**Viruses: What Are They and Why Are They Important?**

**Introduction**

Tiny, transmittable particles which have the capacity to cause diseases are known as viruses. Since their emergence, they have made a significant impact on the world. Dating back to the late 19th century, these infectious particles are credited for causing a plethora of diseases in humans, plants, and animals. How did these highly dominant particles come to be? When early scientists were conducting research on viruses, they did not particularly know what they were dealing with. In 1886, Adolph Meyer discovered that a disease of tobacco plants could be transferred from a diseased plant to a healthy plant. A few years later in 1892, Dmitri Ivanowski conducted an experiment using a filter to study what is now known as the tobacco mosaic virus. The filter identified and removed the bacterial particles, yet for an unknown reason the plant was still infected. After this experiment, the substance got the name of “virus”, which means poison in Latin. Although the virus was discovered in the 1800s, the virus could not be seen until the invention of the microscope in the 1940s. This was only the beginning to what we now know as virology, the study of viruses. Today, viruses are continually being researched and make up two-thirds of all new human pathogens[[1]](#footnote-1).

Much like viruses, bacteria can also cause you to get sick. A common misconception is that bacteria and viruses are the same. This is not the case, however. Bacteria differ from viruses in size, shape, and reproduction methods. Moreover, bacteria are considered to be a living organism because they are independent of a host cell and are single-celled. Contrarily, viruses are not considered to be living because they do not have cells within themselves and cannot perform the reproductive cycle without a host cell. Another difference between the two is how their infections are treated. For example, if one encounters a bacterial infection, antibiotics would be a helpful agent. On the contrary, a vaccination or antiviral medication would help in prevention and treatment of a viral infection. Despite not having basic features, viruses do have genetic variation and nucleic acid genomes, alike to all living creatures. In this chapter, we will examine the viruses’ structure, processes of replication, classification, and the role they play in human disease.

**Structural Forms of Viruses**

Typically, all viruses consist of an outer protein shell, or **capsid**, that is built of protein molecules. The capsid is the part of the virus that holds genetic information about the virus. These protein molecules come together to form units called **capsomers**. The functions of the capsid include protection of the virus in addition to recognition and targeting of a potential host[[2]](#footnote-2). Capsids of some viruses are simple while others may have a complex structure.

The first structural form of viruses we will study is the **icosahedral** shape. Icosahedral capsids have twenty faces, hence the name icosahedron, which is the name for a twenty-sided shape. When a cell dies and its cell walls start to break down, viruses with the icosahedral shape are released into the environment. An example of a virus with icosahedral shape is the poliovirus, which causes muscle weakness due to an infection in the spinal cord. The next structural form is known as a **filamentous** capsid. These appear thin, resembling that of a filament, and can also be referred to as rod-shaped or helical. Most plant viruses are filamentous. In fact, the virus that was discovered on the tobacco plant discussed earlier was classified as filamentous[[3]](#footnote-3) The final shape we will discuss is the **head-tail**. These are similar in structure to icosahedral and filamentous. One way to think about a head-tail capsid is a cross between icosahedral and filamentous. Head-tail capsids possess a long, tall “tail” (similar to that of the filamentous) with a round “head (similar to that of the icosahedral).

One interesting attribute of the head-tail capsids is that they aim to infect bacteria. This type of virus can also be referred to as a **bacteriophage.** The bacteriophage first attaches to the cell via its tail, then creates a hole that it uses to insert its DNA into. On some viruses, there is a membrane that surrounds the membrane, and essentially creates an **envelope** around the virus. This envelope is formed when viruses are leaving the cell. Moreover, the infectivity of viruses highly depends on the envelope[[4]](#footnote-4).Envelopes commonly contain proteins that are specified by the virus, which can be beneficial to viruses to bind to their host cells. Envelopes are common among most viruses but are not seen in all. A few familiar viruses that contain envelopes are Hepatitis C and Human Immunodeficiency Virus (HIV).

**The Virus Lifecycle**

A general virus lifecycle is the process by which the virus enters the cell and usually consists of five main steps. These steps show how the virus uses parts of the cell to replicate itself and consequently, make more viral cells. Each process can be slightly varied from virus to virus, but the general concepts still apply to all.

1. **Attachment** – The virus identifies its potential host cell and attaches onto the cell. A protein that is located on the capsid connects to a molecule on the host cell. The molecule it attaches to is called a **receptor.** In order for the virus to properly attach, the host cell must have a target receptor that allow the virus to bind. If a cell does not have the receptors for a certain virus, the virus will not be allowed to bind, and therefore cannot be infected by that virus.
2. **Entry** – The virus enters the cell. This process typically occurs by **endocytosis**. Endocytosis takes place when a cell engulfs the virus from the exterior of the cell to the interior of the cell.
3. **Replication** – The viral genome, which we will get an in-depth look at in the next section, is replicated and processed to make viral proteins. The virus uses the cells machinery to make its newly infected proteins.
4. **Assembly** – The newly formed viral particles come together to form the full-sized capsid of the virus. This can happen by building a capsid around the genome, or by forming a capsid and filling the genome inside.
5. **Release** – The new viral particles are released from the cell. There are a few processes by which the virus can exit the cell. **Exocytosis** is one of the ways a virus can exit and is the process of a virus leaving the cell using the cell’s own pathways. Although these particles leave the cell, the cell has the capability to continue to make viruses.

**Virus Genomes**

Genetic material that are composed of nucleic acids are **genomes**. Like all other forms of life, DNA is used as this genetic material in viruses. Additionally, viruses use RNA as well. Both DNA and RNA are forms of nucleic acids. Just as in humans, DNA viruses use enzymes for DNA and mRNA synthesis; viruses also use tRNAs and other translation factors to synthesize proteins. Viral mRNAs and proteins are often synthesized in a small amount when a cell is infected, compared to the normal molecules that are synthesized in a large amount. DNA viruses rely heavily on their ability to direct a host cell to replicate proteins. After this is done, by methods of transcription and translation, that specific genome is now a new viral protein. The expression of these specific proteins alters normal processes. Because viruses can infect cells in a large variety, an experimental approach of using genetically modified viruses are used to carry foreign DNA into a certain cell. By doing this, the experimental field of viruses has grown tremendously and sets a basis for gene therapy. Human diseases that DNA viruses are capable of causing are Chickenpox, Hepatitis B, and a variety of others.

DNA viruses can be classified into two different categories. These categories are defined by the number of strands the DNA contains. ***Class I viruses***contain one molecule of double-stranded DNA (dsDNA)5. In this case, the DNA carries out the same processes as indicated earlier – the viral DNA infects the host cell’s nucleus, transcription will turn DNA into RNA, then to viral mRNA. ***Class II viruses***are viruses that contain only one molecule of a single strand of DNA (ssDNA). The ssDNA is copied inside the cell into double stranded dsDNA and then turned into mRNA. To conceptualize how class I DNA viruses are critical to your knowledge, let’s examine well-known DNA viruses. Table 1 shows common class I DNA viruses, their site of infection, and how they affect the human body.

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| Table 1: Common Class IDNA Viruses | | |
| Virus Name | Site of Infection | Illnesses Caused |
| *Adenovirus* | * Upper respiratory tract * Gastrointestinal tract (in animals) | * Pneumonia * Bronchitis * Pink eye |
| *Herpesviruses* | * Skin | * Chickenpox * Cold sores * Shingles |
| *Human papillomaviruses* (HPVs) | * Skin * Cervical cells (occasionally) | * Warts * Skin lesions * Cervical cancer |
| *Table 1: Common DNA Viruses[[5]](#footnote-5)* | | |

RNA viruses are discovered primarily in animals, including humans. These classes are III-VI and are more commonly referred to as *parvoviruses*. For the purpose of this chapter, we will only discuss up to class IV. ***Class III viruses*** are composed of double-stranded RNA (dsRNA). Based on our prior knowledge of RNA, we know that there is a “minus” and a “plus” strand in each double-stranded RNA molecule. In this class of viruses, the minus strand plays the role of the template strand. Each individual virus particle, or a ***virion***, contains roughly ten to twelve double-stranded RNA molecules. Class III viruses use the minus strand of RNA to synthesize mRNA. *Class II viruses* are viruses that contain only one molecule of a single strand of DNA. The DNA is copied inside the cell into double stranded DNA (dsDNA) and then turned into mRNA. ***Class IV viruses*** are single plus strand of genomic RNA and is identical to viral mRNA5. This virus is individually infectious. To replicate class IV viruses, the genomic RNA is copied into a minus strand, which then is a template for the production of even more mRNA. Although all classes of DNA and RNA viruses were not covered, each class has its unique features and knowledge of these classes will lay a solid foundation for future studies in biology.

**Viral Infections and the Role Viruses Play in Human Disease**

As discussed earlier, a virus attacks a host cell to initiate the processes of a viral infection. We have also discussed certain illnesses and what viruses they come from, but what about how to prevent these infectious particles from attacking us? Are there viruses that are permanent? What do I do if I get an infection? In this section, our goal is to take a look at the implications of viral infections (such as the spread of infection), how the human body responds, and how vaccinations and work to prevent viruses from attacking us.

The obvious implications of a viral infection are not feeling one hundred percent up to par. There are several viruses that can cause a wide range of infections. Generally, a runny nose, fever, cough, congestion, and body aches are frequent symptoms seen in those with common cold caused by a virus. These symptoms usually go away within two to three days and can be treated by using over the counter medications. More severely though, let’s look at the causes of meningitis, an inflammation of the lining of brain and spinal cord. There are multiple viruses that can cause meningitis and the most common is non-polio enteroviruses. Specifically, this virus can be found in an infected person’s stool or secretions of the eye, nose, and mouth[[6]](#footnote-6). An exposure of this particular virus can be done by touching objects or surfaces with the virus on them and touching the face before washing your hands.

Moreover, a meningitis **vaccination** is intended to increase one’s **immunity** to a certain virus. This works by injecting either a weakened live virus, killed virus, or some type of subunit of the virus into the body. The main objection is to exert few symptoms within the body and eventually, build cells that are prepared to fight off the virus. The cells that do this are called **memory B cells**. This is not the case, though, for all viral infections. Some vaccines are able to treat an active viral infection. Rabies, for example, is a neurological disease that progresses and can have an elongated time frame from the time it enters the body and when the person elicits an effect. If the person is vaccinated within roughly two weeks, the response by the immune system can be strengthened enough to prevent the virus from having an effect. If this occurs, the implications that occur are far less severe. Vaccinations are not the only option for treating viral infections. Antiviral drugs are another way to treat a viral infection. They are mainly used to limit the symptoms of a certain viral disease, not to cure it. Genital herpes is an example of a viral infection that can be contained with the use of antiviral drugs. Antiviral drugs are used in this case to reduce outbreaks of skin lesions on the body. Though the virus remains in the body forever, antiviral drugs can ease those with viral infections like genital herpes and assist in making their outbreaks manageable. Table 2 shows the effectiveness of the influenza vaccine for all vaccine types against influenza A or B viruses for the 2019-2020 season.

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| Table 2: Influenza Vaccine Effectiveness for All Vaccine Types | | | | |
| Age Group  (years) | Influenza positive total | Influenza positive (% vaccinated) | Influenza negative total | Influenza negative (% vaccinated) |
| All ages | 1060 | 390 (37) | 3052 | 1682 (55) |
| 6 mos – 17 yrs | 751 | (40) | 1677 | 492 (53) |
| 18-49 | 413 | 143 (35) | 1084 | 452 (42) |
| **≥ 50** | 185 | 105 (57) | 1034 | 738 (71) |

Table 2[[7]](#footnote-7)

**Summary**

Understanding viruses is critical, whether one is in the health field or not. Their capsids work as protection and holding the genetic information of the virus. Additionally, viruses have different shapes. These shapes consist of icosahedral, head-tail, and filamentous. Through the process of the virus’ life cycle, we can learn the general aspects of how a virus attacks a host and replicate itself. Moreover, the genetic information within the virus consists of RNA and DNA, which works in viruses to produce new viral cells. Different types of viruses can be identified by determining the number of RNA or DNA sequences. Each different virus has different implications for disease. The importance of all the information in this chapter relates to the impacts on human life. Our ability to adapt to a virus and build a stronger immune system to that virus is an important aspect of vaccination. Nevertheless, wherever you are in your interest in viruses, knowing simply how they infect a host and what to do when infected are two important concepts to take from this chapter.

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