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EPILOGUE 2

COSMIC KIDS COVID-19 EXPEDITION: VACCINE (AS TOLD BY MILO)

I am back working with my old *Cosmic Kids* team, and I am really happy about that. Besides not being on the winning team, there were a bunch of things that I missed. I missed having G-Pa as my coach, and believe it or not, I missed fighting with Lizzy. I also missed writing the journal chapters. But this new activity is really awesome. I am in charge of planning the video on the Covid-19 vaccine.

We invited Uncle Will, who is a doctor, to the *Room* meeting with the *Cosmic Kids* to plan the video production. G-Pa was there too.

"My mom is going to take part in a vaccine trial," Lizzy informed us. "She will get one shot three days from now and a second shot 28 days later. She said she is testing a vaccine based on messenger RNA (mRNA) technology. Can you tell us about it, Uncle Will?"

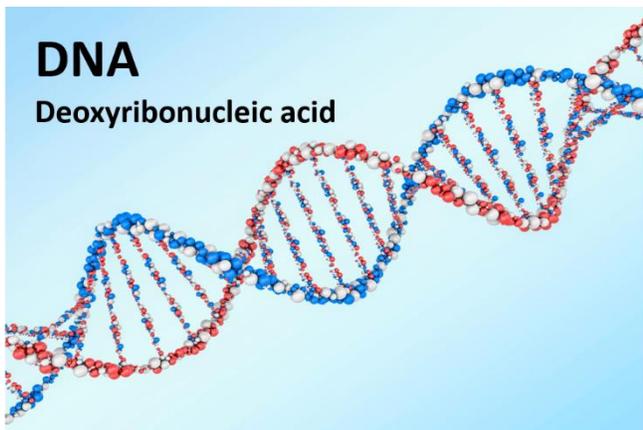
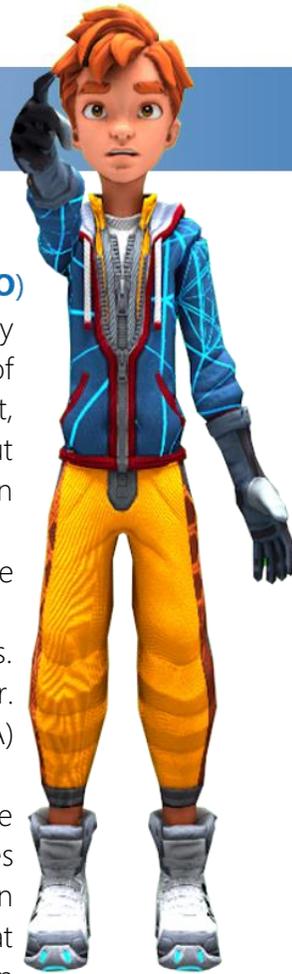
"Of course," answered Uncle Will. "The mRNA technology is the latest thing in vaccines. It is really incredible. Up until now, most vaccines have been developed using dead or weakened forms of the virus. When injected, the body's immune system develops antibodies and other cells that will fight the real virus if it ever appears. Developing such vaccines has, in the past, taken up to eight years."

"Wow," said Neddy, "that's a really long time. How did they get ready to test a vaccine on my mom in six months?"

"All the doctors and scientists were working very hard to get something ready really fast that works," Uncle Will explained. "But a vaccine using the mRNA technology is actually easier to develop. It is really cool stuff, and it's going to change all the vaccines we make in the future."

"So how does it work?" asked VC.

"The keys to understanding how the virus reproduces and how the vaccines will work," explained Uncle Will, "are huge molecules called [RNA](#) and [DNA](#). Here are some pictures of them."

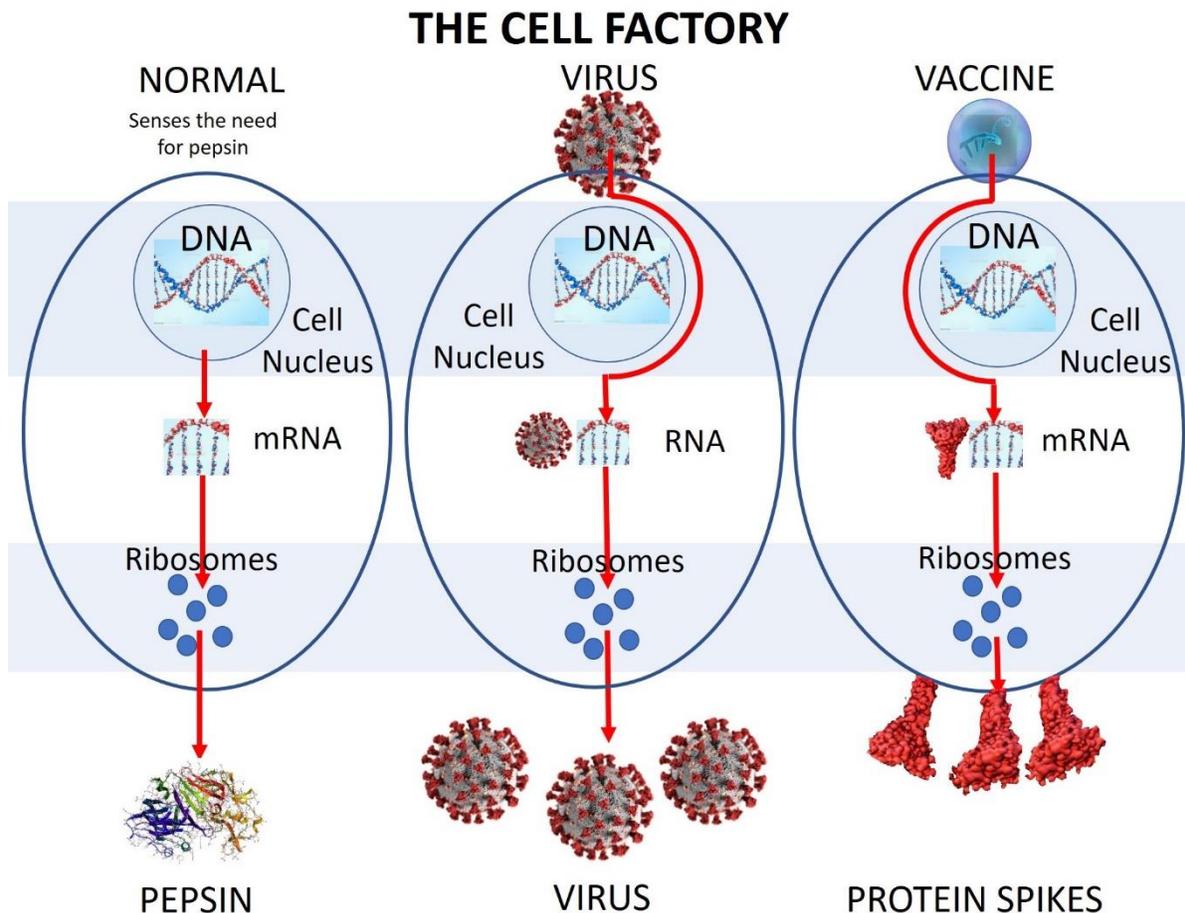


Uncle Will screen shared the pictures and told us about them. "They are both large molecules made of carbon, hydrogen, oxygen, nitrogen, and phosphorus atoms. Different combinations of these atoms in different sequences create the genetic code describing how an organism or virus is built. For us humans, all the information on how to create each piece of us is contained in our DNA. It is a two-strand molecule arranged in a twisted pair. We get one strand from our mother and the other from our father. The virus doesn't have a mother and a father, so for the coronavirus, a single-strand RNA molecule contains its genetic code.

"Do you remember how the [Covid-19 virus](#) reproduced itself in Grandpa's body?" asked Uncle Will.

"Yeah," said VC. "It got into one of Papa's cells and got his cell to make virus copies using the virus's own RNA as the code for how to produce it."

"Yes, that's right," responded Uncle Will, who had made us a diagram. "Our body's cells are little factories that produce things that the body needs. For example, on the left, the diagram shows a cell from the stomach that produces the chemical pepsin, needed for digesting food. The instructions for making pepsin are in a small piece of the DNA genetic code, and every cell has your DNA in a place called the [cell nucleus](#). The nucleus creates a molecule called [messenger RNA](#), mRNA, with the required piece of code for producing pepsin. The mRNA is sent to the cell's factory, called the [ribosomes](#), and it manufactures the pepsin. If a virus had invaded one of those cells, as shown in the middle diagram, the factory would manufacture virus copies."



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"Oh, I get it," I said. "The clever virus hijacks your cell's factory. It presents its RNA to your cell's ribosomes, and the factory responds by manufacturing lots of virus copies like you show in the middle diagram."

"Right," responded Uncle Will. "Well, our doctors and scientists are just as smart as a virus. They took a small part of the virus's RNA and made their own mRNA. It was the code for building the protein spikes that appear all over the virus's surface. Then they figured out how to get that little section of mRNA inside human cells so that the cell's ribosome factory will make copies of those spike proteins. That's the diagram on the right."

"Now I get it," said Lizzy. "When lots of spike protein copies are made, the body's immune system senses these foreign objects and learns how to attack and destroy the spikes and the infected cell. So, when the real virus shows up with those same protein spikes, our bodies know how to deal with it."

"Yes, Lizzy," said Uncle Will. "The immune system will have antibodies and killer T-cells that were created in response to the vaccine. They remain for months to fight the real virus if it should appear. As long as your immune system remembers the spike protein attack, it will use the same strategy to attack and destroy the complete virus, which has those same spike proteins."

When Uncle Will finished explaining, I said, "That is awesome. The vaccine gets your body to produce just the spikes, and you can't get sick from them. But the spikes get your immune system ready to fight the complete virus, which has the same spikes."

"Another thing that is awesome," added Neddy, "is that scientists can pick out just the piece of the virus's RNA that is the code for making protein spikes."

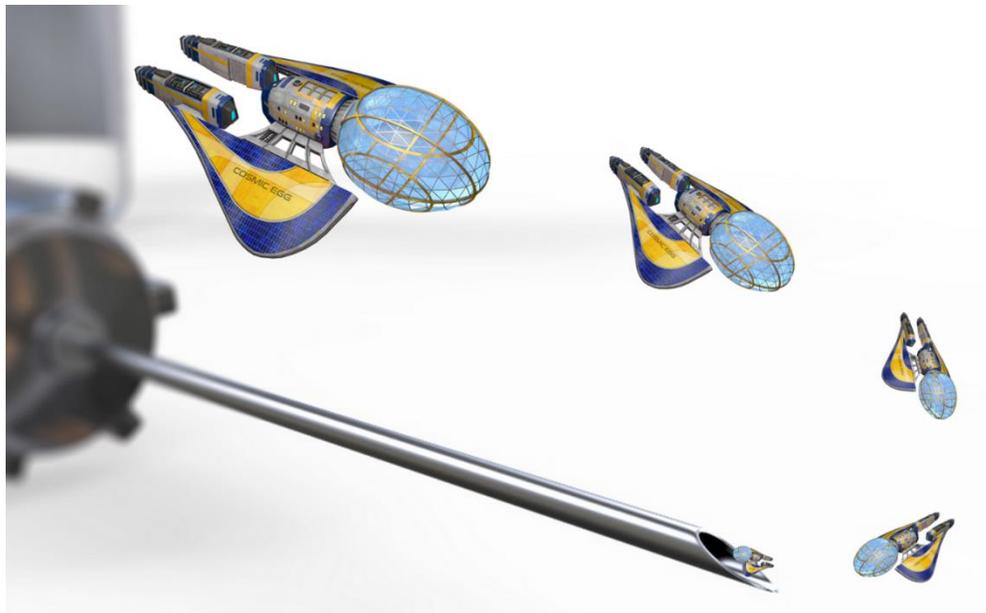
"Thanks, Uncle Will," I said. "I think we got the story straight and are ready to make our video."



We waited for Aunt Debbie to get her vaccine shot and went with her to videotape the event. For the next part of the video, we logged on to the [Virtual World](#) and went to the *Cosmic Egg*. We reduced our size and flew toward a needle with the vaccine that was about to be injected into a person's arm.

Then for our video, we pretended that we were following the vaccine as it worked in my aunt's body.

As we approached the opening at the end of



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the needle, Neddy and VC were loading some of the pictures of what we were looking for into their computer.

“OK, guys,” announced Neddy, “take a look at the screen. The immunization strategy involves reproducing the Covid-19 protein spikes in my mom’s body. The spikes without the rest of the virus won’t make her sick, but they will get her immune system ready to fight the real Covid-19 virus. This is what the protein spikes look like.” She pointed to her computer screen.



Lizzy took over the controls so I could see. Then Neddy brought up the next image of the mRNA that was the code for building a protein spike.



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"The mRNA molecule looks like a short piece of the virus RNA," remarked Grandpa.

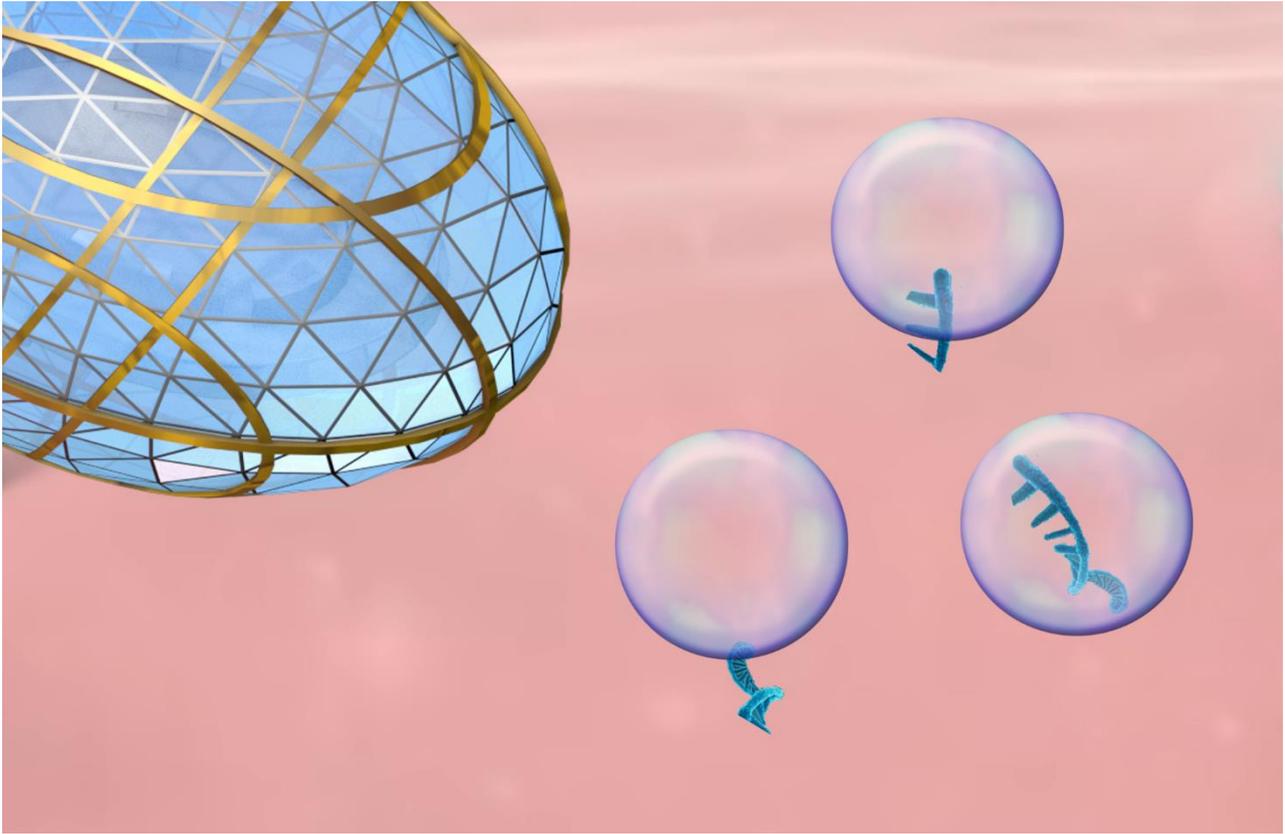


"There was one more thing that we need to show you," said VC, "before we follow the vaccine into Aunt Debbie's arm. The mRNA molecule is not very stable. It has to be kept very cold during storage before it is used. It also has to be wrapped in an oily coating so that the body won't chew it up before it could do its work. So, we need to look for droplets containing the mRNA."



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"OK, now we are ready to go," said Neddy. "Milo, take us into the needle." We entered the needle that was already filled with vaccine. "The nurse is now injecting the vaccine," Neddy observed.



We floated along in the vaccine fluid. Eventually, we were able to view the droplets, containing strands of mRNA, hit the surface of a cell. We watched as the coated mRNA particles started to stick to the cell's surface.

"Neddy," I said, "why don't you launch the drone with the camera so that we can get a closer look using your large computer screen? Yeah, much better."

"Look," said Lizzy, "the mRNA is moving out of the protective coating and burrowing into the cell."

"According to Uncle Will," said Neddy, "this is the important part. Once the mRNA is inside a cell, the cell's ribosomes will take the code in the mRNA and start churning out protein spikes that are identical to those on the virus. Some of them will stick out on the cell surface."

"Right," announced VC. "It's building the protein spike copies because that is the instruction or code in the piece of mRNA that they extracted from the virus."

"You kids have got the story straight," complimented G-Pa. "Now you have reached the stage that is important. The foreign protein spikes are appearing on the cell's surface. They are going to fool the vaccinated person's immune system into sensing that it is being attacked by the Covid-19 virus. Because it is a simulation of an attack and not the real thing, the person won't get sick, so the immune system has plenty of time to respond."

"Milo," asked G-pa, "please advance the time to see how the person's immune system responds."

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"You got it, G-Pa," answered Milo. "Advancing one hour every minute."

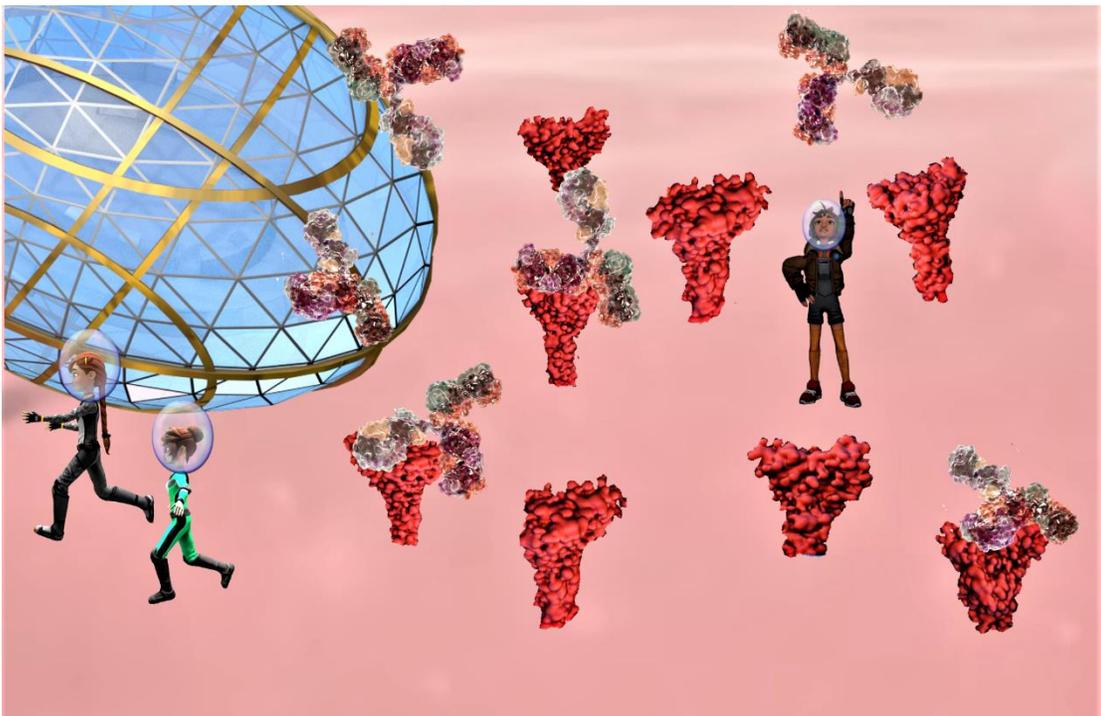
"I got a great idea," announced Neddy. "Let's put on our breathing helmets and go out and see the protein spikes. We can see if any antibodies arrive."

I stayed at the controls, while the girls went out and started to chase each other around the protein spikes growing out of the cell walls..



Soon, the three-pronged antibodies started to appear, and some attached themselves to the protein spikes.

"It looks like one of those antibodies is going to attack me," yelled VC.



Neddy and Lizzy had already figured that out and started running back to the ship. They yelled a warning to VC, and she quickly followed.

When the girls were safely inside, Grandpa said, "we should have predicted the attack on you girls. You are foreign objects, so the immune system is going to attack you, as well as the protein spikes. They are also starting to attack the ship too."

"Now I see how the vaccine works," I observed. "It created the antibodies to attack the protein spikes. Those protein spikes are what the virus uses to get inside a cell to reproduce. So, if any virus particles got into the body, the antibodies which are ready and waiting would hang on to the spikes, so the virus wouldn't be able to get inside a cell to reproduce."

"Not like your case, Grandpa," observed VC, "where your immune system produced hardly any antibodies in time to save you."

Uncle Will added this information. "After a while, a vaccinated person's immune system will get its cleanup crew into action. Killer T-cells and other immune system cells will destroy all of the protein spikes and the infected cells. What will be left in the person's body will be the antibodies, memory B cells that had the recipe for producing more of the right kind of antibodies, and killer T-cells with simulated experience combating the Covid-19 virus."

"After the second shot, Uncle Will continued, "the person's immune system would be ready to spring into action to disable any Covid-19 virus particle immediately. They wouldn't be able to get into a cell to reproduce."

"It would have been great," I suggested, "if G-Pa and Uncle Ken had the vaccine early enough to prevent them from getting sick."

"But we can't complain," concluded G-Pa. "They developed this mRNA vaccine in record time. Only 5 percent of the people who got the vaccine in the trials got sick, and those who did get sick only had mild cases of the virus."

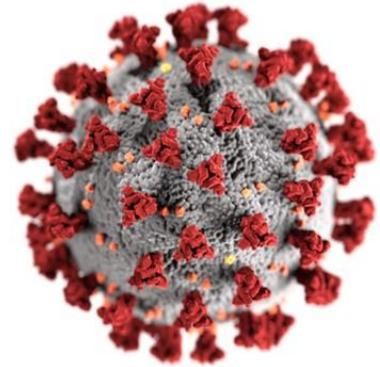
"How long will a person be safe after being vaccinated?" I asked.

"It's possible," responded Uncle Will, "that in the months after vaccination, the number of antibodies and killer T-cells will drop. But the immune system also contains special memory B cells and memory T cells that might retain information about the coronavirus for years or even decades."

GRANDPA'S GLOSSARY

Virtual World: Virtual worlds, also known as virtual environments, use computer technology to create a simulated world that a user can explore and interact with, while creating a feeling as if he or she were in that world. The representation of the user in that world is called an avatar. The user can even wear goggles to make it appear that he or she is surrounded by the 3-D virtual world. That is called virtual reality.

Covid-19/Coronavirus: COVID-19 is a disease produced by a coronavirus that can cause an infection of the respiratory system (sinuses, nose, throat, windpipe, and lungs). The disease spreads mainly by sharing of the coronavirus particles through person-to-person transmission (most often in airborne droplets containing the virus particles). Coronaviruses are named for the distinct crownlike protein spikes on their surface. They cause many different diseases, including Covid-19 and the common cold.



A virus is a particle one-hundredth the size of most bacteria, too small to be seen with an optical microscope. Virus particles consist of their genetic code material in the form of DNA or RNA, a protein coat that surrounds and protects the genetic material and, in some cases, an outside oily layer. The double-strand DNA or single-strand RNA molecules contain the genetic code for the virus's structure. The code is written in the order of atoms and molecules that make up the DNA or RNA.

Some scientists consider viruses to be living organisms because they carry their genetic code, reproduce, and evolve through natural selection. Others disagree because viruses lack cell structure and cannot independently reproduce. To make copies of themselves, they employ the capability of living cells to reproduce organic components from RNA coded instructions. They invade the cells of living organisms and induce the cell's own mechanisms to reproduce the virus based on the virus's RNA genetic code. Viruses can pull off this trick with cells of animals, plants, and microorganisms such as bacteria. When infected, a host cell is forced to rapidly produce thousands of identical copies of the original virus.

One of the vaccines to combat the Covid-19 coronavirus (the mRNA vaccine) uses the virus's own trick to defeat it. A small piece of the virus's RNA with the code to produce the protein spikes is presented to the body's cells. The cells reproduce lots of copies of the protein spikes. These virus pieces get the body's immune system primed to combat the virus without any danger of producing the disease.

DNA (Deoxyribonucleic Acid): Let's say you wanted to build a robot. You look online and find a set of instructions. It would have to contain lots of things: a list of parts; specifications and drawings for each part (for size, shape, color, function, etc.); and instructions for how the parts are connected. If your friend is going to build one too, you need to copy the instructions. If you are building a complicated robot, the list could be very long, requiring a whole book full of instructions. The

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instructions for building you and all living things are contained in the DNA, which is reproduced in every cell. The double-helix structure of DNA was identified by James Watson, Francis Crick, Maurice Wilkins, and Rosalind Franklin in separate papers in the journal *Nature* in 1953. Watson, Crick, and Wilkins (but not Franklin, who died in 1958) received the 1962 Nobel Prize in Physiology or Medicine. You can see a picture of the double helix in Epilogue 2. It is two long chains of molecules that are twisted around each other, like a long rope. The molecules are built of mainly five atoms: carbon, hydrogen, oxygen, nitrogen (CHON), and phosphorus. The building instructions are determined by the order or sequence in which the atoms of the elements are arranged, just as the twenty-six letters of the English alphabet can be rearranged to spell out thousands of different words. Each cell in your body contains a complete twisted pair of chains in the form of DNA. When you started life as a single cell, one of your DNA chains came from your mother and the other from your father. As your cells multiplied, the DNA was copied so that each cell had an identical copy of your first DNA molecule. The instructions on whether you are a girl or boy, the color of your eyes and hair, how tall you will be, and every other physical thing about you are coded in your DNA.

Cells: The cell is the basic building block for all living things. The cell was discovered by Robert Hooke in 1665 from studies of living material in which, using a microscope, he observed very small repeating structures. He called the structures cells because they resembled cells of a honeycomb. The first living things on Earth were single-celled organisms. Each cell was able to perform all the functions necessary for life. They could feed themselves and reproduce. Multicell creatures like humans have highly specialized cells that perform specific functions, such as nerve cells, which are long and can transmit signals; muscle cells which contract to move arms and legs; and killer T-cells, which can attack foreign objects to protect the body. Most cells are between 1 micron (1/1,000,000 of a meter) and 100 microns in size. The human body contains about 100 trillion cells, whose size is like the thickness of a hair. An interesting website with interactive diagrams of cells is at http://www.cellsalive.com/cells/cell_model.htm.

Ribosomes: Ribosomes are complex structures found inside living cells. Their purpose is to produce functional products (proteins) required by the organism according to the instructions contained in messenger RNA created by the organism. Viruses have the ability to hijack a cell's ribosomes to have it make copies of itself from its RNA. The ribosomes are also used by mRNA vaccines to have it make copies of the protein spikes seen on the outside of a coronavirus. The spikes stimulate the body's immune system to prepare it to fight off the virus should it appear.

RNA: RNA or Ribonucleic acid is a very large molecule that is similar to a single strand of DNA. They are both nucleic acids. RNA has the genetic codes for creating substances needed by living things. All known forms of life and viruses have RNA.

Messenger RNA: Messenger RNA, or mRNA, is a single-stranded molecule of RNA that contains the genetic sequence of a gene, a part of the genetic code for a specific functional substance. For example, the protein spikes on the coronavirus are such functional substances. The mRNA is read by a ribosome in the process of synthesizing the substance. The pepsin molecule described in in this

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excerpt is another example of a functional substance created by a cell's ribosomes using mRNA. The process of copying a gene from DNA into mRNA is called transcription.

Cell Nucleus: The cell nucleus is a highly specialized structure of every cell of living things. The cell serves as the information-processing and administrative center of the life form. This structure has two major functions: it stores the cell's hereditary material (the information on the organism's characteristics, the blueprints and instructions for its construction) in the genes, and it coordinates the cell's activities, which include growth, metabolism, protein synthesis, and reproduction (cell division).

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