Bio batteries

At the BDC we aim to convert plants, microbes and biowastes into profitable biorenewable products. The team of scientists specialise in making the most out of biorenewable materials and our vision is to support the widespread use of biorenewables across the world.

What's the problem with batteries?

Unfortunately, a key element in the batteries we use today is cobalt. More than 60% world's cobalt is produced in the Democratic Republic of Congo, where concerns have been raised about the social and environmental impact of mining the metal.

Lithium is another key element in modern batteries. It comes mainly from three big producer countries, Australia, Argentina and Chile, along with emerging producers such as Bolivia, Brazil, Canada and Zimbabwe. Water consumption and scarcity in some producer countries is the big concern here.

Apart from mining these resources – which has a detrimental effect on Nature – a battery contains one or more of the following metals: cadmium, lead, zinc, manganese, nickel, silver, mercury, and lithium, as well as acids. These chemicals are extremely toxic – to us and the environment.

The harmful chemicals found in batteries can find their way into the local water supply, killing plants and animals which negatively affect the ecosystems of streams, lakes, and rivers. Ultimately, the health of people who drink water is also at risk. The same can be said when it comes to eating the plants, animals and fish found in polluted environments.

Can we make batteries from alternative biorenewable resources like plants or biowastes? These would be better for the environment-

- No mines
- Less pollution
- Easier to recycle

Building a fruit cell

Batteries are comprised of a number of cells made from two different metals suspended in an acidic solution. With a fruit cell battery, the two metals are zinc and copper.

The two metal components are electrodes, the parts of a cell where electrical current enters and leaves. In the exchange of electrons between the zinc and the copper over the acid bridge, copper accepts two electrons from zinc which accounts for the current.

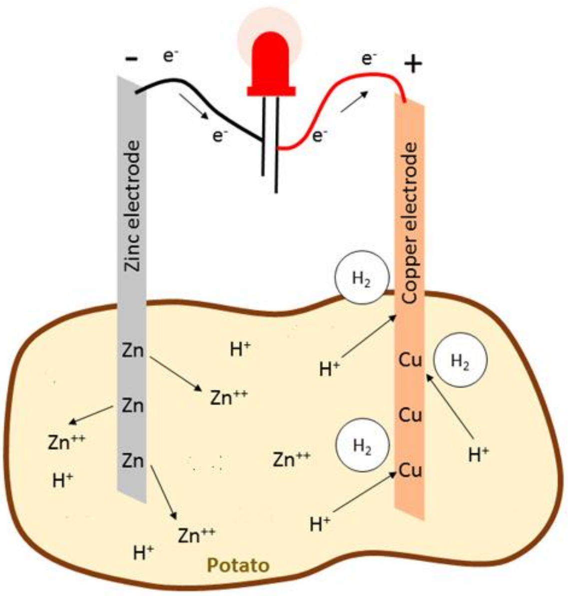
In this project an LED is used to indicate if the fruit-cell is generating an electric current. A **Light Emitting Diode** (LED) is a **semiconductor** device which converts electricity into light. An electric current can flow only in one direction through LEDs, which means that they have a positive and negative terminal (also referred to as the **anode** and **cathode**). The cathode should be connected to the negative zinc metal strip, and the anode (the longer terminal) to the positive copper strip.

Equipment

- Various fruits; lemons, bananas, apples, potatoes and oranges
- Electrodes- copper and zinc
- Wires
- Crocodile clips
- Multi meter
- LEDs bulbs (low voltage)

Procedure

1. Prepare the fruits for this project by squeezing them on all sides with the hands. Make sure not to squeeze too tightly and break the skin!
2. Stick the zinc electrode into the first fruit to be tested.
3. Place the copper electrode in on the opposite side.
4. Connect the longer of the two LED leads to the copper strip and the shorter lead to the metal strip using a crocodile clips and wires.



5. Observe and record what happens.

Once the fruit cell is connected to the LED, you've completed a circuit. As the electrical current passes through the LED, it powers the LED and then passes back through the fruit before getting to the LED again. By the way, an LED is polar sensitive. That means an LED will glow only if the current is flowing through it in the right direction. If you hook up the LED and it doesn't glow, switch the crocodile clips attached to its legs. That should do it.

6. Measure the current using the multi-meter. You can also measure voltage too!
7. Remove the zinc and copper electrodes and wipe off any excess juice.

8. Repeat the same procedure using a different fruit. Record the results for each time.
9. For a more scientifically-accurate investigation, the entire process should be repeated twice more.
10. Calculate the average current and/or voltage produced by adding the values from the three independent results and dividing the sum by three for each fruit.
11. Record the data in a table similar to the one shown.

Current and/or voltage (*milliamps/ millivolts*)	Lemon	Apple	Orange	Potato	Banana
Trial 1					
Trial 2					
Trial 3					
Average					

12. Using the data in the table, plot a bar graph with *name of fruit* along the x-axis and *current* along the y-axis.

Work through the questions below using your fruit cells and what you have learnt so far. Additional battery information can be found at the end, this might help in answering some of the questions.

- What happens to the current and/or voltage when fruits are connected together (in parallel and series)?
- What is a wet cell battery?
- Why do placing two dissimilar metals into a fruit produce an electric current?
- Which fruit-cell produced the most electricity? Which fruit-cell produced the least? Why do you think this is the case?
- Did changing how far in the electrodes were make the current increase or decrease?
- Did putting the electrodes closer together make the current increase or decrease?
- Did putting the electrodes farther apart make the current increase or decrease, or stay the same?
- Did the size of fruit make a difference? If so, did the size make the current increase or decrease?
- Would fruit juice minus the fruit work as an electrolyte?

What the BDC and others are doing

We can make batteries from renewable resources and you have now seen this in action in the experiments with various fruits. But obviously no one is going to have a lemon or potato on the back of their smart phone, so we need to apply some of this science to real world.

Various different materials and construction techniques are being explored to replace current lithium batteries, including Samsung's graphene ball cathode technology and metal air systems, but solid state batteries are seen as the future by many.

Solid state batteries effectively swap the liquid electrolyte for a solid material, typically a polymer or ceramic, which has the potential to dramatically increase energy density, improve safety by removing flammability, and reduce or remove the effects of ageing.

Because of the higher stability of using a solid electrolyte, solid state batteries can use cathodes with higher potential energy and anodes of solid lithium, which could significantly increase the amount of energy they can store. They can also be smaller, lighter and require fewer components not dedicated to generating electricity, such as cooling systems.

The BDC has worked to scale up a process for converting renewable resources (potato starch, alginic acid and fruit pectin) into a building block for energy storage and chemical catalysis.

Now, the BDC team is scaling up the process from a lab-scale of 100g to a pilot line capable of producing up to 20kg per day of the material. This will provide enough sample material for industrial testing, with the aim of adapting the material for different uses, such as batteries for electric vehicles and green catalysts for the chemicals industry.

During the project, the BDC has worked with the Green Chemistry Department at the University of York and Carbolite UK to create a custom rotating tube furnace to convert renewable plant-based resources into materials used to produce batteries & catalysts.

If successful, the BDC will have helped to not only have produced a high-added-value material at a lower cost for various uses but will also have established a pilot-scale production plant, based at our site in York.

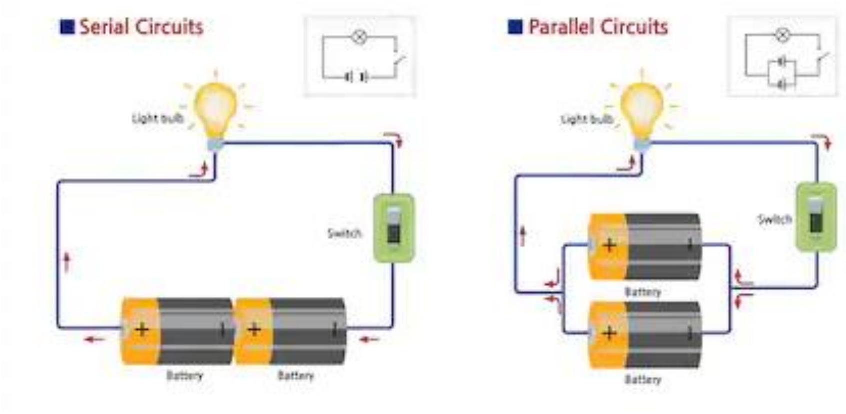
Additional Battery information

Background

Electricity is the movement of electrons in a conductor. Voltage is the pressure, somewhat like water flowing from a pipe. Current the quantity of the electrons, somewhat like the number of litres flowing from the pipe. Batteries generate electricity by a chemical reaction. They can be connected together in different ways to provide either greater voltage, greater current, or both greater voltage and greater current depending on the requirements of the equipment they are powering.

Connecting individual cells in series involves creating a series circuit, which has the positive terminal connected to the negative terminal of another cell with each cell in line. Two 6-volt, 2 amp cells connected this way will produce a 12 volt 2 amp battery.

A parallel circuit has the positive terminal connected to the positive terminal of another cell, and the negative terminal connected to the negative terminal. Two 6-volt, 2 amp cells connected this way will produce a 6 volt 4 amp battery.



When two dissimilar metals are placed in a common conducting solution, electricity will be produced. This is the basis of the electro-chemical cell, or **wet cell**. In the early nineteenth-century, Alessandro Volta used this fact of physics to invent the **voltaic pile** and discovered the first practical method of generating electricity. Constructed of alternating discs of zinc and copper metals with pieces of cardboard soaked in a salt solution between the metals, his voltaic pile produced an electrical current. Alessandro Volta's voltaic pile was the first "wet cell battery" that produced electricity.

A wet cell consists of a **negative electrode**, a **positive electrode** and an **electrolyte**, which conducts **ions** (atoms with an electric charge). In this project, copper and zinc metals were used as the electrodes and the liquid found in fresh fruit is the electrolyte. The chemistry behind the fruit cell is that zinc is more **reactive** than copper which means zinc loses electrons more easily than copper. As a result, oxidation occurs in the zinc metal strip and zinc metal loses electrons which then become zinc ions. The electrons then flow from the zinc strip to the copper strip through an external circuit. In the copper strip, reduction occurs and the hydrogen ions in the fruit's critic acid juice accept these electrons to form hydrogen gas; this explains why the investigator may observe bubbling of gas produced at the copper strip when the two metals are connected by a wire.

Batteries are essential components of most electrical devices. They exist in our cars, laptops, smartphones and other electronic appliances. A battery is essentially a can full of chemicals that produce electrons. The basic structure of battery includes two terminals. One terminal is marked positive, while the other is marked negative. In normal flashlight batteries, the ends of the battery are the terminals. In a large car battery, there are two heavy lead posts that act as the terminals.

Electrons collect on the negative terminal of the battery. When a wire is connected between the negative and positive terminals, the electrons will flow from the negative to the positive terminal as fast as they can. Normally, some type of load is connected to the battery using the wire. The load might be something like a light bulb, a motor or an electronic circuit like a radio.

Inside the battery itself, a chemical reaction produces the electrons. The speed of electron production by this chemical reaction (the battery's internal resistance) controls how many electrons can flow between the terminals. Electrons flow from the battery into a wire and must travel from the negative to the positive terminal for the chemical reaction to take place. That is why a battery can sit on a shelf for a year and still have plenty of power. Unless electrons are flowing from the negative to the positive terminal, the chemical reaction does not take place. Once a wire connects both terminals, the reaction starts.

The simplest battery that can be created is called a zinc/carbon battery. In a container filled with sulfuric acid, a zinc rod is placed in it. Immediately, the acid will start to eat away at the zinc. Hydrogen gas bubbles will be forming on the zinc rod, and the rod and acid will begin to heat up. Specifically, there are multiple reactions taking place. When a carbon rod is inserted in the acid, the acid does nothing to it. But by connecting a wire between the zinc rod and the carbon rod, two things change. First, the electrons flow through the wire and combine with hydrogen on the carbon rod, so hydrogen gas begins bubbling off the carbon rod. Second, there is less heat. You can power a light bulb or similar load using the electrons flowing through the wire and you can measure a voltage and current in the wire. Some of the heat energy is turned into electron motion. The electrons go to the trouble to move to the carbon rod because they find it easier to combine with hydrogen there. Eventually, the zinc rod dissolves completely or the hydrogen ions in the acid get used up and the battery dies. Modern batteries use a variety of chemicals to power their reactions.

Why batteries are an important part of renewable energy?

In the UK, battery installations are primarily being deployed to supply services to National Grid. Such ancillary services are increasingly important to help match supply and demand as a growing amount of intermittent wind and solar power comes online.

There are also the beginnings of “hybrid” renewable energy power plants, where batteries are installed alongside solar farms and windfarms. This is particularly important for the economics of solar farms, which can push down power prices around midday by peaking at the same time. Instead of exporting immediately, hybrid farms can store power to sell later at higher prices.

In other parts of the world, such as South Australia, batteries are being used to make the grid more resilient and avoid blackouts. Crucially, batteries are not yet suitable and do not make economic sense for interseasonal storage – that is, storing up solar power in summer to release in winter.

The future

Companies are working hard to increase the amount of energy that can be packed into a battery, and to bring down the cost of making them.

Lithium-ion batteries first were launched commercially in 1991, and since then have been pushed close to their limits in terms of charge speed and energy capacity. As we have mentioned, many believe solid state batteries will be the next big breakthrough. Several companies are racing to perfect the technology with various different chemistries and construction, including traditional battery manufacturers Samsung and LG, but also a new breed such as Dyson and QuantumScape, in which Volkswagen has a significant stake.