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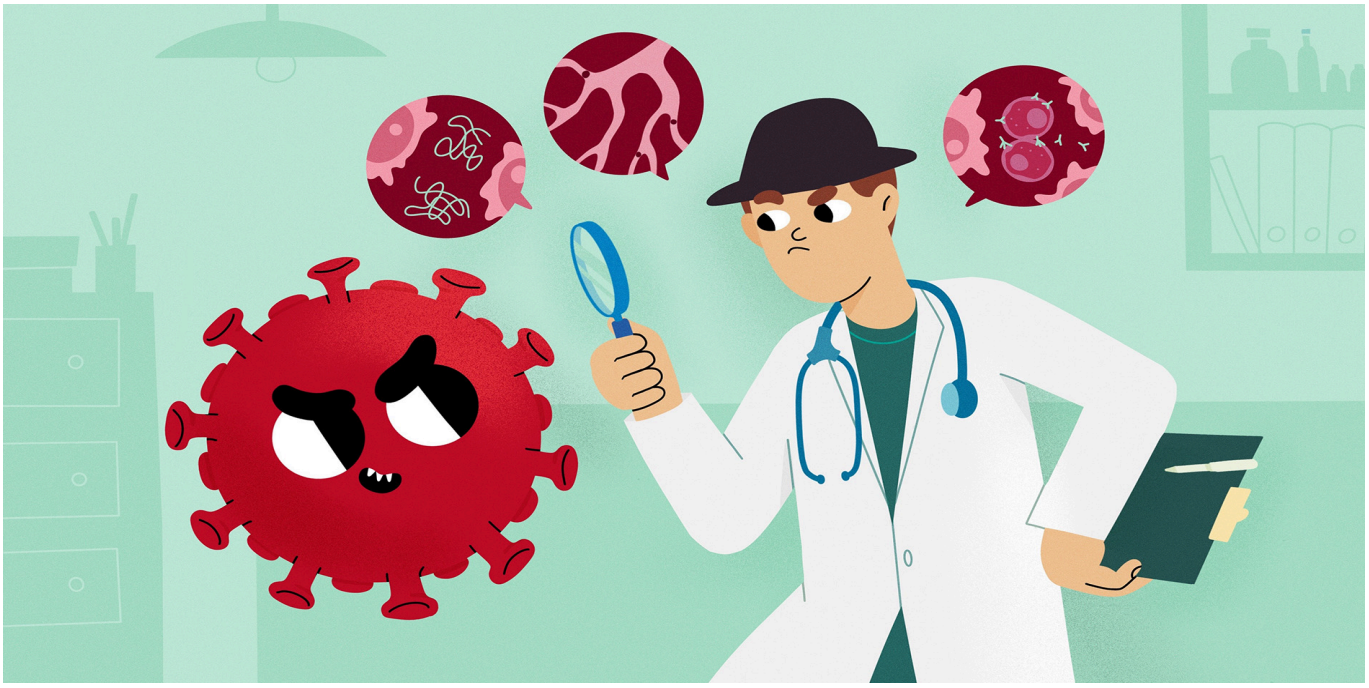

LONG COVID EXPLAINED: THE ULTIMATE GUIDE FOR KIDS!

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YOUNG REVIEWERS:

CLASS 7°F AT ESCOLA BÁSICA D. PEDRO I
AGES: 12–13

LAUREN
AGE: 11

MIA
AGE: 12

SAMANTHA
AGE: 12

COVID-19 is caused by SARS-CoV-2, a virus that affects the upper and lower respiratory tracts. Most kids who get COVID-19 do not get sick at all, or only feel sick for a short time. But sometimes children who have had COVID-19 can feel unwell for several weeks or months after the infection. They continue to feel exhausted, have shortness of breath, and have trouble doing daily tasks. This is called long COVID, and doctors are trying to understand it and find ways to protect people. In this article, we will explain what can happen when kids get COVID-19, what long COVID is, and what might cause long COVID to happen in a number of infected people.

SARS-COV-2: A MEAN VILLAIN

SARS-CoV-2 is a fairly new, harmful virus that was first observed in December 2019 in Wuhan, China. Like a mean movie villain, it quickly spread around the globe, causing a **pandemic**. The name of this virus stands for **S**evere **A**cute **R**espiratory **S**yndrome-**Co**rona**V**irus-2, and

it causes the disease called COVID-19 (**CO**rona**VI**rus **D**isease-2019) [1]. SARS-CoV-2 is one of many coronaviruses that can infect animals and humans. Like most viruses, we cannot see SARS-CoV-2 with a light microscope. However, we can see it under powerful electron microscopes. SARS-CoV-2 and other coronaviruses appear to have spiky proteins covering them, like a crown (corona), which also explains their name.

SARS-CoV-2 is a **respiratory virus** that infects the **upper** and **lower respiratory tracts**. It spreads via droplets when an infected person talks, coughs, or sneezes. The virus can also be transmitted by touching a surface contaminated with the virus and then touching the nose or eyes. So, we can help defeat this virus by practicing good hand hygiene, coughing and sneezing into a tissue, and getting vaccinated when recommended by the local health authority.

WHAT HAPPENS WHEN CHILDREN GET COVID-19?

Infection with SARS-CoV-2 causes COVID-19, a respiratory illness that can range from mild symptoms to severe illness and even death. Common symptoms include fever, cough, and difficulty breathing. Most children who are infected with SARS-CoV-2 do not feel sick. However, since COVID-19 is a respiratory disease, some children who do get sick can have awful breathing trouble or more issues like fatigue, headaches, joint pain, an elevated heart rate, and stomachaches [2].

In addition, some children who are infected with SARS-CoV-2 may develop what is called **Multi-system Inflammatory Syndrome affecting Children (MIS-C)**. This is a rare illness linked to COVID-19. Often, these children recover from SARS-CoV-2 and develop MIS-C a few weeks later. MIS-C can cause **inflammation** in various organs, like the lungs, kidneys, heart, and liver. Young patients with MIS-C may develop a high fever, feel weak, and appear pale. They may also have an elevated heart rate, trouble breathing, and stomachaches. It is not uncommon for their skin color to change, too. Do not worry, doctors are learning more about MIS-C every day. Together with scientists, doctors will find new ways to save kids from the harm caused by MIS-C.

WHAT IS LONG COVID?

Some COVID-19 patients continue to suffer from some COVID symptoms for 2–3 months or more. This means they have developed **long COVID**. Children with long COVID commonly feel fatigued, and they struggle to do routine tasks [3]. Other common symptoms are loss of smell or taste, headaches, joint pain, and tummy pain. Children who have long COVID may have trouble sleeping at night (insomnia),

PANDEMIC

When a disease spreads to a large number of people in many countries worldwide.

RESPIRATORY VIRUS

A type of virus that can infect the respiratory system. The respiratory system is the part of the body that helps us breathe.

UPPER RESPIRATORY TRACT INFECTION

Nose and throat infection.

LOWER RESPIRATORY TRACT INFECTION

Infection of the lungs.

MULTI-SYSTEM INFLAMMATORY SYNDROME (MIS-C)

A body-wide inflammatory disease that can develop, in rare cases, weeks after initial SARS-CoV-2 infection in children.

INFLAMMATION

The protective reaction of the body against an infection or an injury, resulting in heat, redness, and swelling.

LONG COVID

When someone who has had COVID-19, even if they did not have severe symptoms, still feels sick for a long time afterward (up to 2 months or more).

and during the day they may feel depressed and anxious (Figure 1). You may be wondering whether long COVID is caused by SARS-CoV-2 alone. The answer is *no*. Currently, there are three possible causes of long COVID. These include the immune system's "oopsies" (Figure 2A), "nagging" virus that remains in the body [4] (Figure 2B), and itty-bitty blood clots [5] (Figure 2C).

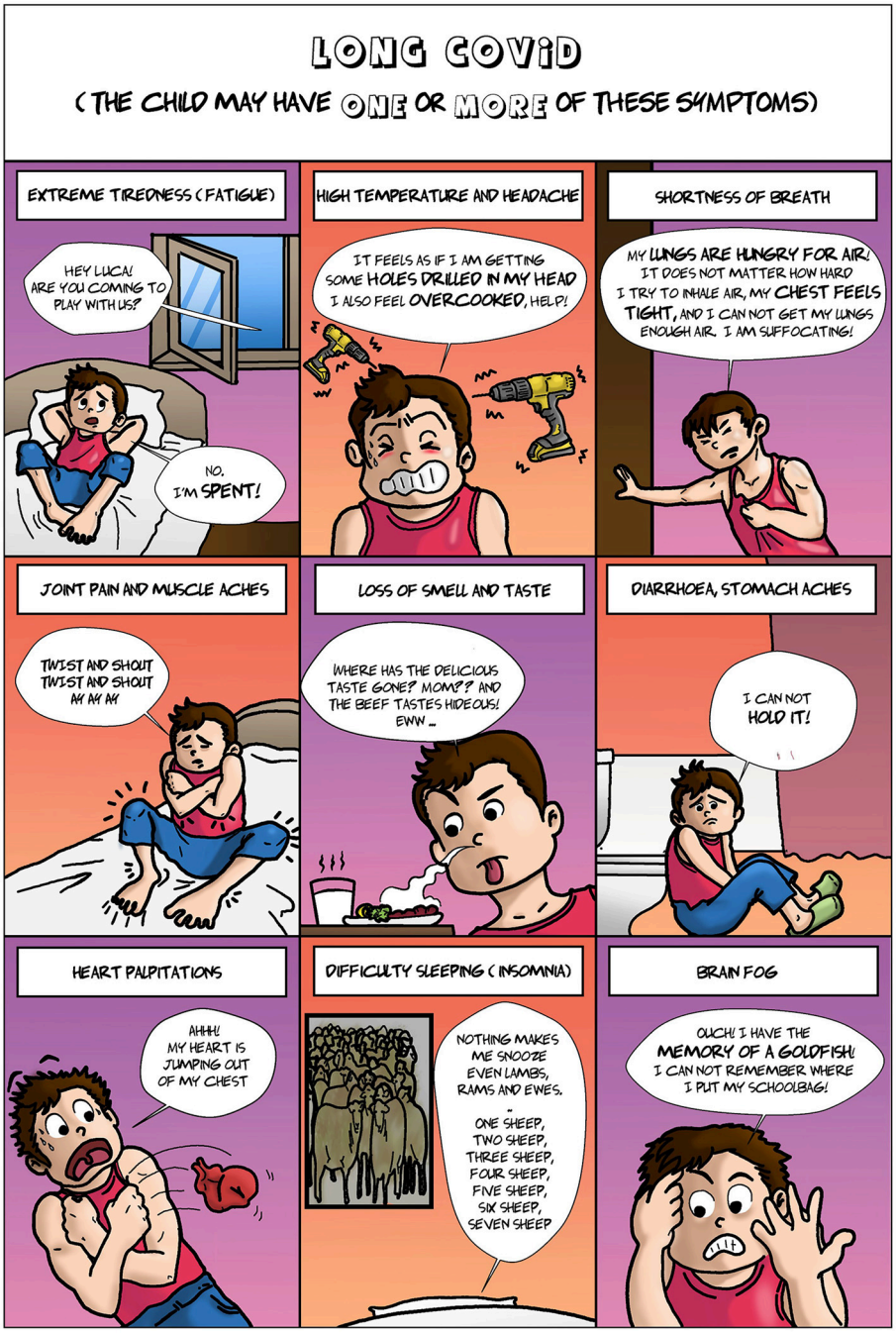

Figure 1

Symptoms of long COVID. Note that a child can get one or more of these symptoms. **Upper left**: fatigue, **upper middle**: high fever and headaches, **upper right**: shortness of breath. **Left middle**: joints pain and muscles ache, **center middle**: loss of smell and taste, **right middle panel**: stomachaches. **Bottom left**: heart palpitations, **middle bottom**: insomnia, **right bottom**: brain fog.

Figure 2

Possible causes of long COVID. **(A)** The immune system's "oopsies." **(B)** "Nagging" virus that remains in the body. **(C)** Itty-bitty blood clots.

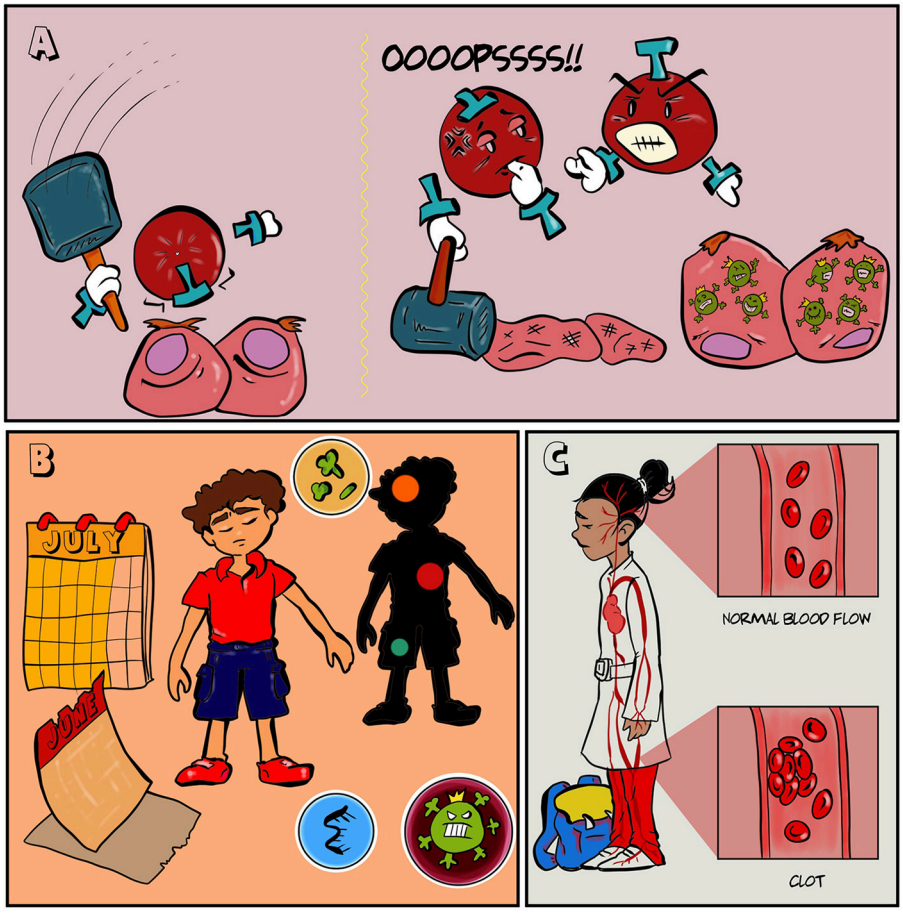

Figure 2

THE IMMUNE SYSTEM'S "OOPSIES"

IMMUNE SYSTEM

The body's natural defenses.

The human body has an **immune system** that is composed of an army of "soldier" cells that are well-trained to recognize and fight off germs. These cells are trained by either the vaccine (if a person is vaccinated) or by the infection itself. Training the immune cells by getting vaccinated is the best and safest way to prevent people from becoming very sick. Normally, trained immune cells will only attack and kill infected cells; that is what they were trained for, after all! However, sometimes the immune cells can accidentally attack healthy cells instead of the infected ones. Oops! When this happens, it can cause the body to feel damaged or have symptoms that can be dangerous and last for many weeks (Figure 2A).

THE "NAGGING" VIRUS

One possible cause of long COVID is that the body does not completely clear the virus. The remaining small amount of "nagging" virus contributes to the development of long COVID. Pieces of SARS-CoV-2 can stay in the body for months after recovery [4]. When

this happens, the immune system keeps immune cells active to fight the virus, even though the person does not feel sick anymore. This can cause inflammation in the body, which can make it take longer for the person to feel completely better (Figure 2B).

ITTY-BITTY BLOOD CLOTS

Although COVID-19 is a respiratory disease, SARS-CoV-2 can damage other body systems, too. The circulatory system (the heart and blood vessels) is another system that SARS-CoV-2 can harm. This can lead to the formation of tiny (itty-bitty) blood clots. Blood clot is when the blood in our body gets sticky and forms a lump. This can sometimes happen when we have a cut or an injury to protect our body, but it can also happen in our veins and block the blood flow preventing some organs from getting enough blood. In this case, a doctor may need to give medicine to help dissolve the clot to save the organs from dying off. Thanks to scientists who have created new instruments that can help doctors find these itty-bitty blood clots, doctors can often treat them before they become dangerous (Figure 2C).

CONCLUSION

In this article, we have told you about COVID-19, a fairly new disease that can affect children and adults. Most children who catch the disease caused by SARS-CoV-2 recover quickly and only have mild symptoms of COVID-19. However, some children can get more serious illnesses, like MIS-C. Thankfully, this disease is becoming rarer. Other children may end up with long-lasting symptoms, which is known as long COVID. If you feel you are not returning to normal a few weeks to 3 months or more after getting COVID-19, talk to your parents or doctor. Doctors and scientists are working around the clock to figure out what causes long COVID and to protect children and grownups from suffering from this rare but serious condition.

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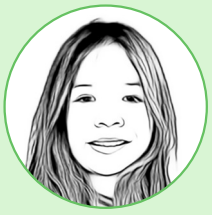
CONFLICT OF INTEREST: DB has received a grant from Pfizer to study Long COVID in children.

The remaining author declares 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

CLASS 7°F AT ESCOLA BÁSICA D. PEDRO I, AGES: 12–13
We are a group of 28 students aged 12 to 13 years old from class 7°F at Escola Básica D. Pedro I, Vila Nova de Gaia, Portugal. Our class wanted to review the article because we are very curious teens and COVID-19 had such an important role in our lives that we will never forget.



LAUREN, AGE: 11
I am 11 years old and really like science, especially biology. My hobbies include reading, sudoku, chess, and video games. I also like geography and nature, and I like to go exploring. I live with my parents, my little sister and my 2 cats.

MIA, AGE: 12

Hi! I enjoy reading, walking, and playing the cello. When I am older I would hope to be a veterinarian or an architect. In my free time I like to eat, cook, sleep, and hang out with my friends.

SAMANTHA, AGE: 12

Hi. My name is Samantha, and I am 12 years old and enjoy reading murder mysteries and historical fiction. In my free time, I like reading, napping, and hanging out with friends and family. I am interested in biology and environmental science.

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Dr. Danilo Buonsenso is a pediatrician who specializes in infectious diseases in the Department of Woman and Child Health and Public Health, Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy. He holds a Ph.D. in Biomolecular Sciences and Public Health (Catholic University of Rome, Italy) and a post-graduate diploma in Pediatric Infectious Diseases from Oxford University, where he is currently enrolled in a Masters of Sciences in Pediatric Infectious Diseases. Danilo is the president and founder of the non-profit organization Surf4Children, aimed at providing medical and social support to fragile families in Italy and Sierra Leone. *danilobuonsenso@gmail.com

SUSAN NASIF

During the development of this manuscript, Susan worked as a strategic consultant in the Fondazione Policlinico Universitario A. Gemelli IRCCS, Rome, Italy. Susan Nasif (Obeid-Adorisio) is a virologist and science communicator. She uses the scientific method to find the most effective forms and languages to reach specific audiences. Susan's comics are fun and informative, and appear in many EU languages and in Arabic. She has received four global recognitions, winning the 2015 Science Hero Award, 2017 Innovation in Science Literacy Award, 2018 Europe (Silver) Vaccines Communication Challenge Award, and 2020 MSD-Merck Health Literacy award. In 2023, she developed the "*The Amazing Adventures of Syrgo and BC,*" a comic miniseries directed to children to raise awareness about the importance of vaccination. Susan's LinkedIn url is: https://www.linkedin.com/in/susannasifphd/ and Twitter: @DrSusanNasif.