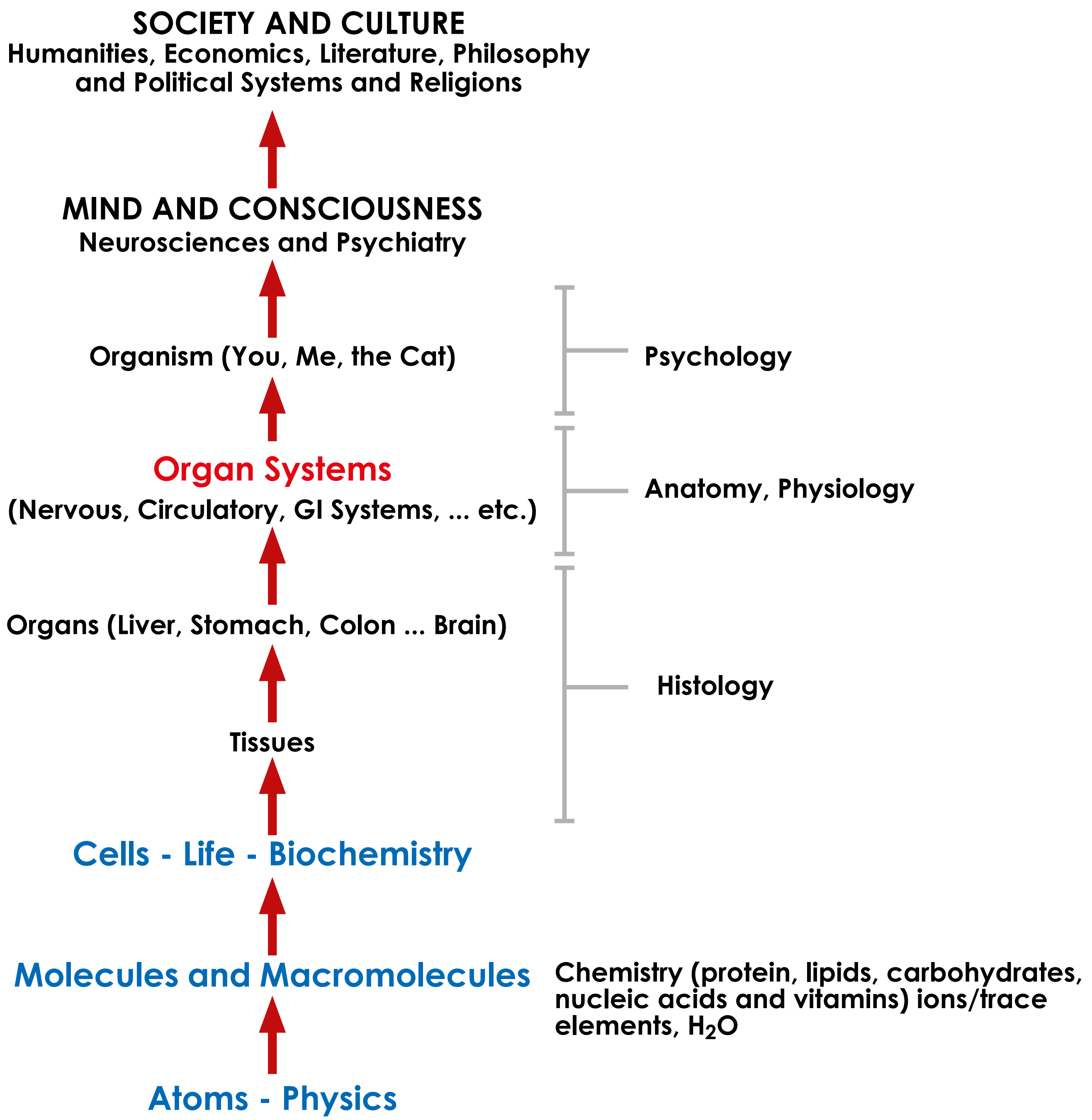

Figure 6.1: The different levels of living things, from atoms to living organisms to human beings and societies

Eventually, after another billion and a half years, more complex cells called eukaryotic cells (which have a nucleus that contains their genetic material) emerged. They are the cells that make up trees, cats, humans, and most complex forms of life on this Earth (see Figure 6.1).

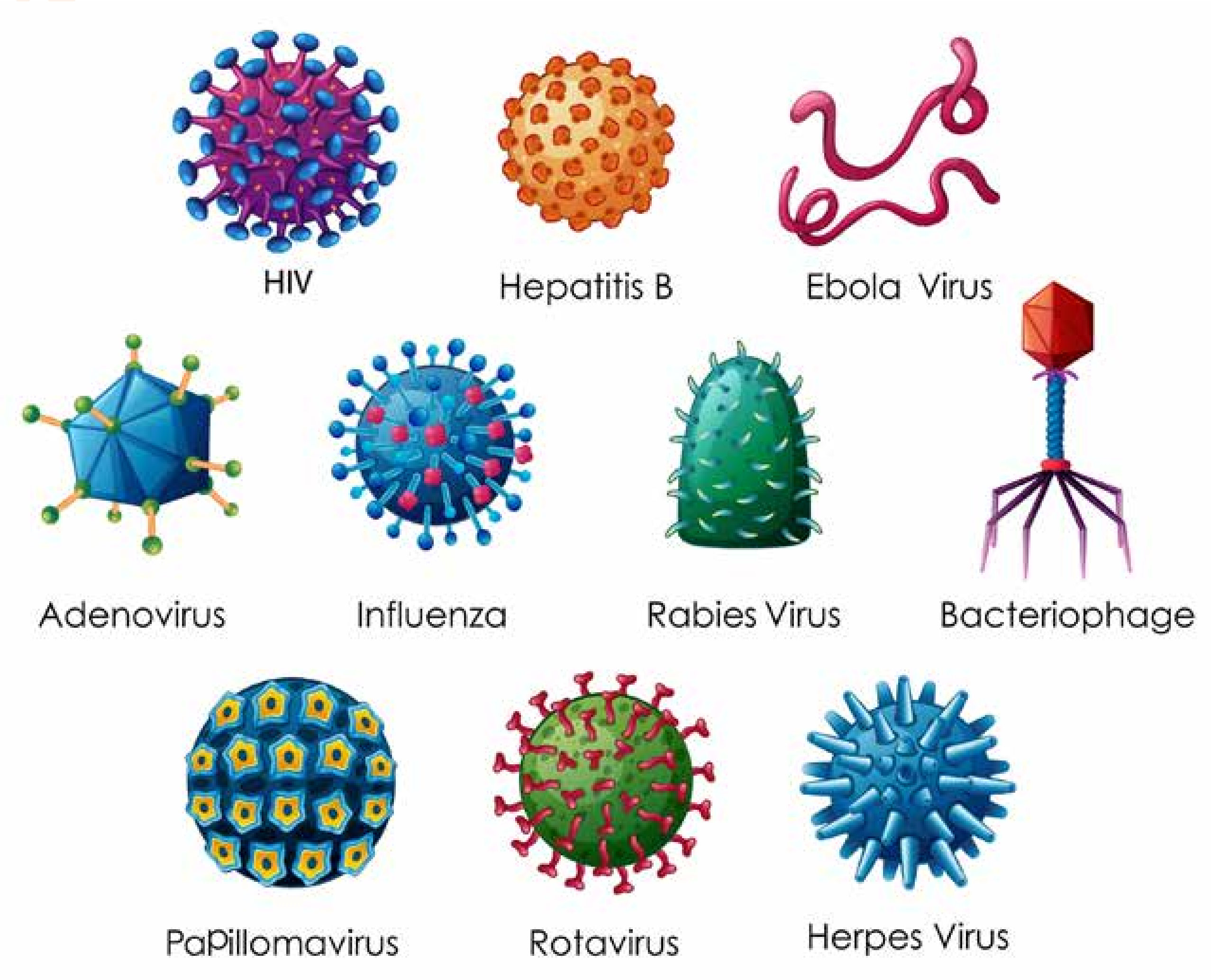

Figure 6.2: Different kinds of viruses that cause different diseases

How does one define a virus?

A virus is a particle made of a protein shell enclosing nucleic acid genetic material in the form of either RNA (ribonucleic acid) or DNA (deoxyribonucleic acid). Human disease-causing viruses cause harm by entering our bodies and replicating in our cells. Some viruses enter the nucleus of the cell and replicate in the nucleus, and a small subclass, the retroviruses, even insert their genetic material into the host DNA. Other types of viruses, like coronaviruses, replicate their genetic material in the host's cytoplasm. The virus takes over the cell and uses the cell's machinery for copying DNA or RNA to make copies of its own genetic material. During this process more viruses form. The cell can burst or, depending on the kind of virus, these new virus particles might be released in what seems to be a controlled way, thereby releasing a new population of viruses, which, in turn, can infect more cells. This is the start of a viral disease in the body. The individual carrying this large number of new virus particles can spread it to others (viral transmission).

There are many types of viruses (Figure 6.2), causing a variety of diseases such as HIV-AIDS.

We are interested in the coronavirus (SARS-CoV-2), which has caused the coronavirus disease pandemic (Figure 6.3).

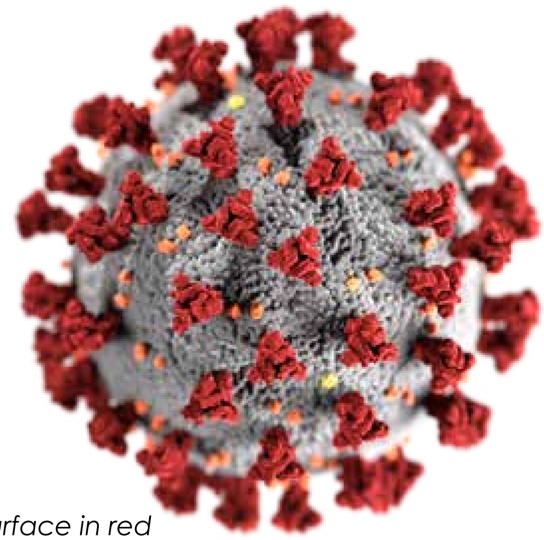

Figure 6.3: The coronavirus with the spike proteins on its surface in red

Source: Centres for Disease Control & Prevention; https://www.cdc.gov/
US Centres for Disease Control and Prevention/Wikimedia Commons

What are communicable and non-communicable diseases?

Diseases may be divided into two categories. On the one hand, there are `communicable' diseases, which for practical purposes are all 'infectious' diseases in which a pathogen is passed on from one organism to another (they are also known as `transmissible' diseases.) When infectious diseases are transmitted from person to person (i.e.,between humans), they are said (by agreed convention) to be 'contagious', even though the word (which means 'arising easily from close contact') could in principle also be applied to transmission from an animal to a person, or sometimes from a person to an animal and back to a person, as in the case of malaria where the mosquito plays the role of an intermediary.

'Non-communicable' diseases (NCDs), by contrast, arise spontaneously within the body, usually as a result of environmental factors interacting with the intrinsic processes of maturation and subsequent ageing. Often, but by no means always, they also arise partly through inheritance of particular sets of genes from the mother and father. Examples are 'sugar diabetes', hypertension, and heart disease. These are called 'diseases of lifestyle' and are common in our modern societies. They are thought to be caused in part by stress, poor dietary habits, and a lack of exercise. It must be noted that no disease is due to purely environmental factors. Genes are often involved. People can contract heart problems, for example, because it runs in their families. We call this a 'familial predisposition' to heart disease. However, that does not mean that everyone with a bad family history of heart problems will have heart disease. One can avoid a 'disease of lifestyle', even though one's relatives have the disease, by leading a healthy lifestyle.

It is important to remember in the case of infectious diseases that the condition of the host body at the time of infection plays a very significant role in determining the course and outcome of that infection.

Widespread transmission of a pathogen from a non-human animal to a human is called zoonotic in nature. If the integrity of the body has to be breached for transmission to occur, you won't catch the disease from someone you are talking to or pass on the street. An example would be Lyme disease, which is transmitted by the bite of an infected tick. Becoming infected with a newly mutated form of influenza virus, on the other hand, can happen through inhalation or ingestion of infectious materials from a slaughtered chicken or pig.

Contagious diseases (such as the flu, colds, or strep throat) spread from person to person in several ways. One way is through direct physical contact, like touching or kissing a person who is carrying the infection. Another way is when an infectious microbe travels through the air after someone nearby sneezes or coughs. Sometimes people get contagious diseases by touching or using something an infected person has touched or used, such as sharing a straw with someone who is infected. And sexually transmitted diseases (STDs) are spread through all types of sex: oral, anal, or vaginal.

You can protect yourself against contagious diseases by washing your hands well and staying away from those who are sick, keeping up to date with all vaccinations, and always using condoms during any type of sex.

Vaccines against the coronavirus

Since the early days of the coronavirus pandemic, the world was warned that there was no cure for this complex disease. Its signs and symptoms are highly variable, often reflecting a spectrum of diseased organs and systems in the body, each affected to differing degrees. Thus the overall clinical picture manifests itself in different ways. Some carry the virus but are asymptomatic–that is, they show no symptoms. Others show a variety of mild symptoms. Yet others become very ill, often, but not always, initially involving the lungs (pneumonia). There can, instead or additionally, be problems such as strokes arising from abnormal blood-clotting, kidney dysfunction, skin ailments, or gastrointestinal disorders, to name a few examples.

The only hope for eradicating the disease is the development of a vaccine against this virus. Presently, several vaccines against Covid-19 have become available, including vaccines from Astra Zeneca, Johnson and Johnson, Moderna, and Pfizer-BioNTech.

When a foreign agent, or pathogen, such as a bacterium or virus–in this case the coronavirus–enters the body, the body's immune system, its 'police' and 'army', is alerted. The 'police' are a group of cells that represent the elements of innate immunity, which is non-specific in terms of the kind of pathogen they protect us against, but is capable of removing the invaders very quickly if they are present in small numbers. The 'army', which is called adaptive immunity because it is directed by the body against the specific invading pathogen, is called up more slowly over a number of days and includes two main types of 'soldiers'. One type is a cell called a B cell, which produces proteins called antibodies that bind to the surface of the foreign agent, leading to its removal from the circulatory system. Another group of 'soldiers' are the T cells. These are active 'cell-killers' that seek out the body cells that contain the virus and destroy them. In summary, the main components of the body's adaptive immune system, or 'army', against the coronavirus are the pathogen-specific T cells and the similarly specific antibodies secreted by the B cells.

Vaccines work by presenting the immune system with a readily identifiable part of a pathogen, which the immune system remembers so that it can quickly respond should it encounter that same pathogen in the future.

Vaccines work by training the immune system to recognise and fight off infectious agents or pathogens, such as bacteria and viruses. A vaccine often contains a slightly altered form of the pathogen. The vaccine presents to the body's immune system a part of the virus that the immune system could recognise. For example, in the case of the coronavirus, this could be the spike protein found on the surface of the virus (see Figure 6.3). Other vaccines could carry a part of the coronavirus genome in the form of DNA that codes one of the virus proteins. When introduced into the body, usually as part of a harmless virus called an adenovirus, this DNA, through transcription as messenger RNA (mRNA), leads to the synthesis of the viral protein by the host cell. This causes the immune system to respond to the 'foreign' protein and to mount an immune response to it, and, thereby, against that protein on the surface of the virus. Sometimes, messenger RNA coding for the viral spike protein is used as the vaccine. Thus if in the future a person who has been vaccinated comes into contact with the actual virus, that person's immune system will quickly recognise the virus or virus-infected cell. It will mobilise the two components of its adaptive response and target both the free virus (with antibodies) and virus-infected cells (with T cells), thus offering immunity or protection to that individual against the specific infection.

In summary, vaccines work by presenting the immune system with a readily identifiable part of a pathogen, which the immune system remembers so that it can quickly respond should it encounter that same pathogen in the future.

Once researchers are sure that they have developed a vaccine, they must select groups of people from the population to test out the safety and efficacy of the vaccine as a phased series of vaccine trials. The scientific method (described in detail in Appendix C) is used to determine whether the vaccine is safe and whether it is effective.

In the case of the Oxford vaccine, two groups were selected for this initial trial called Phase 1, each including 543 people. One group of subjects is called the 'control' group. This group is not given the real vaccine but rather another compound called a 'placebo,' designed to have no biological effect. The second group is the 'experimental' group. This group is given the real vaccine. The trial is analysed by looking at differences between the two groups. None of the subjects knows whether they have been given the actual vaccine or the placebo. This comparison removes a lot of possible errors, including the 'placebo effect', a psychological effect where people given a fake drug falsely believe to have benefited.

Before testing a vaccine in humans, researchers also first test the same vaccine candidate on mice and rhesus macaque monkeys. These experiments have shown that the vaccine is probably safe and able to induce a strong immune response. In fact, a far higher dose of the coronavirus was used in the animal models than humans got through infection, but the vaccine still protected them from severe disease.

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The Parliament of South Africa passed the Academy of Science of South Africa Act (No 67 of 2001), which came into force on 15 May 2002. This made ASSAf the only academy of science in South Africa officially recognised by government and representing the country in the international community of science academies and elsewhere.

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