Building Instructions
for Synthetic Abdominal Cavity Simulator

1. **Make the synthetic intestine** by either using either a latex sheet or used bicycle tire tubes.

A. If using a latex sheet:

Lay a portion of the 10-yard, 0.02-in thick, 6-in wide latex rubber sheet lengthwise on a long table; drape the remaining sheet off the table and onto the floor. Squirt a continuous bead of super glue along one edge of the latex. Place a 1.5-in to 2 -in PVC pipe lengthwise on top of the latex sheet (Figure 1-left).Adhere opposing edges of the latex by loosely wrapping the pipe with the latex and overlapping the opposing edges. Use the pipe to apply uniform pressure to the newly adhered seam. Apply pressure along the seam with the pipe for about 30 seconds (Figure 1-middle).Wait 5 minutes for the seam to fully cure, then remove the pipe. Repeat the procedure for the entire length of the latex sheet (Figure 1-right). Cut the tubing into shorter sections for easier filling, with lengths varying between 1 to 4 ft. Varied lengths create a more realistic environment of rough terrain in the abdomen.

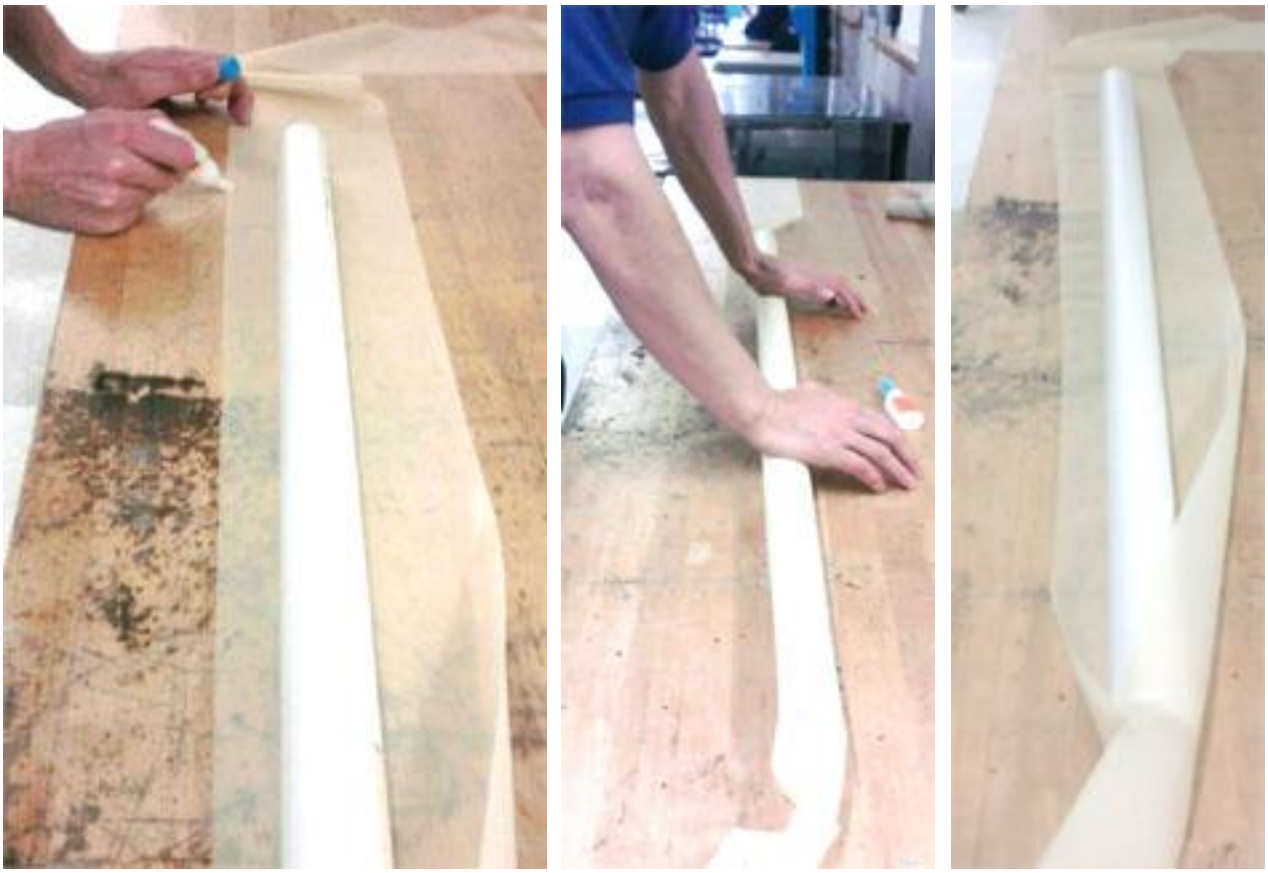

Figure 1. (left) Apply adhesive to latex sheet edge. (middle) Wrap sheet around 1.5 to 2-inch diameter PVC pipe to adhere latex sheet edges. (right) Remove PVC pipe from the sealed latex tube and continue adhering edges of latex sheet.

B. If using used bicycle tubes:

Locate the hole of the used bicycle tube and cut out this part of the tube. Inspect the tube for any other damage and cut damaged portions out of the tube. Cut the tubing into shorter sections for easier filling, with lengths varying between 1 to 4 feet. Varied lengths allows for a more realistic environment of rough terrain in the abdomen.

2. Make silly putty to fill the synthetic intestine.

Add 2 cups warm water to 2 cups Elmer's glue in a plastic container and stir until well mixed. Make sure the solution has a uniform consistency or the silly putty takes longer to form.

In a separate container, make the borax solution: Add 2 teaspoons borax to 1 cup warm water and stir until borax is dissolved.

Add borax solution to water and glue mixture. Stir and mix by hand until mixture forms consistency of silly putty and no water is left in the container.

Fill the latex tubes (or bicycle tubes) with the silly putty mixture, piece-by-piece (Figure 2-left), and knead the putty into the latex (or bicycle) tube (Figure 2-right) until the entire tube is filled. Make sure that air gaps do not form or remain in the tube. Close one of the open end of a tube with a zip tie, make sure that the entire tube is filled with silly putty and then close the other open end of the tube with another zip tie. *Optional for latex tubing:* Line the seam of the tube with duct tape to prevent students from opening this seam with their devices.

Figure 2. Use your hands to push and knead the silly putty mixture into the latex tubes.

3. Build the abdominal cavity.

Build the abdominal cavity so it looks like the Figure 3 diagram. Use 1½-in wood screws to fasten the 1 x 2-in boards to each other, forming a 2 x 4-ft rectangle. Use ½-in wood screws to fasten the rectangle to the ¼-in plywood. Drill two 5/64-in holes in the ends of the 3-ft long aluminum strips. Using a 1/16-in drill bit, pre-drill the rectangle boards at the ends and middle attachment points to secure the aluminum strips. Use ½-in screws to attach the aluminum strips to one side of the rectangle. Pull the free sides of the aluminum strips down into contact on the other side of the rectangle, forming arcs (or ribs) across the box. Attach the free sides of the aluminum strips to the rectangle sides using ½-in screws.

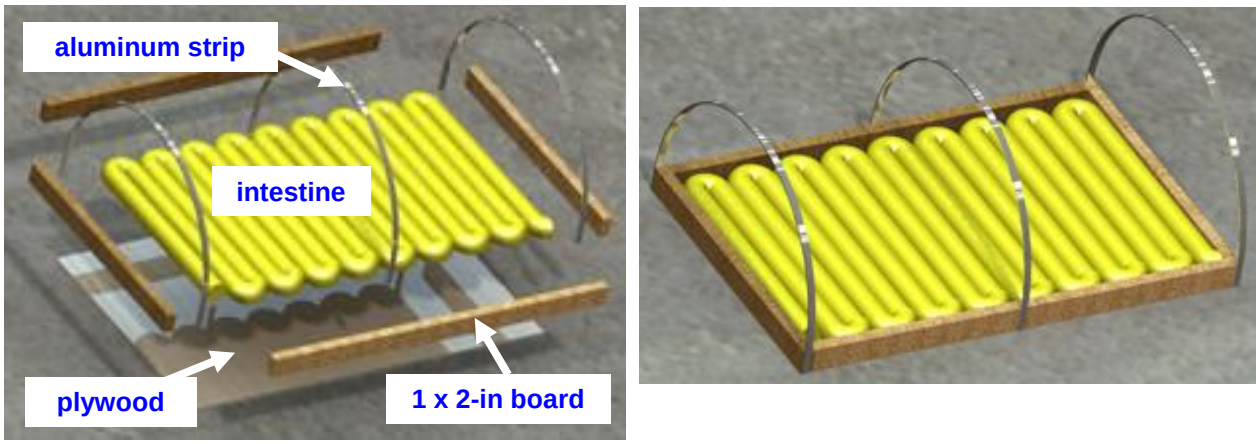

Figure 3. Exploded (left) and assembled (right) views show the assembly of the synthetic abdomen.

Use electrical tape to attach a standard light bulb socket (Figure 4) to the middle aluminum rib to provide illumination for the *in vivo* robots once an enclosure (black plastic garbage bag) is placed around the entire synthetic abdomen (see Figure 5). Screw the fluorescent bulb into the socket. Fluorescent bulbs are used because they generate less heat than standard light bulbs, preventing the bag from melting during testing. This replicates a laparoscopic surgery environment in which a light source is provided by the surgeon. Alternatively, require that the robots provide their own illumination.

Finally, cut two semi-circle shaped flaps from a black plastic garbage bag and attach one to each of the end ribs (see Figure 5); this flap conceals the interior of the abdomen during testing. *Optional:* Cut small rectangles of hardboard (approximately 3.5 x 4.5-in) and hot glue to the inner edge of the rectangular base of the abdomen. Drill one screw halfway into the top of each rectangle. This can be another surface on which to stick Playdoh if you do not want all of the endometriosis locations to be on the abdomen floor. Playdoh on these boards are typically easier to biopsy as well (see Figure 5).

Figure 4. Standard light bulb socket with an attached wire and on/off switch.

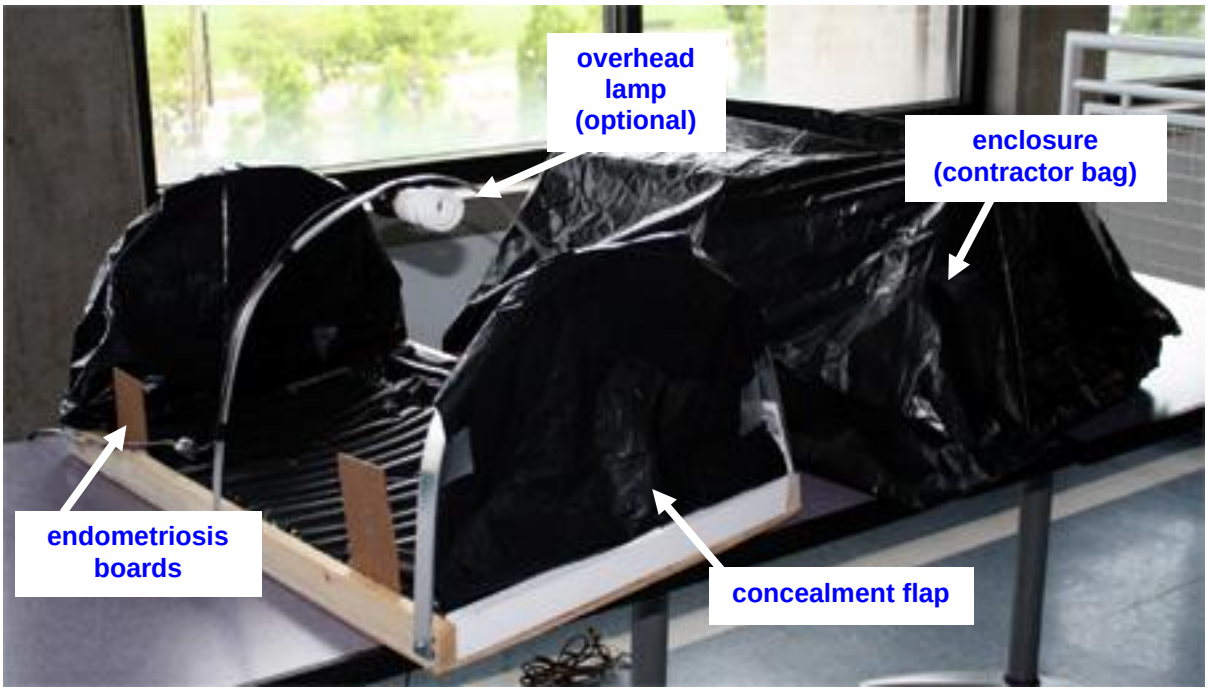

Figure 5. Two completed synthetic abdomen cavity simulators. One with cover removed and one with cover in place.

4. Put together the intestine and the abdominal cavity.

Place the intestine in the abdominal cavity as shown in Figures 5 and 6. Stack additional segments of intestine so that the robotic devices must climb or navigate around "hills" (see Figure 6).

5. Add endometriosis lumps.

Place one or more Playdoh lumps inside the abdomen to represent the suspected endometriosis. Vary the location of the Playdoh between testing, checkpoints, and final competition day so that students are unaware of the location of the diseased tissue. Suggested locations include on the intestines, on the hill or on the endometriosis boards. The robotic devices biopsy by retrieving Playdoh lumps.

6. Enclose the simulator.

Place the entire abdominal cavity in a large black plastic trash bag (Figure 5). Students pierce the black trash bag on one end and insert their devices through the incisions. They push their devices past the concealment flap prior to the start of the competition. Use a new bag after each "surgery."

Figure 6. Completed (and uncovered) synthetic abdominal cavity simulator with "hill."

Image sources:
Figures 1, 2, 4, 5, 6: Brandi N. Briggs
Figure 3: Benjamin S. Terry
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