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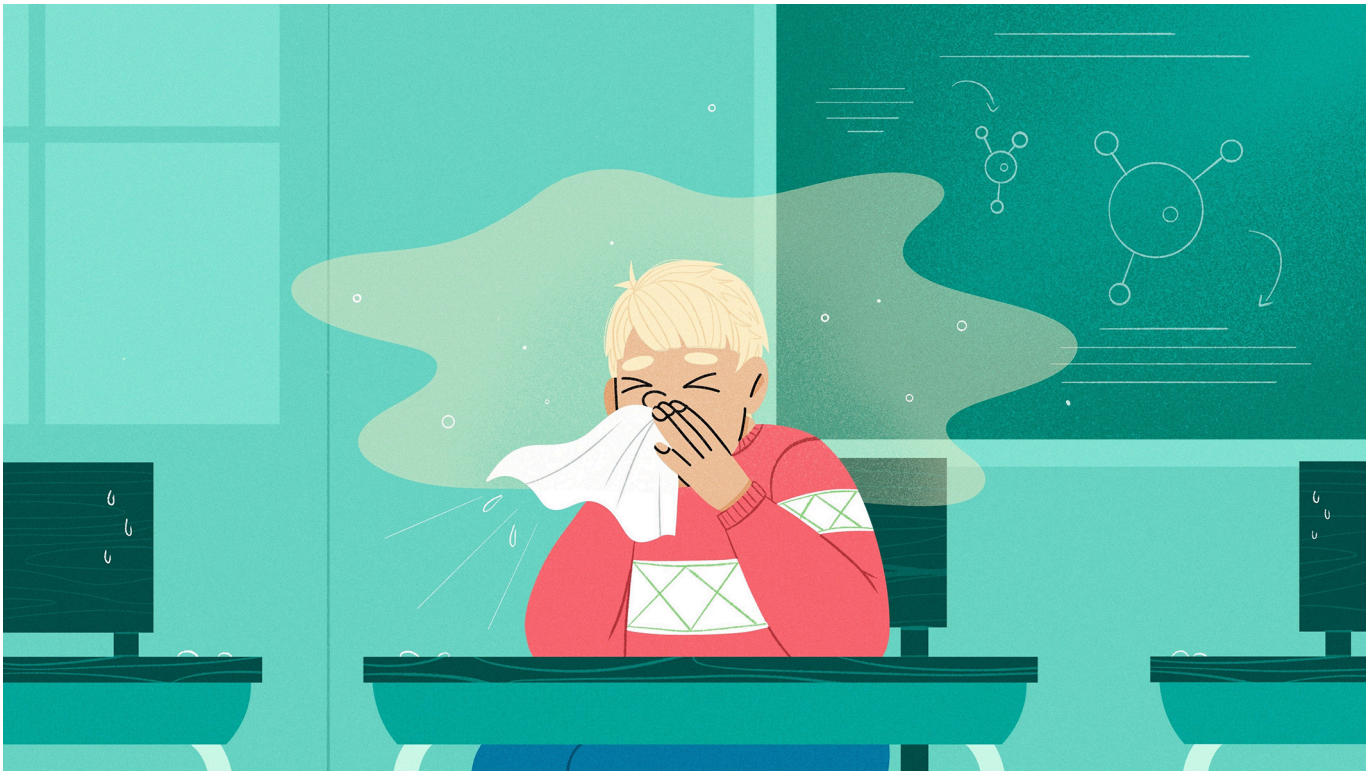

EXPLORING RESPIRATORY VIRUSES: A DAY AT SCHOOL

Marie Gjessing Bruun and Daniel Steven Shaw*

Department of High-Capacity Diagnostics, Statens Serum Institut, Copenhagen, Denmark

YOUNG REVIEWERS:

YI CHUN
AGE: 11

The COVID-19 pandemic prompted people to stay home to stop the spread of SARS-CoV-2 (the virus responsible for COVID-19). But did you know that other respiratory viruses, like the ones that cause colds and flu, can also spread indoors? We spend a lot of time indoors. This might be at home, school, or elsewhere. That is why indoor air quality is an important topic for public health. In this article, we explore viruses and how they spread indoors. By knowing more about viruses and how to improve air quality, we can help to keep ourselves healthy.

HOW IT BEGAN: TWO ABSENT CLASSMATES

It is the middle of the school day, the air is heavy, and you realize you have been sitting in the classroom for hours. It is becoming harder to pay attention to what your teacher is saying. As you glance around, you notice that two of your classmates who were present yesterday

are absent today. You raise your hand and ask your teacher why those students are not at school today. Your teacher explains that they both have colds. While you think about how they are feeling and what might have made them ill, the teacher continues the biology lesson, delving into the intriguing world of viruses.

CAPSID

The protein shell of a virus, enclosing its genetic material.

GENOME

The complete set of genetic material present in an organism, which may be DNA or RNA.

WHAT ARE VIRUSES?

The term "virus" comes from a Latin word that means "poison". Viruses are tiny particles that can infect our cells and make us ill. Even though we cannot see them with our eyes, thousands of types of viruses exist—with many different shapes and sizes. A typical virus might be about 20–300 nm in diameter. That is about 1/100th the size of a bacterium! One thing viruses often have in common is a protective protein shell, known as the **capsid**, which holds their **genome** (Figure 1).

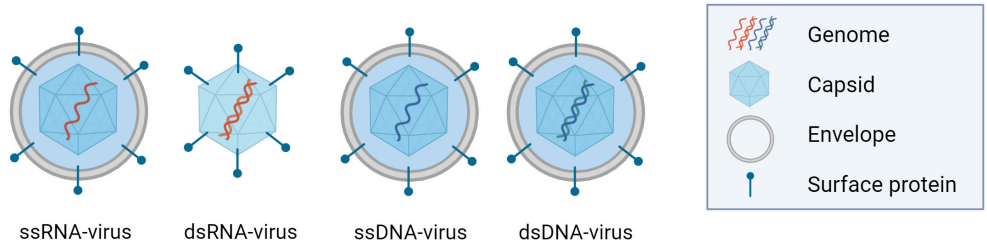

Figure 1

Figure 1

Viruses have a variety of structures. They can contain single- or double-stranded (ss or ds) RNA or DNA as their genetic material. The viral genome is often protected by a surrounding shell, called the capsid. Additionally, some viruses have an outer envelope and surface proteins. Figure created with BioRender.com.

The viral genome is different from the human genome. Our genome is made of double-stranded DNA. We received one DNA strand from our biological mother and the other from our biological father.[1] In contrast, some viruses contain DNA as their genetic material, but others contain RNA. Viral DNA or RNA can exist in single-stranded or double-stranded forms. Outside the capsid, some viruses have a membrane layer, called an envelope. The envelope is made of lipids (fats) and proteins. For example, SARS-CoV-2, the virus that causes COVID-19, has an envelope with large surface proteins on it, known as spike proteins. SARS-CoV-2 is a single-stranded RNA (ssRNA)-virus (Figure 1; to learn more about viruses, see this Frontiers for Young Minds article).

ARE VIRUSES ALIVE?

There is no single definition of life that everyone agrees on, but most definitions include the ability of an organism to reproduce on its own and use energy to maintain itself. Viruses have genomes but they lack the machinery to reproduce by themselves. Instead, they invade living cells and hijack the cellular machinery to replicate their genomes and produce new virus particles. The cells they infect are called their

[1] Note
While the article explains DNA heritage in humans in terms of a biological mother and father, it should be noted that not everyone sees their family background through traditional parental roles.

host cells and can be all kinds of living cells, such as plant, bacterial, or human cells. Viruses rely on living cells to replicate and maintain themselves, and cannot survive for very long without a host cell. This is why viruses are often classified as non-living entities existing "at the threshold of life" [1] or not living at all [2].

HOW VIRUSES REPLICATE

The steps involved in the production of new virus particles are often referred to as the virus replication cycle [3]. This cycle begins when a virus attaches to a host cell.

A respiratory virus typically enters the human body with the air we breathe. Once inside, it attaches to a host cell when its surface proteins bind to proteins called receptors on the cell surface of a host cell. Think of receptors and surface proteins as specialized locks and keys. When they fit together, the virus can enter the cell (Figure 2, step 1). The virus and the host cell then fuse, after which the virus releases its genome from its capsid shell (Figure 2, step 2). The virus then acts like a sneaky intruder, taking over the cell's **gene replication** and **gene expression** machinery. By tricking the cell, the virus forces the cell to replicate the viral genome and produce viral proteins (Figure 2, step 3). As more viral components are made, they assemble to form new capsids containing the viral genome. This is how new viruses form (Figure 2, step 4). Eventually, multiple new viruses are released from the cell (Figure 2, step 5). These new virus particles may infect nearby cells and repeat the cycle.

GENE REPLICATION

A cellular process by which genetic material is copied.

GENE EXPRESSION

A process by which genetic information is used to synthesize a functional gene product.

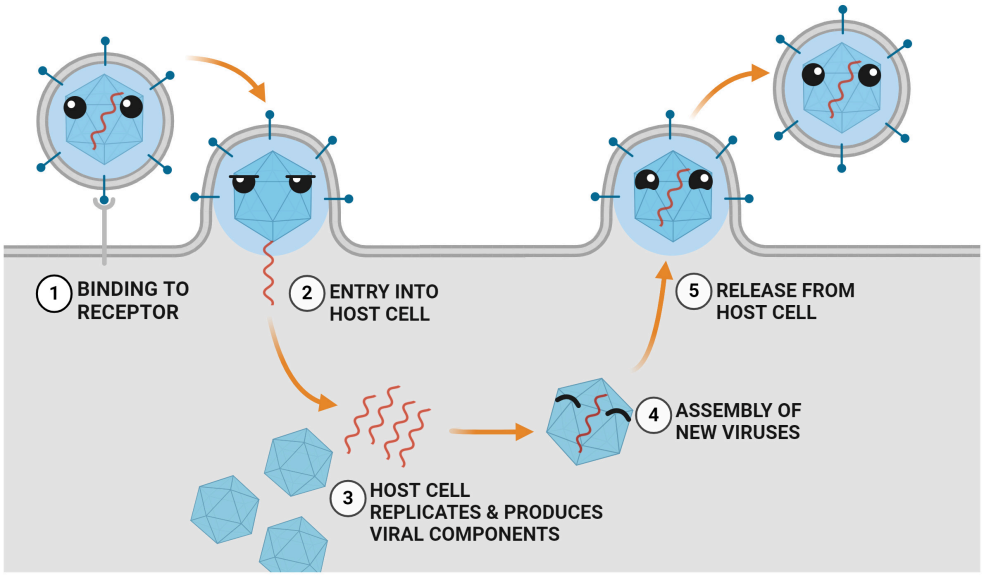

Figure 2

The virus replication cycle. **(1)** Viruses attach to host cells when their surface proteins bind to receptors on the surface of a host cell. **(2)** The virus enters the cell by fusion, allowing the viral genome to be released. **(3)** Viruses use the cell's machinery to replicate the viral genome and produce viral proteins. **(4)** As viral genomes and proteins are made, they assemble to form new viruses. **(5)** The new viruses are then released from the host cell. Figure created with BioRender.com.

HOW THE HUMAN BODY DEFENDS ITSELF AGAINST VIRUSES

We often experience symptoms of sickness when infected by viruses. These symptoms result from both the damage the virus does to our cells and our **immune system** fighting the virus. When viruses invade our bodies, the immune system springs into action to protect our health.

IMMUNE SYSTEM

The system that detects and responds to a wide variety of harmful agents while distinguishing them from the organism's own healthy tissue.

The immune system uses innate and adaptive immune systems to respond to a wide variety of harmful agents, including viruses. Our first line of defense are barriers like skin and the wet linings of the eyes, nose, and mouth. The innate immune system is quickly triggered if these barriers are breached and a virus is recognized. The response is non-specific and protects us in several ways such as by recruiting immune cells to infection sites and activating the adaptive immune system. The adaptive immune system then provides a targeted response that develops over time, involving specialized cells called **lymphocytes** that can recognize and, importantly, *remember* specific viruses. There are different types of lymphocytes; some types produce proteins called **antibodies** that stick to viruses marking them for destruction and some types eliminate virus-infected cells. Lymphocytes remember viruses through a process called immunological memory which allows the immune system to adapt and make a faster and stronger defense if the same type of virus is recognized again [4, 5] (to learn more about the immune system, see here, here, or here). In the same way, vaccines stimulate the immune system to recognize an agent and thus provide active acquired immunity to a particular disease. However, we might still get ill while our bodies work to defend us against viruses. And if we sneeze or cough while infected, the virus can spread to other people.

LYMPHOCYTES

Specialized cells responsible for producing antibodies and killing infected cells.

ANTIBODIES

Proteins generated by the immune system that recognize and bind onto antigens such as disease-causing viruses.

HOW VIRUSES SPREAD INDOORS

Viruses spread between people in many ways—through physical contact, contaminated surfaces, or through the air (called airborne transmission) for example. Droplets are expelled into the environment when an ill person coughs or sneezes (Figure 3). Talking to a friend or even simply breathing can also generate droplets. These airborne droplets may contain virus particles that can infect another person.

Virus-containing droplets come in various sizes. The size of droplets influences their fate. Droplets larger than $>100\,\mu m$ in diameter typically fall to the ground within 2 m of the person emitting them. Small droplets ($<100\,\mu m$) may be suspended in the air as **aerosols**,

AEROSOL

A suspension of fine solid particles or liquid droplets in air or another gas.

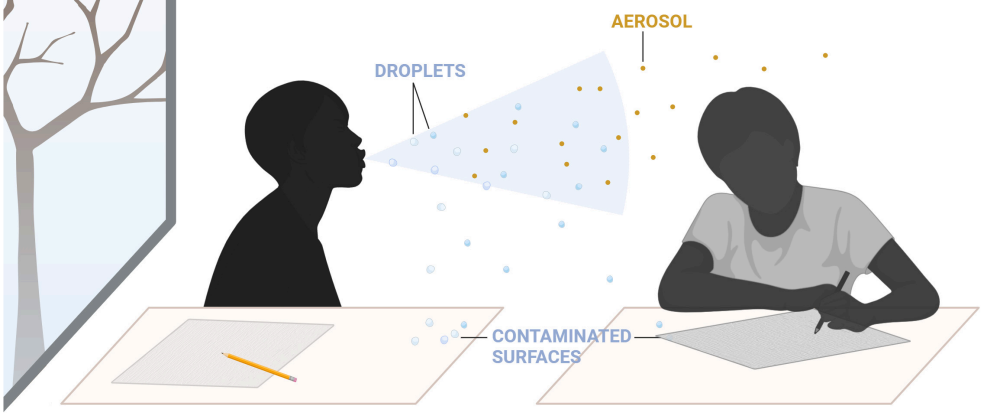

Figure 3

Transmission of respiratory virus between people. An infected person expels respiratory secretions containing larger droplets and aerosols. These can be spread through the air or when a person comes into contact with virus-contaminated surfaces. Figure created with BioRender.com.

which allows them to spread over a large area. The spread of virus-containing aerosols is affected by environmental factors such as temperature, humidity, and airflow. Additionally, aerosols can accumulate in closed rooms increasing the risk that they enter our bodies as we breathe [6].

Have you ever been in a classroom where the smell of lunch becomes overwhelming? This may be because the room has insufficient ventilation. Ventilation is a method for diluting and removing airborne contaminants such as virus-containing droplets. Closed rooms with recirculated air have the potential for much higher virus infection rates. Classrooms with poor ventilation may accumulate virus-containing aerosols, droplets, and contaminated surfaces, which increases the risk the virus spreading to more people [7].

To reduce virus transmission indoors, we must practice good hygiene. This could involve regular handwashing and cleaning frequently-touched surfaces that may have become contaminated, such as tables, door handles, and light switches. Additionally, wearing a facemask can limit the transmission of respiratory viruses by impeding the spread of virus-containing droplets and aerosols by infected individuals. Maintaining a safe distance (2 m) from people infected with respiratory viruses can slow virus transmission. To improve ventilation, windows and doors should be opened regularly. Furthermore, introducing ventilation systems and air cleaners can dilute and remove virus-containing aerosols from classrooms [8]. Overall, ensuring good indoor air quality can reduce the spread of viruses and contribute to everyone's wellbeing.

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CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

YI CHUN, AGE: 11

A person with a dimple only has two, but I have three dimples. When I was learning to speak, I pronounced the ceiling light as "ka" because I heard the sound when the button was pressed and thought my parents were teaching me how to pronounce it.

AUTHORS

MARIE GJESSING BRUUN

Marie has a Master of Science in molecular biology from Aarhus University. Her current research focuses on public health, specifically indoor air quality in schools, virus transmission patterns, and sampling of airborne viruses. With a strong commitment to health, both professionally and personally, she enjoys staying active through running and yoga in her spare time.

DANIEL STEVEN SHAW

Daniel Steven Shaw (Ph.D.) is the Section Leader of High-Capacity Diagnostics at Statens Serum Institut, Denmark. He has held research and teaching positions at the University of Leeds, University of Bristol, University of Bath, and the University of Cambridge. During the global COVID-19 pandemic, Daniel led a team of scientists to establish and manage a flagship diagnostics laboratory for the UK Health Security Agency. Working in public health, Daniel applies the science of preventing disease to improve the health of people and their communities. Daniel enjoys playing in the park with his family. *dsts@ssi.dk