**Exercise 2**: **Battery “evolution”**
After giving the second part of the presentation (“lecture”) where biological batteries and the “stepwise” nature of evolution are discussed, students will engage in an activity to promote understanding of these topics. In this activity students will complete circuits using batteries, tin foil, and small light bulbs. The students will see how increasing the number of batteries increases the intensity of the light, and how a more powerful battery can have the same effect with less space. This will be related back to serial evolution, and specialization of the mormyrid electric organ.

Required materials: 3 AAA batteries per group, 1 9V battery per group, string or yarn, roll of tin foil, string of christmas lights or other small light bulbs (1 light bulb per group), masking tape, modeling clay, colored mormyrid outline from Exercise 1, powerpoint slides and display.

1. Have students segregate into groups (ideally groups of 2, although more is acceptable) based on the electric discharge they chose for their mormyrid. Biphasic students should segregate with other biphasic students, and triphasic with other triphasic.
*Remind the students that mormyrids prefer to pair with other mormyrids that have similar discharges.*
2. Distribute 3 AAA batteries to each group and hand out squares of tinfoil, a light bulb, and a small amount of modeling clay.
It may be useful for the instructor to have their own setup to demonstrate to the children with
3. Have students complete a circuit using one battery and the light bulb. One piece of tinfoil will touch the “+” electrode and one side of the light bulb wire, while a second piece of tinfoil will connect the “-” electrode and the other side of the light bulb wire.
-*Students should make the tinfoil long enough to complete a circuit with three batteries eventually- it may be best to distribute tin foil of an appropriate length or fashion these pieces ahead of time.
-Modeling clay can be useful to steady the light bulb.
-Make sure the two pieces of tinfoil do not touch.*
	1. This exercise is meant to reflect the first electricity producing ancestor of mormyrids. The AAA battery represents a slightly modified muscle cell that can produce a small amount of electricity to power the light bulb, allowing the fish to sense its environment slightly.
4. Ask students to predict what will happen to the light intensity if additional batteries are added to the circuit. To do so, connect the “+” electrode of one AAA battery to the “-” end of another and use tape to secure the batteries together.
Have students complete the circuit with two batteries. This will have a more intense light output than a single battery.
Have students add the final battery to the circuit, complete the circuit and note the very intense light.
	1. This exercise is meant to illustrate how through evolution adaptations are modified to be more efficient, thereby increasing animal fitness. The mormyrid ancestor was able to sense its environment and find food and escape predators better, its offspring then mutated through evolution to add more “electric muscle” and were able to sense more of its environment in turn.
5. Have the students “mutate” the tin foil into string. This mutation will render the proto-electric organ that has been “evolving” useless as string will not conduct electricity.
	1. The intention of this part of the exercise is to remind students that mutations that are detrimental can also arise over the course of evolutionary time. The particular individual or population that developed the “string” mutation would likely die off.
6. Have the students place their “proto-electric organ” onto the mormyrid outline. Direct their attention to the fact that to produce the intense light, the batteries are stacked but are WAY bigger than the electric organ outlined; they won’t fit!
Remind the students that the mormyrid is the product of many millions of years of evolution, and was able to produce more efficient “electric muscle” by making a new cell type, called electrocytes.
7. Give each group of students a single 9V battery. Have them complete the circuit with the 9V battery. Have the students note the intensity.
	1. Each 9V battery is roughly the same size as a AAA, but takes up less space and is more powerful. This is similar to how the specialized electrocytes (9V battery) are more efficient than the “electric muscle” of the ancestor.