# Table of Contents

## Overview
- Parts List -- For Each Gameboard 4
- Parts List -- To Share 5
- Suggested Materials 7

## How It Works
- How It Works 8

## Build the Box
- Prepare the Game Board 10
- Draw the Design 10

## Create the Circuit
- Attach Foil Inside the Box 13
- Attach the Motor and/or the Buzzer Inside the Box 15
- Attach the LED to the Inside and Outside Foil 17
- Attach the Tweezers and Battery 19

## Make the Board Playable
- Draw the Design 20
- Cut Out the Openings 21

## Finish and Play!
- Make the Game Pieces 25
- How to Play 25
- Troubleshooting Tips 26
In the classic board game Operation, players must remove organs from their "patient" without setting off a buzzing, flashing alarm. The inventor, John Spinello (https://adafru.it/K6C), got the idea from a childhood memory of sticking a safety-pin into a light socket -- although getting shocked when you make a false move has always been part of the fun!

There are a lot of DIY versions of the game Operation (including a really cute Adabot Operation game (https://adafru.it/FsO) that uses the Adafruit Circuit Playground Express). But to try out this project with a group of middle-schoolers studying anatomy, I came up with a low-tech, low-cost version so every student could make their own.

This version uses mainly everyday household and recycled materials, and it's easy for kids to build themselves. There's no programming involved -- just a simple paper circuit, basic components, and 3V coin battery for power.
Your game needs an LED to light up. I like the big gum-drop style, which also have nice long leads for connecting to the circuit.

To make a noise, you can use either a vibrating mini motor disc -- which provides a low hum as well as some haptic feedback -- or a tiny buzzer, which is much louder and squeakier. For the example shown, here, I used both, which created a nice two-tone effect (and toned-down some of the buzzer’s squeakiness).

**Diffused 10mm LED Pack - 5 LEDs each in 5 Colors - 25 Pack**
Need some chunky indicators? We are big fans of these diffused LEDs. They are fairly bright, so they can be seen in daytime, and from any angle. They go easily into a breadboard and...
[https://www.adafruit.com/product/4204](https://www.adafruit.com/product/4204)

**Vibrating Mini Motor Disc**
*BZZZZZZZZZZZ* Feel that? That's your little buzzing motor, and for any haptic feedback project you'll want to pick up a few of them. These vibe motors are tiny discs,...
Hey want to hear a really loud noise? Apply 3V to 5V to this buzzer module and you'll be rewarded with a loud 2KHz BEEEEEEEEEEEEE. Unlike a [https://www.adafruit.com/product/1536](https://www.adafruit.com/product/1536)

CR2032 Lithium Coin Cell Battery
A perfect match for our sew-able coin cell holder. This non-rechargeable coin cell is CR2032 sized: 20mm diameter, 3.2mm thick. It...

Parts List -- To Share

Conductive tape lets you make a good connection between the components and the foil circuit. While I really love fabric conductive tape for most applications, I chose the copper foil tape for this one because it can be squeezed down more tightly against the foil.

Stranded wire will endure more bending and twisting than solid-core. You only need one or two 25-foot rolls for an entire class, but it's nice to have a color selection!

The ceramic knife is a safer alternative to a regular craft blade, so kids can cut out their own gameboard openings. It's less likely to nick the skin, but it's still sharp, so caution is always advised!

Along with the pack of LEDs, above, these items contain enough material for 25-30 individual gameboards. Keep whatever's left on hand for use with other projects.
Copper Foil Tape with Conductive Adhesive - 6mm x 15 meter roll
Copper tape can be an interesting addition to your toolbox. The tape itself is made of thin pure copper so it's extremely flexible and can take on nearly any shape. You can easily...
https://www.adafruit.com/product/1128

Hook-up Wire Spool Set - 22AWG Stranded-Core - 10 x 25ft
This is a box of ten 25ft spools of stranded-core wire. Stranded-core wire is best used for wiring jigs where...
https://www.adafruit.com/product/3175

Slice Craft Knife with Ceramic Blade
Cut through materials like a boss with the elegant Slice Craft Knife, a safer cutter with a ceramic blade. This ergonomic...
https://www.adafruit.com/product/4306

Hakko Professional Quality 20-30 AWG Wire Strippers
These are the finest wire strippers we have used, and if you have to do a lot of wiring, you will agree! They have soft rounded grips - very comfortable to use, and precision ground...
https://www.adafruit.com/product/527
If you can't order the parts you need at the present time, you can use aluminum foil and/or aluminum foil tape instead of copper foil tape. LEDs can be salvaged from light strands, tea lights, or old toys or devices. You may also be able to find a small vibrating motor in an old disposable toothbrush or pager.

Suggested Materials

In addition to the parts above, you will need:

- thin, smooth-sided cardboard box (such as an empty cereal, cracker, or cake mix box)
- glue stick (or spray-on glue)
- heavy paper, such as construction paper or cardstock
- markers or other drawing tools
- aluminum foil (regular kitchen foil is fine)
- aluminum foil tape (found with heating duct supplies -- or just glue regular foil down)
- metal tweezers (look in the dollar store, or in a pinch, make your own by bending a thin strip of cardboard in half and cover with foil)
- small binder clip

How It Works
How It Works

The basis of Operation is a simple circuit with an LED, a vibrating motor, and a buzzer. When you close the circuit, the components do their thing.

However, for kids who are not used to working with circuits, it's a little hard to picture what's going on. The sample circuit here makes it a little clearer:

**Educators: Make a sample board like this, and/or a cutaway box, so students can see both the inside and outside of the circuit at the same time. It helps them visualize what's going on!**
• All the positive wires, or leads, of the components are connected to one piece of foil -- in this case, on the right side of the sample.
• All the negative leads are connected to a second piece of foil on the left.
• One end of the wire is connected to the positive side of the battery.
• The other end is connected to the metal tweezers (represented here by a blob of foil).
• The negative side of the battery is attached to the negative piece of foil.
• When you touch the "tweezers" to the positive piece of foil, the wire closes the circuit and zzzzzzap!

The gameboard works the same way -- but in that case, the positive piece of foil is attached to the inside of the box, and the negative piece of foil is attached to the outside of the box.

To connect them and close the circuit, you touch the tweezer wire to the inside foil where it comes up through the openings in the top of the box.

It's a little convoluted, but it works!
Build the Box

Prepare the Game Board

Close any open flaps and tape them down.

To make the top of the game board, you first need to cover the front of the box with construction paper. This is where you'll draw your design later.

Take a piece of construction paper and trace around the box. Cut out the paper. Use the glue stick to apply glue all around the front of the box, near the edges.

Attach the paper, lining up the edges and smoothing it down where needed.

Next, flip the box over. Draw a line around the sides of the box, near the back. You will use the back of the box later, and it helps to have a tiny bit of the sides still attached.

Cut along the line, leaving some of the flap attached. Trim the extra flap piece to make a tab you can pull if you need to open up the gameboard after it's all put together.

Set the back of the box aside for now. You will use it later as the bottom of the game board openings.

Draw the Design

Educators: If you want students to do the whole project in one session, skip to the next page, Create the Circuit, then come back to the instructions here for
Traditionally, the Operation gameboard features an unclothed surgical patient. After giving it some thought, I decided to give my students other ideas to draw.

For inspiration, I provided diagrams of specific bodily systems. Students could make games where you do open-heart surgery, dissect a brain, or even extract teeth from a patient's mouth!

You don't even need to stick to a medical theme. Some DIY boards use robots and vintage cars. The prototype depicted in this guide is a beehive, and requires players to remove all the bees to get to the honey. And it's OK to be completely non-literal, too.

The gameboard's circuit is designed to allow you to make openings anywhere (and even add openings after its finished). So let your imagination run wild!

how to Draw the Design.

Students can continue to work on their drawing after the class is over without needing any additional materials, except for scissors or a blade to cut the openings.
The only guidelines to keep in mind as you draw involve the openings you will cut into the gameboard:

- Make the openings big enough. The body parts (or other items) you are going to make need to fit inside. And players need to be able to reach in with the tweezers without setting off the buzzer. Leave extra room around each opening in your drawing so you can make it bigger if you need to.
- Space the openings around the drawing, to avoid wear and tear on any one section of the gameboard.
- Don't place the openings too close to the edge of the box.
Create the Circuit

Attach Foil Inside the Box

Cut foil to fit inside the box. (In the example here, I tried snipping off one corner so the motor would connect directly to the cardboard. It's probably not necessary.)

Apply glue stick around edges. Attach foil, smoothing as you go.

On the outside of the box, where you want to place the LED, attach a strip of foil tape at least 3 inches long and a little less than the height of the box (or just glue on a strip of kitchen foil).
Attach the Motor and/or the Buzzer Inside the Box

For the motor: Strip the ends of its wires. The red wire is positive, but with the motor it doesn't really matter which way you connect them.

Attach the motor to the inside of the box, near the outside foil. Play around with ways to let the motor vibrate as much as possible. In this example, I fastened the wires near the motor to the box with clear tape, but left the motor hanging loose.

Use copper foil tape to attach the stripped end of one wire to the foil.

Use a jumbo push pin to poke a hole through the side of the box near the motor. Thread the other wire through to the outside of the box.

For the buzzer: Carefully bend the wires out to the sides. Poke a hole for the buzzer wire with the push pin. Position the buzzer with the negative wire sticking out through the hole. Use copper foil tape to attach the positive wire to the foil inside the box.

For both: Use the copper foil tape to connect the outside wire to the outside piece of foil.
For the circuit to work, make sure "metal touches metal" -- the metal part of the wire should touch the foil and the foil tape (or the conductive glue on the copper foil tape).

For extra security, you can add a piece of clear tape on top.
Attach the LED to the Inside and Outside Foil

Position the LED near the outside foil.

Poke a hole through the top of the box and insert the longer wire (positive lead).

Bend the lead so it touches the inside foil. Secure with copper tape.

Attach the shorter wire (negative lead) to the outside foil with copper tape.
Attach the Tweezers and Battery

Cut a piece of wire about 12" long. Strip the ends.

Connect one end to the positive (+) side of the battery with copper tape.

Connect the other end to the tweezer with copper tape.

Use CLEAR tape to attach the battery to the outside foil, positive side out. Insulate the rest of the outside foil and wires with clear tape.

For a better connection, use a binder clip to hold the battery tightly against the foil.

STOP AND TEST YOUR CIRCUIT! Touch tweezers to foil around the edge of the holes to make sure they all work. If needed, add more foil or use copper foil tape.
Make the Board Playable

Draw the Design

If you haven't already, draw your design on the construction paper. (See Build the Box for tips.)

Draw the openings, making sure they're big enough to get the body parts (or other game pieces you choose to make) in and out of the opening.
Cut Out the Openings

Cut the Foil
With the push pin, punch 4-6 holes around the openings.

On the foil side, cut across the openings in an X shape.

Fold the foil out of the way.
Remove the binder clip before doing this step so you don't accidentally short-circuit your gameboard! I neglected to do that in these photos.
Cut the Cardboard
Cut out the cardboard holes. Save the cut-out piece to help you measure the game pieces that fit in the openings!

Fold the foil back up through the opening to the outside. Scrunch it up around the edges.

Add additional foil or foil tape if needed.
Make the Sides and Bottom of the Openings
Cut a strip of construction paper or cardstock to fit around each opening and tape into a loop.

Tape the loops around each opening on the foil side.

Add extra loops around the edges to support the bottom of the box.

Insert the bottom of box back into the box until it rests on the loops.

The binder clip should be outside the box bottom.
Educators: To save time with a group, cut the cardstock strips for the sides of the openings beforehand. Make them all the same width so the bottom of the box rests evenly on them.

Finish and Play!

Make the Game Pieces

Trace around the openings you cut out onto a foam plate.

Draw game pieces to fit through the openings. Color if you want, then cut them out.

STOP AND TEST: Make sure you are able to remove the pieces with the tweezers. Adjust as needed.

When everything is working, you’re ready to play!

How to Play

See how many game pieces you can remove from the openings without setting off the buzzer and light!

You can play by yourself against the clock to see how fast you can clear the board.

With other players, each player keeps going until the buzzer sounds. Then switch turns to the next person. See who can collect the most pieces by the end of the game!
Troubleshooting Tips

- If the LED, the buzzer, or the motor don't work, check that they are connected firmly to the foil.
- If just the LED or just the buzzer doesn’t work, check that it is not in backwards. The motor will work no matter which way around you connect it.
- If nothing works, check that the battery is firmly connected to the outside foil. Also check that the wire is firmly connected to the top of the battery.
- If one of the openings doesn't work, add more foil around the edge.