# Mental and Physical Changes in Space

**Astronauts face many challenges to both their physical and mental health in space. NASA has been studying these challenges by comparing astronauts on Earth to astronauts living on the International Space Station. An important study that was just completed compares two astronaut twins. Scott Kelly spent almost a year on the ISS, while his twin brother Mark remained on Earth. NASA hopes that this one-year study will help them understand the physical and mental challenges astronauts will face during a 3 year round trip journey to Mars.**

**The study looked at 5 stressors NASA expects astronauts will experience on a trip to Mars:**

**1. Gravity**

Gravity on Earth exerts a strong force on the human body. When people move around on Earth, they are constantly working against gravity and strengthening their muscles. The twin astronaut in space, Scott, lost 7% of his body mass on the ISS. This is because he felt weightless and his body was not working against the force of gravity. Gravity does exist on Mars, but it has less than half the strength that it does on Earth. NASA not only anticipates that the change in gravity will physically affect an astronaut, but it could also affect the way an astronaut thinks. For example, they may have trouble thinking clearly or even have less hand-eye coordination.

**2. Isolation/Confinement**

Astronauts do not have a lot of contact with other people while they are in space. Astronauts on a trip to Mars will be confined to a small space (about the size of a small RV) with the same 6-7 people. These conditions can result in several mental health changes, including depression and fatigue, or tiredness. These mental health changes can affect an astronauts ability to make decisions and perform tasks. For example, Scott took more time and made more mistakes on computer tests when he returned to Earth compared to his brother who stayed on Earth.

**3. Hostile/Closed Environment**

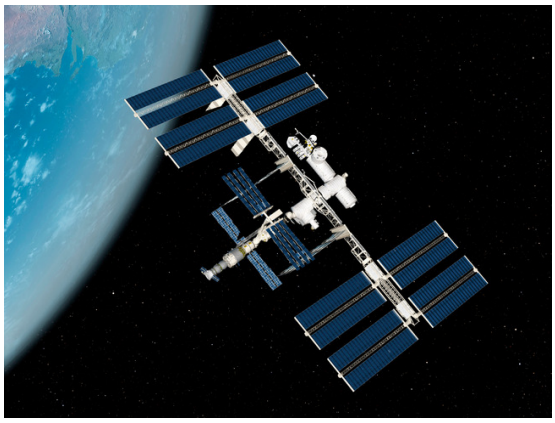
NASA does its best to create conditions similar to Earth while astronauts live in space or on another planet like Mars. But, there are still major changes to a person's body due to living in an unfamiliar and closed environment. For example, Scott's poop changed because his digestive system was exposed to new microorganisms. Living in a small and confined space with other people also increases stress hormones. This can result in astronauts experiencing more illnesses and allergic reactions.

**4. Space Radiation**

On Earth, astronauts rely on Earth's atmosphere to protect them from space radiation. Astronauts on the ISS receive about 10 times as much radiation as on Earth. This can lead to changes in an astronauts DNA. NASA even found that some of Scott's DNA had been damaged on the ISS. Once astronauts are outside of Earth's atmosphere, astronauts are exposed to much more space radiation and they rely on their spacecraft, space suits, and clothing to keep them safe. Space radiation can cause radiation sickness, vomiting and fatigue. It can also cause long term problems like damaging DNA, causing cancer, and mental health issues.

**5. Distance from Earth**

Scott hid out in an attached Russian capsule when a piece of space junk almost hit the ISS. Mars is about 140,000,000 miles from Earth! Being that far away means that astronauts need to be self-reliant. They have nowhere to go to get away from dangers, and they need to make any of the tools, structures or medicines that they may need in an emergency.

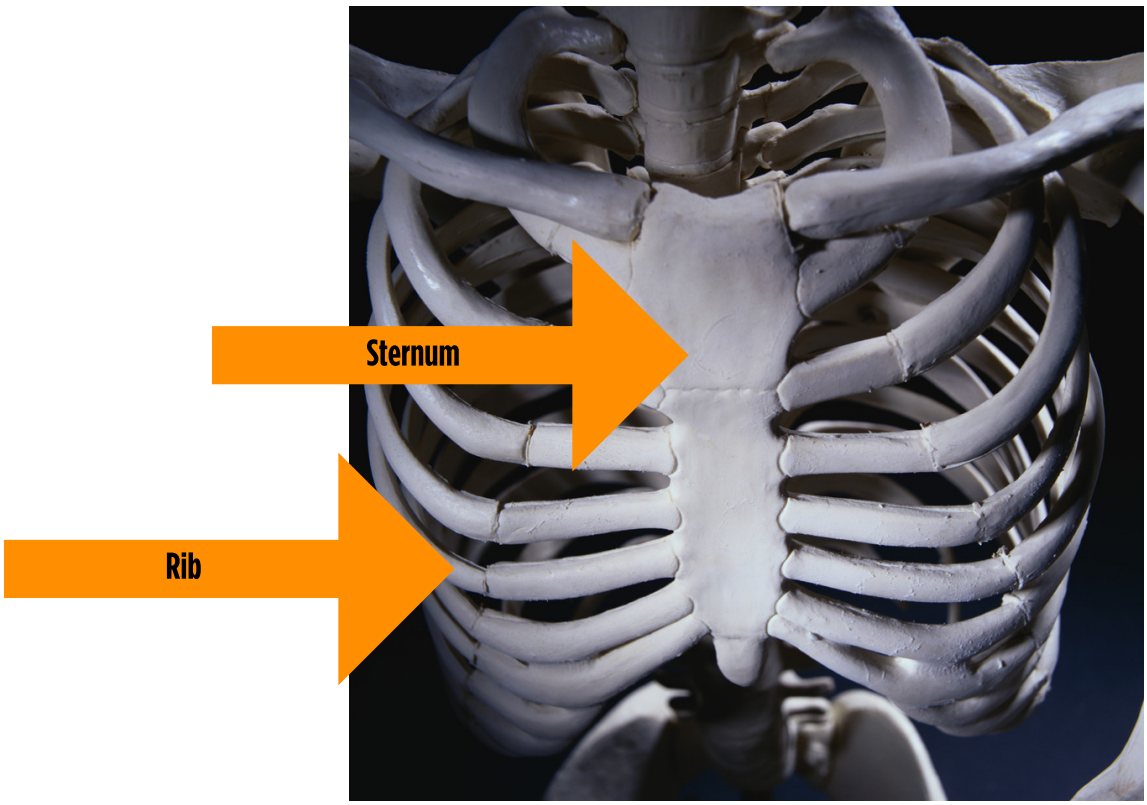


# 3-D Printing a Rib for Humans

3-D printing creates a 3-dimensional object using a printer. Recently, scientists have figured out how to use stem cells and a person's DNA to print actual working body parts. This means that scientists and physicians will be able to print working bones, muscle tissue, lungs, and even hearts!

The radiation level in space is extremely high. Normally, our bodies are protected from this radiation by the Earth's atmosphere. On Mars, humans will not have this same protection. As a result, the radiation can destroy bones and organs inside the astronaut's body.

For example, radiation exposure could destroy an astronaut's rib. Astronauts could create a 3-D model and print a replacement rib. On a person's body, the sternum is straight up and down and the ribs stick out almost perpendicularly in respect to the sternum. Each rib attaches to the sternum at a different angle and then bends to wrap around the person's body. The rib cage offers protection of the internal organs, like the heart and lungs.



# 3-D Printing a Replacement Rib

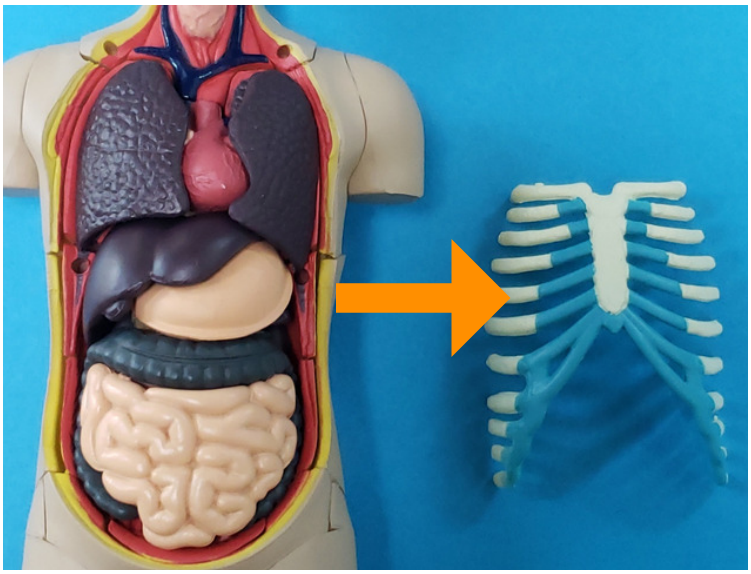
Follow the steps below to print a replacement rib with your 3-D printer.

**Step One: Measuring Your Rib**

To create the 3-D model of the 4th rib, you will use a scale model of a person to figure out the size and shape of the rib. You will need to use a protractor to measure each place the rib is angled or bends (the angle down from the sternum, the angle the rib is bent from the front of the body to the back of the body, etc.). You will also need to use a ruler to measure how tall, long, and wide the rib is. See the example below and then take your own measurements and record them in the box on the next page.

For example, on this model, when measured:

- The part of the 4th rib that lays flat on your body (the blue part on our model):
  - Using a protractor to measure, the rib is angled down 25 degrees at the sternum
  - Using a ruler to measure the blue part of the rib is 7 mm long
- The part of the 4th rib that curves around to the back of your body (the white part on our model):
  - Using a protractor to measure, the rib is angled up 25 degrees (so that it is perpendicular to the sternum)
  - The rib is angled toward the person's back 40 degrees
  - Using a ruler to measure, the rib is 9 mm long
- Each section of the rib is 1 mm tall and 2 mm wide.



Get a model of a rib from your teacher. This rib can come from a full-sized skeleton or a small toy model. Use a ruler and a protractor to measure each area of the rib. Be sure to measure the angle of each curve, the height, width, and length of each piece. Use the box below to sketch your rib and fill in your measurements. Tip: You may want to draw your rib twice; once from the front and once from the back. This will make sure you have a place to fill in all of your measurements.

# 3D Printing a Rib For Astronauts

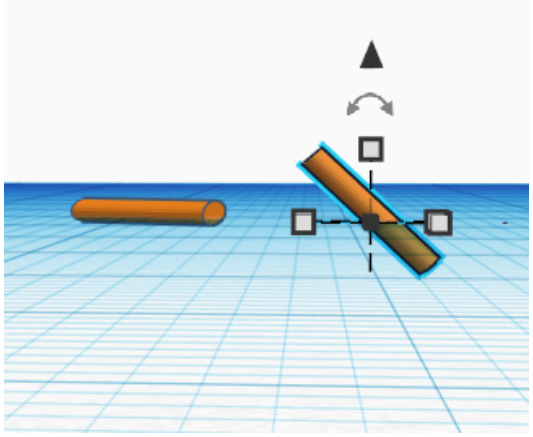
## Step Two: Create a Computer Model of an Astronaut's Rib

- Create a new design in Tinkercard.
- Click on the name in the top left corner and change it to "4th Rib_YourName".

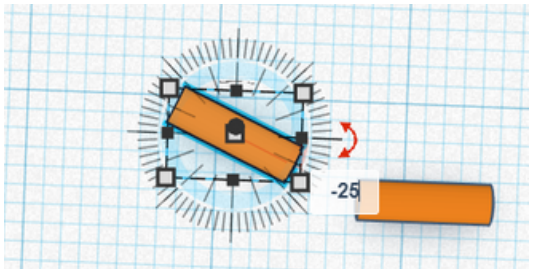
Note: All of these instructions are based off of the measurements taken on our model rib. Any measurement that is specific to our model is highlighted in orange. Be sure to use your own measurements instead of the measurements included here.

The work space shows a grid that goes in the "x" and "y" direction. The direction above and below the grid is the "z" direction.

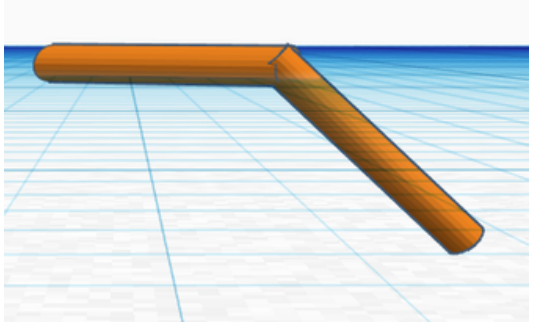
- Use the scale drop down menu in the lower right corner to change the scale of the grid to 0.1 mm.
- Use the shapes drop down menu on the upper-middle right hand side to choose basic shapes.
- Pull a cylinder into the work space.
- Choose "Front" view and rotate the cylinder 90 degrees so that it is laying on its side.
- Change the dimensions of the cylinder so that it matches the measurements of the flat part (blue part of the model) of your rib. The example model is 1 mm tall, 2 mm wide and 7 mm long.
  - Don't forget you can zoom in so that you can see your tiny object better!
- Copy and paste this cylinder so now you have two identical cylinders on the work space.



- Choose the "Top" view and rotate the 1st cylinder -25 degrees so that it is angled down (from horizontal) in the y direction.
- Choose the "Front" view and rotate the 2nd cylinder -40 degrees so that is angled down (from horizontal) in the z direction.




- Move the two pieces so that the right side of the 1st cylinder connects to the left hand side of the 2nd cylinder.
- Use your cursor to highlight both cylinders and click the "group" icon to group the two separate objects into one object.
- You now have a 3-D model that is the same size and shape as the rib in the model that needs to be replaced. However, it is much smaller than a human sized rib.
- Export your 3-D model file in a format that will work with your 3-D printer.



# 3D Printing a Rib For Astronauts

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## Step Three: Understanding Scale

Our model rib is WAY too small for a real person, but once you have created a 3-D model, you can change the scale to fit a real person. First, we need to know that the astronaut we are creating the rib for has a 4th rib measurement of 320 mm long. Next, we need to know that our model rib is 16mm long (flat length or blue part of the model + curved length or white part of the model). We can use this information to figure out the scale difference between our model rib and the rib we need to print.

$$\frac{\text{320 mm (actual rib size)}}{\text{16 mm (model rib size)}} = 20$$

**The scale factor of this print should be 20. Meaning we would print our computer model 20 times larger than the measurements on the screen. This is also represented as 2000% larger.**

Use your measurements to figure out the scale to turn your model rib into a rib that can fit our astronaut.

$$\frac{\text{320 mm (actual rib size)}}{\text{\_\_\_\_\_ mm (model rib size)}} = \square$$

When NASA sends 3-D printers to the ISS or Mars, they will be very large and able to print full sized items. However, most schools and businesses do not have access to printers able to handle printing a 320 mm (12.5 inch) rib. This means, depending on the size of your printer, you may not be able to print a life-sized rib. In order to actually print your rib, you will need to know the maximum print area of your printer. We are using the da Vinci mini w+. It has a maximum print size of 6in. x 6in. x 6in. (6 inches = about 150 mm). We need to determine what scale to print at so we can print the largest rib possible. (It will not be life-sized, but it will give us an idea of what our rib would look like). To do this, we will use the following formula:

$$\frac{\text{150 mm (maximum print size)}}{\text{16 mm (model rib size)}} = 9.375$$

**The largest rib we can print on our machine is 9.375 times bigger than our model. We will round down to 9 times to make it easier to enter into the printer. We will enter this into our printer as 900% in the next step.**

Note: Since we started with a tiny model, we are scaling our print to be larger. If you started with a human sized model, you may need to scale your print down. You will use the same formula. However, you will get an answer similar to .47. This would be entered into the printer as 47%.

Figure out your print ration below:

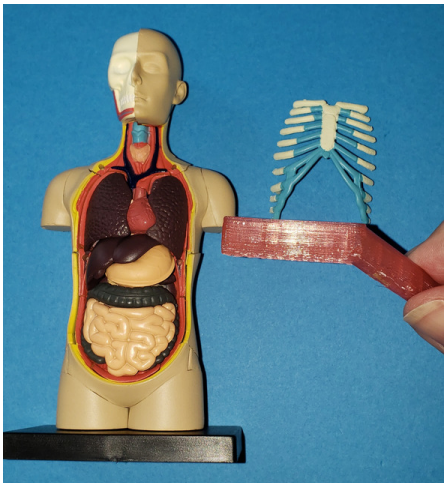
$$\frac{\text{\_\_\_\_\_ mm (maximum print size)}}{\text{\_\_\_\_\_ mm (model rib size)}} = \square$$

# 3D Printing a Rib For Astronauts

## Step Four: Print Your 3-D Model (using da Vinci mini w+)

Once you have your model created on the computer and you know what scale to use while printing, you are ready to print your model! Follow the steps below to print your rib.

- Open the "4th Rib" 3-D model file. You will see your 3-D model in a work space.
- Click on the rib and then click on the scale icon. Change the scale to the percent figured out in the last step.
- Rotate your 3-D model so that it is laying flat on the x-y plane.
- Make sure you are on the "Print" tab. Click on the supports arrow in the lower left and enable supports. Supports are small pieces of plastic that hold the 3-D model in place as you print it.
- Click on the "Prepare" button in the upper left. This allows the printer to figure out the slices that it will print each time it passes over the printer surface and where it is going to place supports.
- Click on the "Print" button in the upper left to print your 3-D model.
- When your model has printed, carefully remove the small plastic supports to see your finished 5th Rib.

## Step Five: Improving Your Ribs

After you have designed and printed a replacement rib, experiment with different ways to improve your rib model. Try the following:

- Improve your rib model by improving the shape to better match the rib on the scale model of a person.
  - You can do this by fixing the model you already created, or starting from scratch and using other shapes and methods in the 3-D modeling software.
- Try measuring, designing and printing several ribs attached to the sternum.
- Try measuring, designing and printing other organs like the lungs or heart. Consider including the major veins and arteries that are attached to these organs.