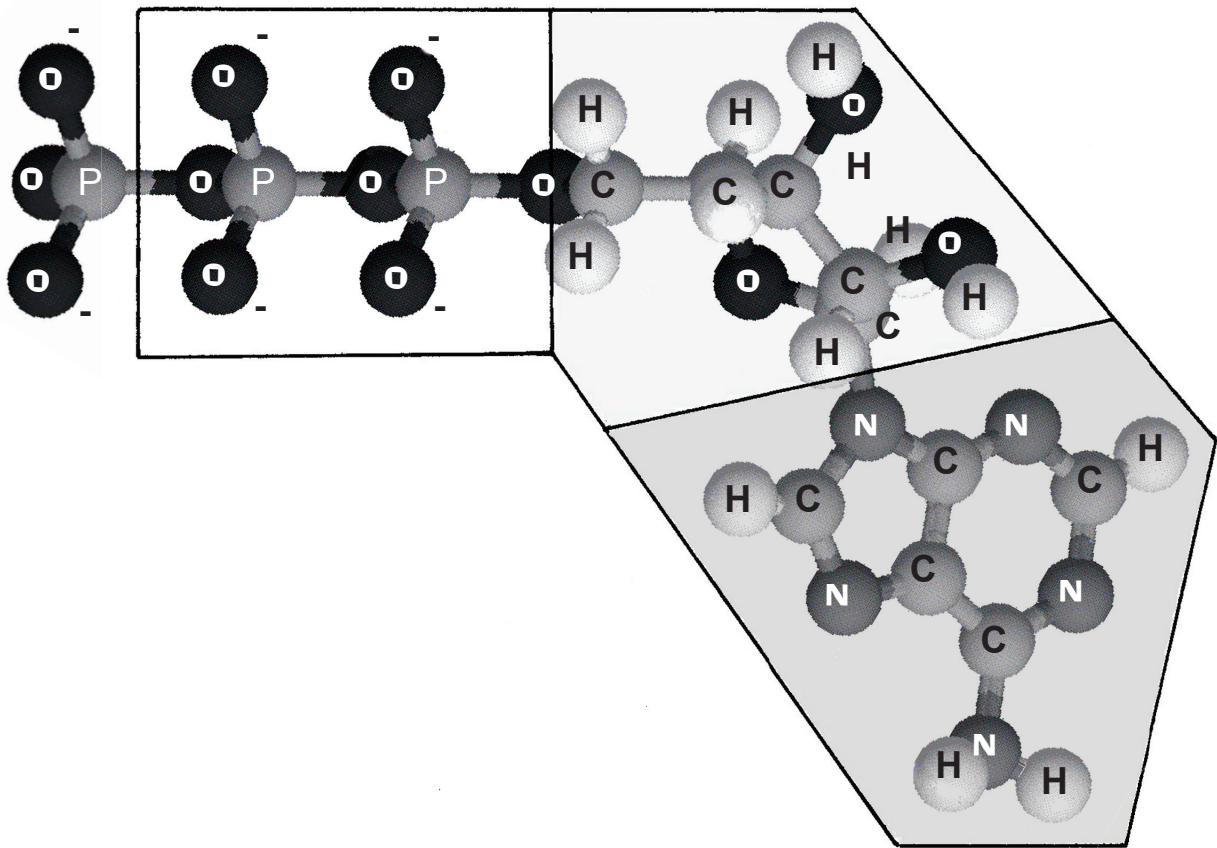


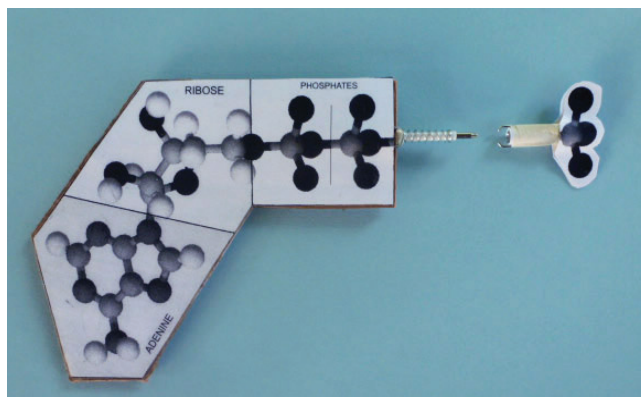
# ATP “POP GUN”

(adenosine triphosphate)



# ATP “POP GUN”

Here is a fun way to help your students remember what ATP (adenosine triphosphate) is and what it does. This toy has a lot of science packed into it! The gun is labeled showing the chemical structure: adenine (the same adenine found in the rungs of DNA), ribose (very similar to the ribose sugar found in the “backbone” of DNA), and three phosphate groups. The third phosphate acts as the “bullet” and pops off, just like in real ATP. So the gun itself, without the bullet, is ADP (adenosine diphosphate).



The springs that launch the phosphate bullet represent the repelling forces between the oxygen molecules on the phosphates. The oxygens have a negative charge. According to the basic rules of chemistry, “like” charges repel and opposites attract. So the oxygens don’t want to be next to each other. This repelling force is overcome, however, by the strength of the chemical bond, represented by the metal clip that holds the phosphate bullet in place until released. There is a fine balance between holding and repelling.

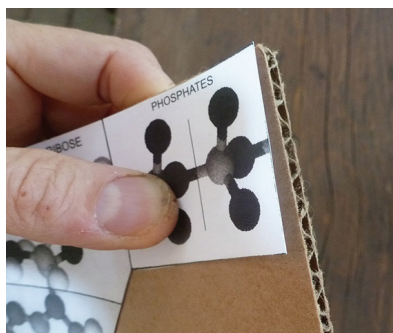
## You will need:

- A copy of the following pattern page (there are two guns per page, so you’ll only have to make one copy per two students)
- A piece of corrugated cardboard for each gun (the piece must be large enough so that you can orient the corrugate line to go parallel to the barrel of the gun)
- Optional: a sharp craft knife (a kitchen knife with serrated edge) for cutting the cardboard
- Two ball point pens per gun (the kind of pen that has a [clicking button](#) at the top, not the kind that has a removable cap)
- Three paper clips per gun
- White glue (a glue stick if you are using regular paper—glue stick will wrinkle the paper less)
- Needle nose pliers (pliers with a very pointed end)
- Scissors
- Tape: Masking tape is best, duct tape is a little thick but would work, clear tape is third choice because it will be hard to glue patterns on top of it. (If all you have available is clear tape, don’t let this stop you from doing the project.)
- Possibly helpful: A tube of all-purpose craft glue (the smelly stuff that comes in a tube and promises to stick to plastic, wood, paper and metal) This is just in case you have trouble getting the springs to stay in.

## Construction:

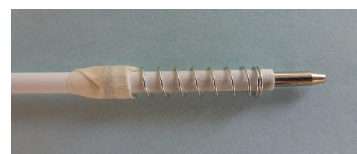
1) Copy the pattern page into heavy card stock if possible. (If you can’t get card stock, you can make do with regular paper.) If you want your students to label the individual atoms, now would be a good time.

2) Cut out the gun patterns. Cut off the third phosphate on the end; it will be turned into the bullet. You can simply cut a rectangle around this phosphate, or you can trim around the shape more closely. Trimming can be done as the last step. For right now, set these pieces aside.



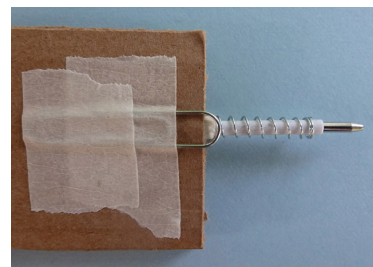
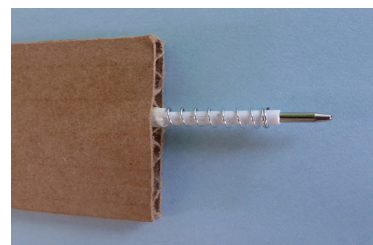
3) Take one of the gun patterns you have cut out and place it on top of the corrugated cardboard. You must be very careful to place the pattern so that the corrugate lines are going parallel to the barrel. Cut out the cardboard shape. Do not glue the gun pattern on top yet. This will happen in a later step.

4) Take apart the pens. Salvage both springs and one of the ink tubes. Take one spring and put it on the end of the ink tube and secure in place with a tiny strip of tape.



5) Slide the ink tube into one of the slots in the barrel section of the corrugated cardboard gun. Make sure it is secure. If it wants to slip back out, put a dab of all purpose glue on the tube before sliding it back in. (If you have no glue available, you can secure it at the end with a thin strip of tape. Tear the tape lengthwise so that it is only a third of its original width.)

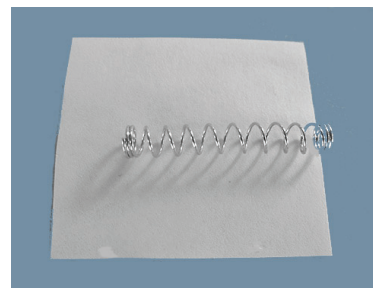
6) Take two of the paper clips and bend them just slightly on one end. Tape the paper clips right at the end of the barrel so that the ends of the clips stick out just a bit. You should be able to squeeze the clips together a few millimeters and have them bounce back to their original position. This will be the release mechanism that fires the phosphate bullet.



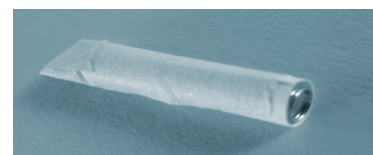
7) Now you can glue the pattern pieces to the sides of the cardboard. You have now finished the ADP section of the project. Remember, ATP without that third phosphate is ADP. See the picture on the previous page for an image of the completed ADP gun. (Optional: Draw negative charge signs (-) next to the oxygens.)



8) Cut a piece of regular paper 3 centimeters square (1 1/4 inches). You might be able to use a scrap of your card stock, but since this square will be rolled up, the card stock might be too thick. Set the spring on the edge of the paper, with one edge of the spring flush with the end of the paper, and roll the paper around the spring. The tricky part of this step is to make the roll snug but not so tight that the spring can't move inside the tube. The spring will need to be able to contract and spring back inside the tube. Once you get it wound just right, secure the roll with tape.



9) Pinch the end of the tube that has a bit of extra space. Secure with tape.



10) Take the remaining paper clip and snip off the small inner portion so that you are left with a long U shape. Make tiny bends in the ends, forming angles of about 45 degrees. It is important to make these bends as small as possible. If they are too long you will have trouble releasing the bullet. You may have to make small adjustments to these hooks later on if your gun will not fire properly. (Some troubleshooting is to be expected!)

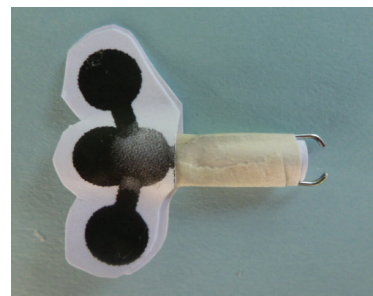


11) Tape this U-shape onto the paper tube so that the ends stick out over the open end of the tube. Secure with tape.



12) Glue the phosphate pieces back to back at the end of the bullet tube. Don't use too much glue. If there is glue seeping out, you've used too much. Press and hold the phosphates for at least twenty seconds. White glue usually sticks well enough after twenty seconds that you can let go.

13) Now you are ready to try out the gun. You will probably have to make small adjustments to get it to fire perfectly every time. The gun should shoot the bullet several meters (over 10 feet).



## How to fire the gun:

Slide the bullet onto the end of the ink tube. The two springs will compress (representing the repelling forces of the negatively charged atoms that do not want to be next to each other). Pinch the two clips at the end of the barrel so that they get closer together. This should give you enough space to be able to slide the hooks over the clips. Slowly release tension on the end clips. The tension of the end clips pushing outward should keep the bullet hooks in place. When you let go, the bullet should stay in place.

To fire the gun, simply press the barrel's end clips together. The bullet should shoot quite a distance.

## An extra feature you can add:

In a real ATP molecule, the release of the third phosphate is caused by a water molecule. It pops apart into an H and an OH. (These split-up pieces are called ions.) The H has a positive charge and is written like this: (H<sup>+</sup>). The OH has a negative charge and is written like this: (OH<sup>-</sup>). These two pieces can “plug” the electrically awkward “gaps” left behind by the third phosphate when it goes flying off. (After all, electrical bonds are broken when an atom leaves a molecule. Often there are some unhappy atoms or electrons left behind!)

You can make a hands-on way to remember how a real ATP fires its phosphate. Cut two paper circles and label one (H<sup>+</sup>) and the other (OH<sup>-</sup>). Tape one circle to your thumbnail and one to the nail of your index finger. (Or you can take a permanent marker and draw these letters on the fingernails. Permanent marker scrubs off fingernails fairly easily.)

With your thumb and index finger labeled correctly, you can scientifically fire your ATP gun using a water molecule. When water splits something apart is called **hydrolysis**. “Hydro” means “water,” and “lysis” means “split.” (Actually, to be perfectly accurate, your thumbnail (with the OH on it) would have to go flying off with the phosphate bullet!) If the students simply remember that water is involved in splitting off the third phosphate, that will amaze all their future teachers until they get to AP biology or college biochem.

## TROUBLESHOOTING TIPS:

1) If your bullet will not stay clipped, you need to check two things. First, make sure that the hooks on the end of the bullet are bent in far enough. They don't need to be completely at a right angle, but they need to be at enough of an angle that they catch onto the ends of the paper clips adequately. Second, you may need to adjust how much the end paper clips are bent. They need to be far enough apart that they can apply adequate outward pressure on the bullet clips.

2) If your bullet won't release and fly, check to see if the clips on the end are spread too far apart. You might have too much tension on the bullet hooks. Also, your bullet hooks might be too long. You may need to clip them a bit.

3) If your bullet doesn't go very far, check to see if both springs are operating as they should. If only one spring is providing impetus, the bullet will only go half as far as it should. Check to see if the spring inside the bullet is stuck. This spring should be able to contract and release even though it is inside the paper tube.

NOTE: There is a brief video posted on [www.YouTube.com/TheBasementWorkshop](http://www.YouTube.com/TheBasementWorkshop) showing tips 1 and 2.

## ONE FINAL SCIENCE NOTE:

To state the obvious, your ATP gun is not very powerful. It launches a tiny, lightweight paper bullet. It might be able to knock down a small paper target, but it certainly isn't going to cause any damage to anything. Real ATPs are a bit like this, too. They release only a minuscule amount of energy. Your body must make and use trillions of ATPs every day. If you could collect all the ATPs your body makes and uses in one day, you'd find that your bucket full of ATPs would weigh almost as much as you do. That's millions of ATPs per second.

The fact that ATPs release only a small amount of energy is not a bad thing. If they released a lot of energy they would damage cells. ATPs are the perfect size for cellular tasks.



