

# Surgical Solutions

**Program Type:** Classroom Program

**Audience Type:** Grades 3–8

**Description:** Students will develop, build, and test a surgical tool to use in various model medical challenges.

## LEARNING OBJECTIVES

*For Next Generation Science alignment, see end of outline.*

- Students will use the engineering design process to design tools for performing different types of surgery.
- Students will use creative problem solving and the iterative process to improve their designs.

## TIME REQUIRED

**Advance Prep**



1 hour

**Set Up**



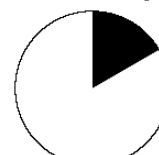
15 minutes

**Activity**



60 minutes

**Clean Up**



10 minutes

## SITE REQUIREMENTS

- One horizontal space (6' × 3') for each group. Desks can be clustered together or students can work on the floor.

## PROGRAM FORMAT

---

### Segment

Introduction  
Design, Test, Improve  
Wrap-Up

### Format

Large group discussion  
Group activity  
Large group discussion

### Time

10 min  
45 min  
5 min

# Preparation

## SUPPLIES

Permanent Supplies	Amount	Notes
Felt fabric or butcher paper	1/group	For body cutouts, approximately 60" × 24"
Scissors	1/group	
Dominoes or blocks	Approx. 8/group	Wooden or plastic, all the same size
Pennies	2/group	
Marbles	1/group	
Metal washers	6/group	Approx.. 3/4" or smaller
Toothpicks	1/group	
Popsicle sticks or dowels	1/group	
String or yarn	8"/group	
Craft foam	1–2 sheets/group	
Magnets	2/group	1/2" diameter or smaller
Thin plastic storage containers	3/group	1- approx. 3" × 6" × 3" 2- approx. 2" × 3" × 2" Must be thin enough to be cut using scissors and/or a razor knife
X-Acto® knife	1	Only used for advance preparation
Sticky tack	1 pack	(Optional) For advance preparation only
Clear disposable plastic cups	1/group	
Opaque disposable paper cup	1/group	
Surgery Design Challenge cards	1 set/group	Templates in the <i>Appendix</i>
Laminated organ images	6/group	Found in the <i>Appendix</i>
<i>Meet a Scientist Video – Nancy Yen Shipley</i>	1	(Optional) Found on USB flash drive provided with manual and website listed in <i>Advanced Prep</i>
Computer with screen and internet connection	1	(Optional) To show videos
Velcro	6 pieces/group	(Optional) To secure organs to body cut out

Suggested Building Materials	Amount
Paper clips	12/group
Wooden craft sticks	12/group
Rubber bands	12/group
Binder clips	12/group
Paper straws	4/group
Yarn	4 ft. length/group
Cardboard or Tack board	4/group
Pipe cleaners	8/group
Wooden skewers	8/group
Aluminum foil	6" × 8" sheet/group
Craft foam	5–6 sheets
Play dough	1 small piece/group
Twist ties	4/group
Magnets	1/group
Sticky tack	1 small piece/group

**Note on Activity Set-Up Option:** This activity can be easily adapted to “rotation stations.” If your group size is small or if you have minimal materials, this option may be a good choice. In this case, you will only need to build one of each type of model challenge (one for each station). When gathering permanent and suggested supplies from the lists above, you will need 5–6 felt or paper body outlines (one for each station) and only one set of the rest of the materials. These will then be distributed to each station rather than having all of the model challenges occurring with each group.

## ADVANCE PREPARATION

### Videos

- Prepare the projector and computer to show one or more of the following videos:
  - *Meet a Scientist Video – Nancy Yen Shipley* found on the USB flash drive provided with this manual (if applicable), or at <https://vimeo.com/296710292/3257a06d06>
  - YouTube – Michigan Engineering - “FlexDex: A Revolutionary Surgical Tool” <https://www.youtube.com/watch?v=x6WI4MFEXeY> (Duration 4:40).

## Body Outlines

- Trace and cut out one human body shape from each piece of felt or butcher paper (approximately 60" × 24"). You can trace a friend (or yourself) as a model for the felt cut-out.



Figure 1: Shape suggestion for felt human body outline

## Organ Cutouts

- Print, cut out, and laminate images of individual organs for each group. Images can be found in the *Appendix* section. Add a small piece of Velcro to the back of each laminated image to hold it in place on top of the body cut out.

## Surgery Design Challenge cards

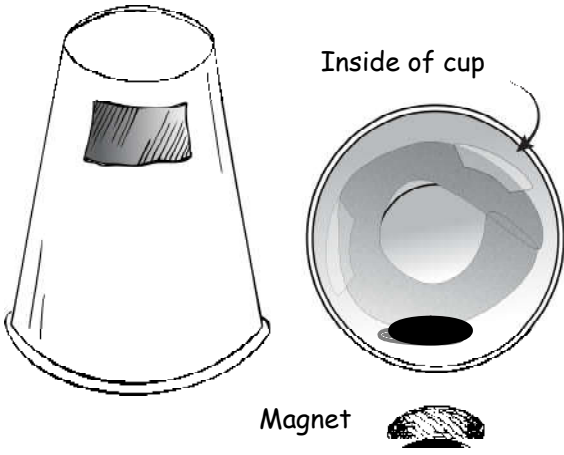
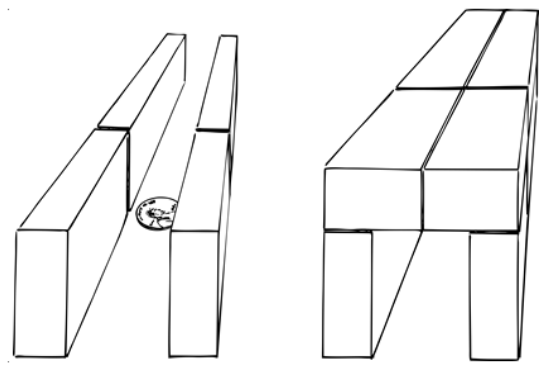
- Print and cut out a set of the Surgery Design Challenge cards for each group. Laminating the cards makes them easier to reuse.

## Model Surgery Challenges

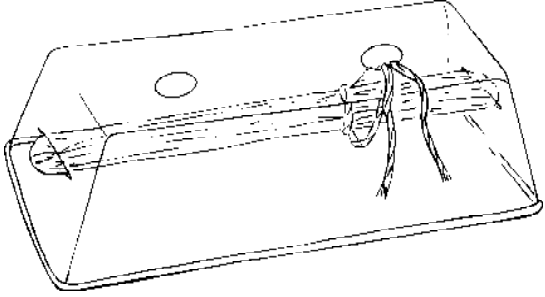
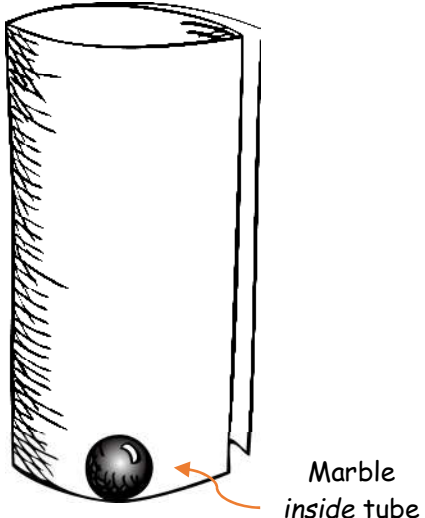
- Use the table below and assemble one of each of the surgery challenges for each group. (Or, if you are doing rotation stations, assemble one challenge per station). The obstacles shown are just examples; you can alter them depending on what materials you have. Feel free to choose which ones to do, as some may be too difficult or too simple for your students.

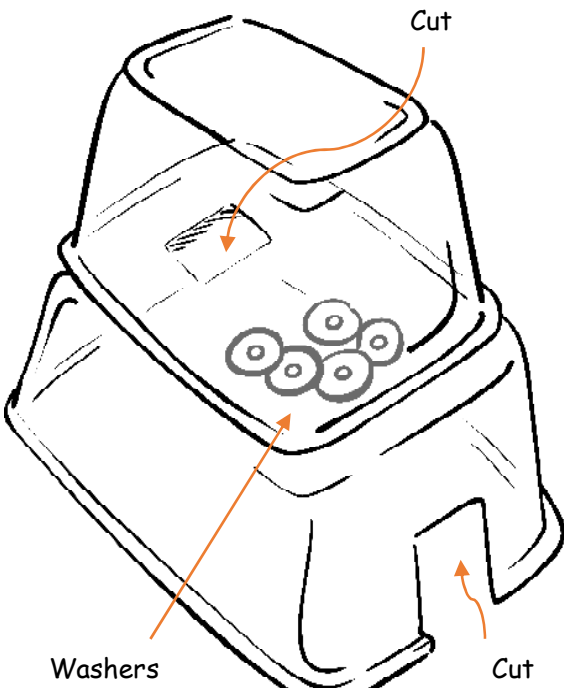
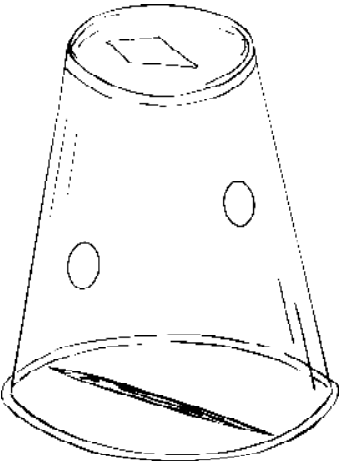
Model Surgery Challenge	Goal and Instructions	Difficulty (out of 5)
-------------------------	-----------------------	-----------------------

# Preparation

<p><b>Remove a Kidney Stone</b></p> 	<p><b>Goal: create a tool to pull the magnet out through both holes.</b></p> <ul style="list-style-type: none"> <li>• Cut a hole on the side near the base of an opaque paper cup</li> <li>• Cut a 1" round hole in a piece of craft foam</li> <li>• Fold and insert the foam in the cup below the first hole and tape it in to make the cup opening smaller</li> <li>• Place the cup over a small magnet</li> </ul>	<p>★★</p>
<p><b>Place a Patch on a Lung</b></p> 	<p><b>Goal: place a penny on top of another without disturbing the blocks.</b></p> <ul style="list-style-type: none"> <li>• Place four small wooden blocks in two parallel rows</li> <li>• Place a penny in the middle</li> <li>• Glue together four blocks to place across the top to create a tunnel</li> </ul>	<p>★★</p>
<p><b>Model Surgery Challenge</b></p>	<p><b>Goal and Instructions</b></p>	<p><b>Difficulty (out of 5)</b></p>

# Preparation

<p><b>Tie-off an Artery in the Heart</b></p> 	<p><b>Goal: tie the string in a knot around the wooden craft stick using only tools and the top two holes to reach inside.</b></p> <ul style="list-style-type: none"> <li>• Cut two slits on the side of a clear rectangular container slightly shorter than a wooden craft stick</li> <li>• Cut two 1/2" holes at the base of the container</li> <li>• Cut a piece of string 8" long</li> <li>• Insert the wooden stick horizontally through the side slits and place the container face down</li> </ul>	<p>★★★★★</p> <p><i>This challenge is particularly difficult. Consider saving it as a bonus!</i></p>
<p><b>Remove a Brain Tumor</b></p> 	<p><b>Goal: remove the marble without knocking the tube over.</b></p> <ul style="list-style-type: none"> <li>• Roll a tube of craft foam 6" tall and 1 1/2" in diameter and seal it with hot glue (alternatively, you may use a paper towel tube)</li> <li>• Balance the tube vertically so there is only one opening facing up and place a marble inside</li> </ul>	<p>★★★</p>
<p><b>Model Surgery Challenge</b></p>	<p><b>Goal and Instructions</b></p>	<p><b>Difficulty (out of 5)</b></p>

<p><b>Remove Objects from Stomach</b></p> 	<p><b>Goal: build a tool that can remove the washers through both holes without lifting the plastic containers.</b></p> <ul style="list-style-type: none"> <li>Stack a smaller rectangular plastic container on top of a larger rectangular one. Glue the rim of the small one to the base of the large one</li> <li>Cut a passage to the small container through the base of the large container</li> <li>Cut a 1" square notch from the lip of the large container on the side opposite the hole in the base</li> <li>Insert a few metal washers into the small container and then invert them</li> </ul>	<p>★★★</p>
<p><b>Remove a Shard of Bone from a Leg</b></p> 	<p><b>Goal: remove the toothpick through the holes in the cup.</b></p> <ul style="list-style-type: none"> <li>Cut three 1/2" holes in a clear plastic cup: one on the base and two on the sides mid-way up</li> <li>Place cup upside down over a toothpick</li> </ul>	<p>★★★★</p>

## SET UP

Provide to each student group:



# Preparation

---

- A felt body shape outline
- Six laminated organs
- Six obstacles
- One set of the Surgery Design Challenge cards
- Building supply kits
- A table large enough to accommodate the entire length of the felt body; otherwise, students can work on the floor

## Set up instructions:

- Place the body outline on the table. If necessary, secure the felt bodies to the floor or table
- Place organs in their respective places on the felt body
- Place the model surgery challenges on the appropriate organs. Use Velcro® and/or sticky tack to secure them to the laminated organs

## INTRODUCTION

10 minutes

*Let students speculate before offering answers. The answers given are primarily for the instructor's benefit.*

Suggested script is **shaded**. Important points or questions are in **bold**. Possible answers are shown in *italics*

Welcome! Today we are going to be designing tools for doctors that will help save people's lives. We'll be making tools that can help make surgery safer.

**Can you think of some tools that doctors use when they do surgery?**

*Knives, scalpels, scissors, tweezers, cameras.*

Not very long ago, doctors didn't have a lot of surgical tools. They had to make really big holes when they cut people open, and sometimes other organs and muscles would get hurt. That meant that surgery could be dangerous and it took a long time to recover from it.

Engineers called biomedical engineers work with doctors to develop tools that make surgery safer. One of the big changes that has made surgery safer is the invention of tools and special tiny cameras that allow doctors to see and perform surgery through very small holes in the body, which is a lot less dangerous than having to cut somebody wide open. But if a surgical hole is small, like only half an inch wide, you need to have tools that will fit inside and can be moved around remotely.

*(Optional)* Show video(s) highlighting the use of specialized tools in surgery:

- *Meet a Scientist Video – Nancy Yen Shipley*
- YouTube – Michigan Engineering - "FlexDex: A Revolutionary Surgical Tool"

Today we will be biomedical engineers designing tools that can be used to do operations on a human.

Hold up the felt body outline. Then hold up each organ as you introduce it.

We have six model surgery challenges for you that represent different types of surgery. In one of the challenges, you'll have to remove a tumor from the brain. A tumor is tissue inside the body that is growing where it shouldn't be. In other challenges, you'll need to take out other things out, like metal from a stomach that someone swallowed by accident, a shard of bone from a broken leg, or a kidney stone. But then there are other

challenges where you have to put things *inside* the body in just the right way. In one, you'll need to put a patch on the breathing tube that leads to the lungs. In another one you will need to make a knot around an artery in the heart.

Hold up the surgery challenge cards.

These challenge cards explain what the goal of each surgery is. You will need to read the cards very carefully to understand exactly what type of tool you will need to design for a successful surgery.

## GROUP ACTIVITY

## Design, Test, Improve

45 minutes

Divide the class into groups of 3–5 students. Groups should sit at their previously set up “operating room” workspace (either a large table or the floor). Let each student choose or draw a Surgery Design Challenge card.

Give students a moment to orient themselves to the body and where their organ/model surgery challenge is located. Encourage them to help one another and remind them that they are all sharing the same “person.”

### **What are some things we'll have to be careful about when trying out our tools?**

*We can't bump, shake, or move the body or the obstacle. The tool is the only thing that can go inside, no fingers.*

### **Is it okay to use neighbors' ideas?**

*Yes! Engineers rely on other engineers to continue inspiring new ideas while developing their own.*

Hand out a container of building materials to each group.

Use these materials to design your surgical tool. Think carefully about the challenge and observe the model carefully before you start designing your tool.

You can instruct groups to work on one challenge at a time together, or have each group member work on their own challenge separately.

When you've designed your tool, go ahead and test it on your surgery challenge. Call me over to your group when you've successfully tested your tool so you can share how your design works. Remember, you are

designing your tool for a surgeon, so it should be easy for others to use. I will try out some of your tools to see how easy they are for others to use.

As you try out students' tools, give them specific feedback on how well their design works, and suggest how they could improve it to make it easier for you to use.

### WRAP-UP

5 minutes

*Ask for student observations. There is no correct answer. Allow students to guide the discussion.*

**Tell us about your design.**

**Is there anything you had to change to make the tool work well?**

**Which challenge was hardest to complete?**

**What would you do differently if you had more time?**

If time allows, ask the groups to share their designs, either as a whole-class showcase or by partnering with another group.

**Were all of the designs similar, or very different?**

### CLEAN UP

10 minutes

- Collect the laminated body part images, Challenge cards, obstacles, unused building supplies, and body outlines for future use
- Ensure play dough is returned to an airtight container for re-use

## OPTIONAL EXTENSIONS

- Draw your ideal surgical tool that you envision would work best. How does it differ from the design your group came up with? What extra materials would you need to construct it?
- Try using the surgical tool while watching through a cell phone camera, similar to how surgeons perform a type of surgery called endoscopic surgery. Is it more difficult now to use your tool?
- Try to make one tool that can complete all challenges as quickly as possible

### BACKGROUND INFORMATION

Bioengineers apply the principles of engineering to solve problems related to health and medicine. Bioengineers develop all kinds of products and devices, including drugs and drug delivery systems, prosthetics, mobility devices, surgical tools, and more. Many of the products we take for granted—like contact lenses or thermometers—were once new biomedical innovations.

Surgery is one area where biomedical engineering has made a particularly significant contribution. The earliest surgeries in history were performed without anesthesia, and with relatively imprecise tools that made large wounds, which were susceptible to infection and tissue damage. The development of anesthesia in the mid-1800s and antibiotics in the early 1900s dramatically reduced surgical mortality and made many more kinds of surgery feasible. The last 100 years has seen amazing innovations in surgery, including:

- Laser surgery – Lasers can make finer—and therefore more precise—cuts than even the smallest razor. As such, they are often used in eye surgery.
- Robot-assisted surgery – Robots are used in a variety of surgical applications. The da Vinci robotic surgical system, for example, can assist in prostate surgery and coronary artery bypass.
- Laparoscopic surgery – Instead of cutting the patient wide open to access internal tissue, the surgeon makes a small hole and performs the work by inserting long, flexible tools into the hole.
- Endoscopic surgery - Instead of cutting a hole, the surgeon enters the body through an existing opening, like the nostril.
- Computer-assisted surgery – Often used in conjunction with laparoscopic or endoscopic surgery, the surgeon inserts a tiny camera, which can be snaked around inside the body to better view the surgical site.

## GLOSSARY

<b>Endoscopic surgery</b>	A type of surgery in which very small incisions are made and tools are inserted into the body through those incisions
<b>Surgery</b>	The treatment of injuries or disorders of the body by incision or manipulation, especially with instruments.
<b>Tumor</b>	Abnormal growth of cells, which may be cancerous

## NEXT GENERATION SCIENCE STANDARDS

	<b>Practices</b>
✓	Asking questions and defining problems
	Developing and using models
✓	Planning and carrying out investigations
	Analyzing and interpreting data
	Using mathematics and computational thinking
✓	Constructing explanations and designing solutions
	Engaging in argument from evidence
	Obtaining, evaluating, and communicating information

	<b>Crosscutting Concepts</b>
	Patterns
✓	Cause and effect
	Scale, proportion, and quantity
	Systems and system models
	Energy and matter
✓	Structure and function
	Stability and change

	<b>Disciplinary Core Idea</b>	<b>3</b>	<b>4</b>	<b>5</b>	<b>MS</b>
<b>Physical Science</b>					
PS1	Matter and Its Interaction	n/a	n/a		
PS2	Motion and Stability: Forces and Interactions		n/a		
PS3	Energy	n/a			
PS4	Waves and Their Applications in Technologies for Information Transfer	n/a		n/a	
<b>Life Science</b>					
LS1	From molecules to organisms: Structures and processes				
LS2	Ecosystems: Interactions, Energy, and Dynamics		n/a		
LS3	Heredity: Inheritance and Variation of Traits		n/a	n/a	

LS4	Biological Evolution: Unity and Diversity		n/a	n/a	
<b>Earth &amp; Space Science</b>					
ESS1	Earth's Place in the Universe	n/a			
ESS2	Earth's Systems				
ESS3	Earth and Human Activity				
<b>Engineering, Technology, and Applications of Science</b>					
ETS1	Engineering Design	✓	✓	✓	✓

### **DCI Grade Band Endpoints**

#### **3-5 ETS1.A: Defining and Delimiting Engineering Problems**

- Possible solutions to a problem are limited by available materials and resources (constraints). The success of a designed solution is determined by considering the desired features of a solution (criteria). Different proposals for solutions can be compared on the basis of how well each one meets the specified criteria for success or how well each takes the constraints into account. (By the end of Grade 5)

#### **3-5 ETS1.B: Developing Possible Solutions**

- Research on a problem should be carried out before beginning to design a solution. Testing a solution involves investigating how well it performs under a range of likely conditions. (By the end of Grade 5)
- At whatever stage, communicating with peers about proposed solutions is an important part of the design process, and shared ideas can lead to improved designs. (By the end of Grade 5)
- Tests are often designed to identify failure points or difficulties, which suggest the elements of the design that need to be improved. (By the end of Grade 5)

#### **3-5 ETS1.C: Optimizing the Design Solution**

- Different solutions need to be tested in order to determine which of them best solves the problem, given the criteria and the constraints. (By the end of Grade 5)

#### **MS ETS1.A: Defining and Delimiting Engineering Problems**

- The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions. (By the end of Grade 8)

#### **MS ETS1.B: Developing Possible Solutions**

- A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. (By the end of Grade 8)
- There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. (By the end of Grade 8)



- Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. (By the end of Grade 8)
- Models of all kinds are important for testing solutions. (By the end of Grade 8)

**MS ETS1.C: Optimizing the Design Solution**

- Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. (By the end of Grade 8)
- The iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. (By the end of Grade 8)

**Performance Expectations**

<b>3-5-ETS1-1</b>	Define a simple design problem reflecting a need or a want that includes specified criteria for success and constraints on materials, time, or cost.
<b>3-5-ETS1-2</b>	Generate and compare multiple possible solutions to a problem based on how well each is likely to meet the criteria and constraints of the problem.
<b>3-5-ETS1-3</b>	Plan and carry out fair tests in which variables are controlled and failure points are considered to identify aspects of a model or prototype that can be improved.
<b>MS-ETS1-1</b>	Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.
<b>MS-ETS1-2</b>	Evaluate competing design solutions using a systematic process to determine how well they meet the criteria and constraints of the problem.

# **Surgical Solutions** **Appendix**

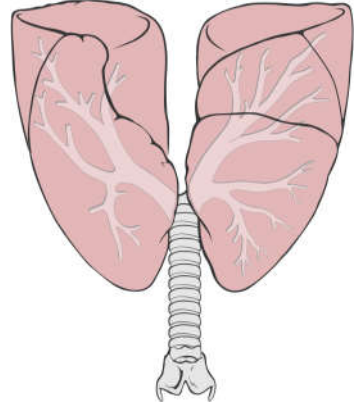


**SURGERY  
DESIGN  
CHALLENGE**

**SURGERY  
DESIGN  
CHALLENGE**

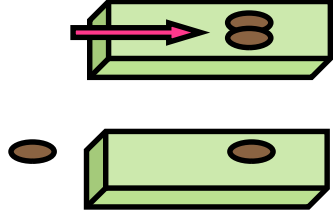
**SURGERY  
DESIGN  
CHALLENGE**

**SURGERY  
DESIGN  
CHALLENGE**



**Lung Patch**

...to place a patch  
on the lungs.

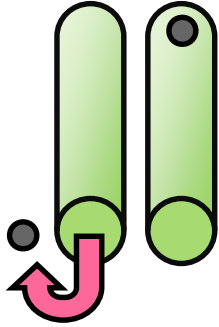


*Design a tool...*



**Brain Tumor**

...to remove a tumor  
from the brain.

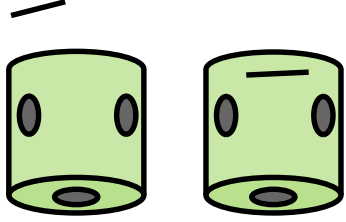


*Design a tool...*

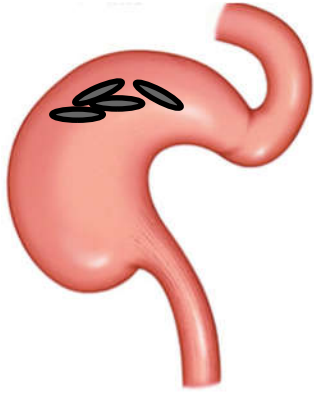


**Bone Shard**

...to remove a shard of bone  
from a broken leg.

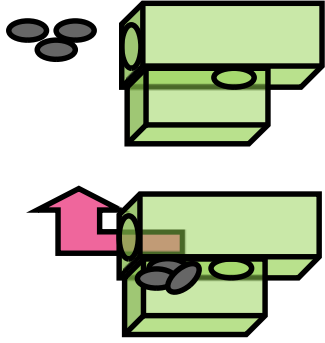


*Design a tool...*



**Stomach  
Surgery**

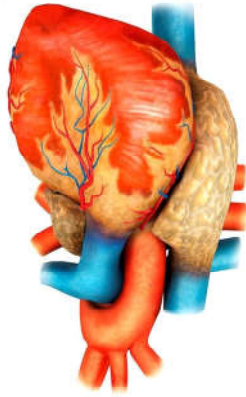
...to take the items  
out of the stomach.



*Design a tool...*

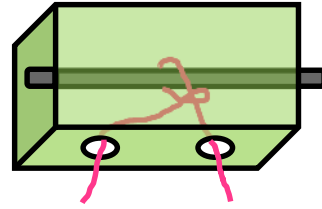
**SURGERY  
DESIGN  
CHALLENGE**

**SURGERY  
DESIGN  
CHALLENGE**

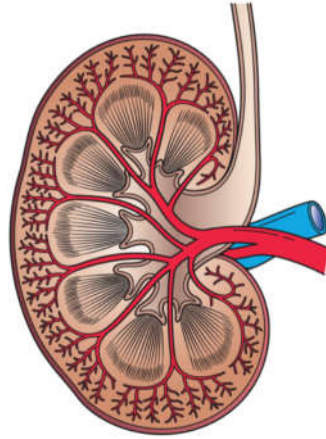


**Heart Artery**

...to tie off a blood vessel  
in the heart.

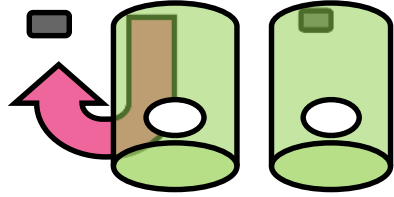


*Design a tool...*



**Kidney Stone**

...to remove  
a kidney stone.



*Design a tool...*

**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**

**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**

**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**

**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**

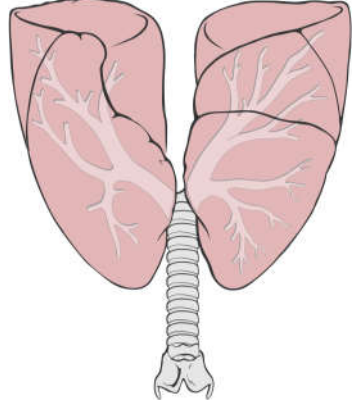
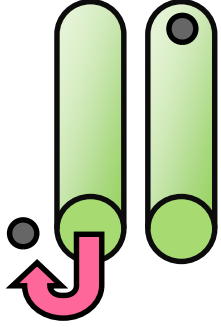




**Tumor cerebral**

*Diseña una herramienta...*

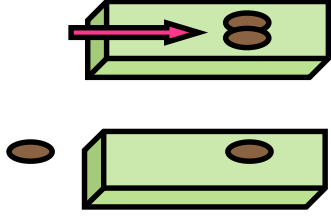
...para sacar el tumor del cerebro.



**Parque pulmonar**

*Diseña una herramienta...*

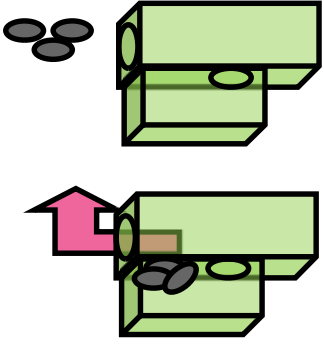
...que coloque un parche sobre la lesión pulmonar.



**Cirugía estomacal**

*Diseña una herramienta...*

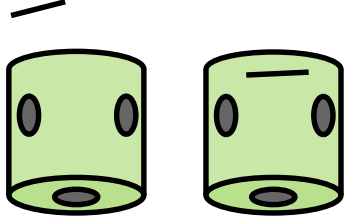
...para sacar los objetos del estomago.



**Hueso fragmentado**

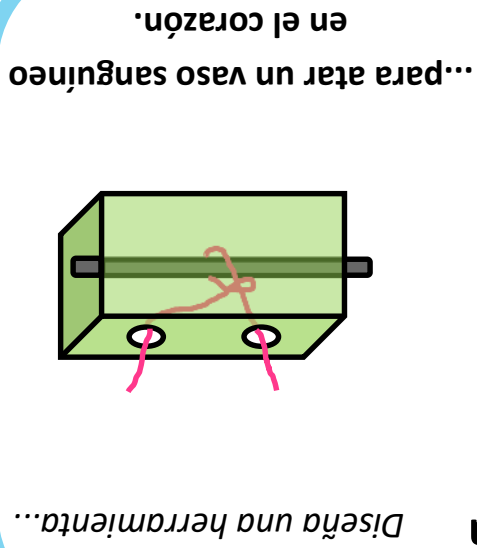
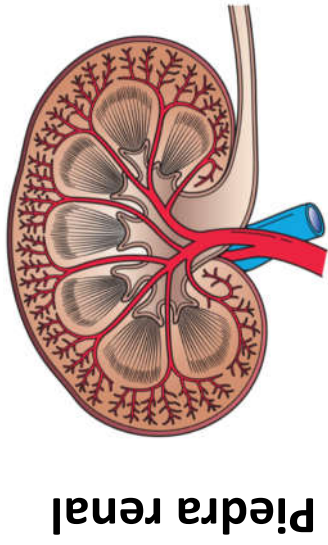
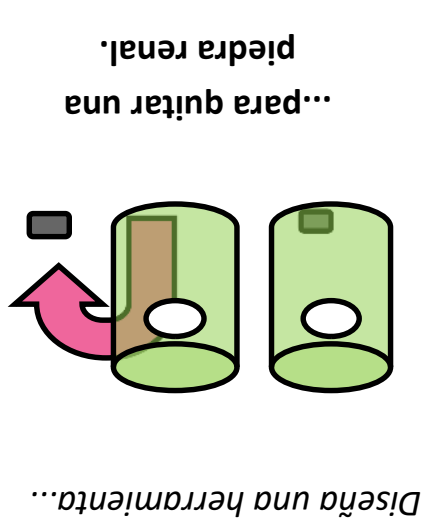
*Diseña una herramienta...*

...para quitar un fragmento de hueso de una pierna herida.

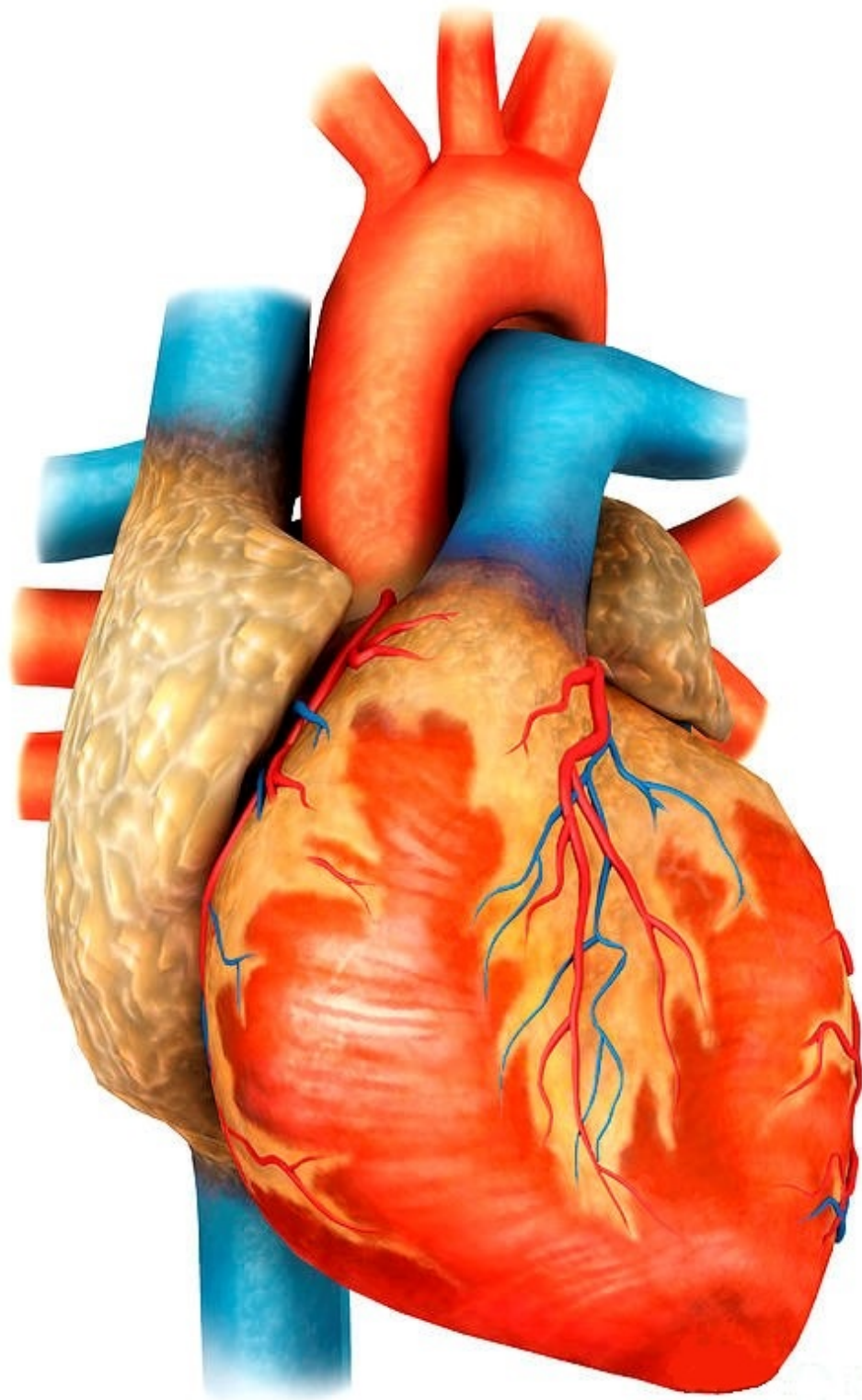


**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**

**DESAFÍO  
DE DISEÑO  
QUIRÚRGICO**



### Arteria cardíaca



www.123rf.com



