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How we found out about

ELECTRICITY

Contents

1. Rubbing and attracting

The story of electricity begins 2,500 years ago near the western coast of the land we now call Turkey.

In that place there was a city called Magnesia where the people spoke Greek. Near the city a shepherd boy watched his sheep. The story is that he used a stick with an iron tip to climb over stony places.

One day, he touched the top to a stone and it happened to stick a little. Could the stone have something sticky on it? He touched it with his finger. It wasn't sticky at all. Nothing stuck to it except for the iron tip of his stick. The shepherd boy told others about this odd rock.

A wise man named Thales lived in that area. Today he would be called a scientist. He heard about this stone from Magnesia and had such a stone brought to him. It attracted iron objects and nothing else—just iron objects.

Thales called it the "magnetic stone" after the name of the city. We call it a "magnet". Thales wondered how a piece of dead stone could attract and pull something to itself. He wondered why it should only attract iron. Did anything else have this strange ability? He tested other objects. One of the materials he tested was a glassy substance with a golden colour. We call it "amber", but in the Greek language it was called "elektron".

The amber didn't attract iron. However, amber has a pleasant odour and this odour becomes stronger if it is rubbed with the fingers. Thales probably rubbed the amber and noticed that it attracted some things after it had been rubbed. In fact, it attracted tiny bits of many things—light pieces of fluff, thread, feathers, and tiny splinters of wood. This was not at all the way a magnet acted. Rubbed amber had a different kind of attraction.

Thales couldn't figure out why this happened, but he wrote down what he had done. Other people read and thought about his experiments.

It turned out that the magnetic rocks were useful. If a steel needle is stroked by a magnetic rock, the needle becomes a magnet too. The needle then attracts iron objects. If a magnetic needle floats on a cork in water or turns on a pin, it turns so that one end points north. Sailors use such a floating needle to tell in which direction they are sailing when they can't see land.

Magnetic needles, used to point north, were called "compasses". By 1400 AD, European sailors were using them to cross oceans and explore distant lands. It would have been very difficult for Christopher Columbus to reach America in 1492 if he hadn't had compasses on board his ships.

But what about rubbed amber? It didn't seem to be useful and very few people bothered with it.

About the year 1570, an Englishman named William Gilbert began to work with magnets. He also wondered about amber. Why should amber attract objects after being rubbed? What was special about amber?

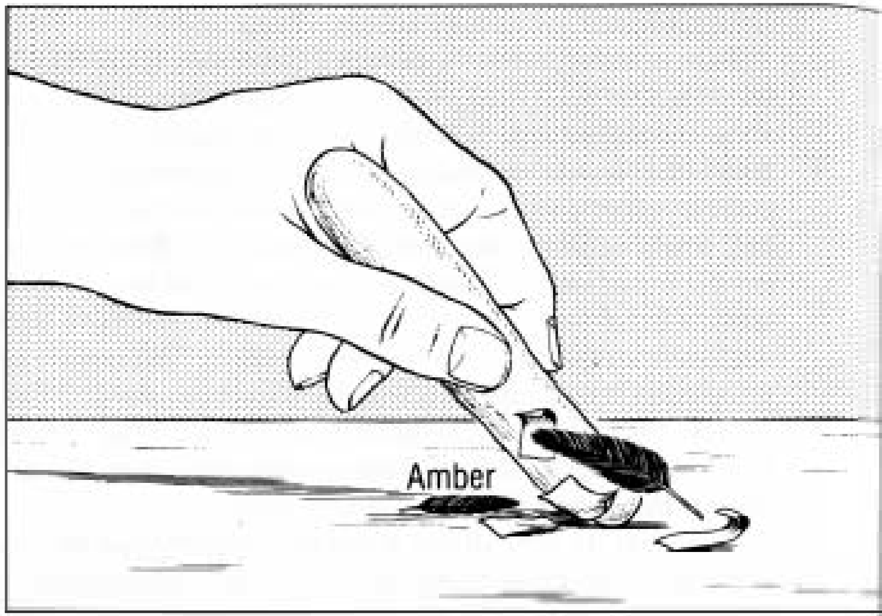
For one thing, amber was such a beautiful colour that it was often used to make jewellery. Would other jewels also show the ability to attract when they were rubbed? Gilbert tried other jewels and found that they, too, attracted light objects when they were rubbed. Diamonds, sapphires, and opals behaved like amber, for instance. Some rocky crystals that were too common or dull to be jewels also behaved that way.

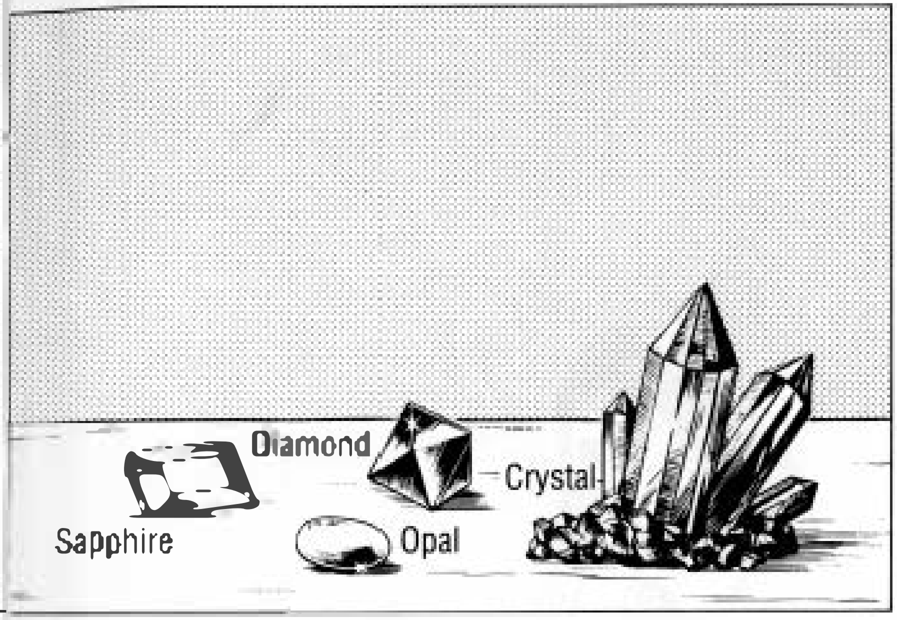
Gilbert knew that amber was called "elektron" in Greek and "electrum" in Latin. He therefore called all the objects that showed the ability to attract after being rubbed "electrics". He used the word to show that they all resembled amber in having this ability.

But what do we call the attraction itself? What do we call the stranger power that makes a small scrap of paper cling to a piece of rubber amber? About 1650, an Englishman named Walter Charleton called it "electricity".

At this time, people in Europe were becoming more and more interested in nature. They were asking questions and experimenting to see what happened when objects were treated in different ways.

For instance, amber attracted light objects when it was rubbed. What if it was rubbed harder? Would the attraction grow stronger? Would the amber contain more and more electricity? Someone who tried this particular experiment was a German named Otto von Guericke. He rubbed a piece of amber with a cloth as hard as he possibly could. Then, when he pressed it between his fingers, he could hear it make tiny crackles. If he pressed it between his fingers in pitch darkness, he could make out a very tiny flash of light with each crackle.





Maybe the amber could not hold all the electricity caused by the rubbing. Maybe some of the electricity spilled out again, making noises and flashes of light as it did so.

But the crackles were so small and the flashes of light so tiny that Guericke grew impatient. If he was going to carry this experiment further, he needed to pack more electricity into the amber. For this he needed a bigger piece of amber which would hold more electricity. Since big pieces of amber were expensive, Guericke used, in 1672, a yellow substance called sulphur. It was an "electric" that attracted light objects when it was rubbed, but it was cheaper than amber.

He broke a large quantity of sulphur into pieces and put them into a large, round glass flask. He heated the flask and the sulphur melted. He added more and more sulphur until the flask was filled. Then he put the end of a wooden handle into the melted sulphur and let it cool. The sulphur hardened into a yellow solid again, filling the flask.

Carefully, Guericke broke the flask and removed the pieces of glass. He had a yellow ball of sulphur larger than his head, with a handle. He placed this ball in a wooden holder. He could turn the ball of sulphur by using the handle. If he placed his other hand on the sulphur as it turned, the rubbing, or friction, filled the sulphur with electricity.

Guericke's sulphur ball experiment

Nobody had ever before collected so much electricity in one place. The sulphur ball made loud crackles once it was filled, or "charged", with electricity. When the electricity spilled out, or was "discharged", it made sparks that were so bright they were even visible in daylight.

Guericke was the first to invent a "friction machine" for producing electricity.

2. Conductors and non-conductors

People became more and more interested in studying electricity after reading about Guericke's experiments.

An Englishman named Stephen Gray decided to try some experiments of his own. He used glass as an electric because it was cheap enough to use in large pieces.

If Guericke had known that glass was a good electric when he was doing his experiments years before, he wouldn't have had to crack away the pieces of glass around the sulphur. He would have used just the glass and skipped the sulphur altogether.

Gray rubbed a hollow glass tube about 1 metre long from end to end. It attracted feathers, showing that electricity had been rubbed into it.

Since the glass tube was open at both ends, Gray thought dust might get in and spoil his experiment. He put corks in both ends. Then he noticed a strange thing. The feathers were also attracted to the corks. Yet he hadn't rubbed the corks; he had rubbed only the glass. Gray decided that when he rubbed electricity into the

glass tube, the electricity travelled into the cork also.

Could this be true? Could electricity travel? Gray tried other experiments that would test this possibility. He took a stick about 10 centimetres long and stuck it into the cork at one end of the tube. At the other end of the stick he put an ivory ball.

Next he rubbed only the glass. He was very careful about that and didn't touch the cork or the stick or the ivory ball. Yet feathers clung to the ivory ball after he had rubbed the glass. There seemed no mistake about it: electricity travelled.

Water and air can be made to travel through a hollow tube. Such travel is called "flowing". Any liquid or gas can flow. A river is a flowing liquid and a wind is a flowing gas. Liquids and gases are called "fluids" from a Latin word meaning "to flow".

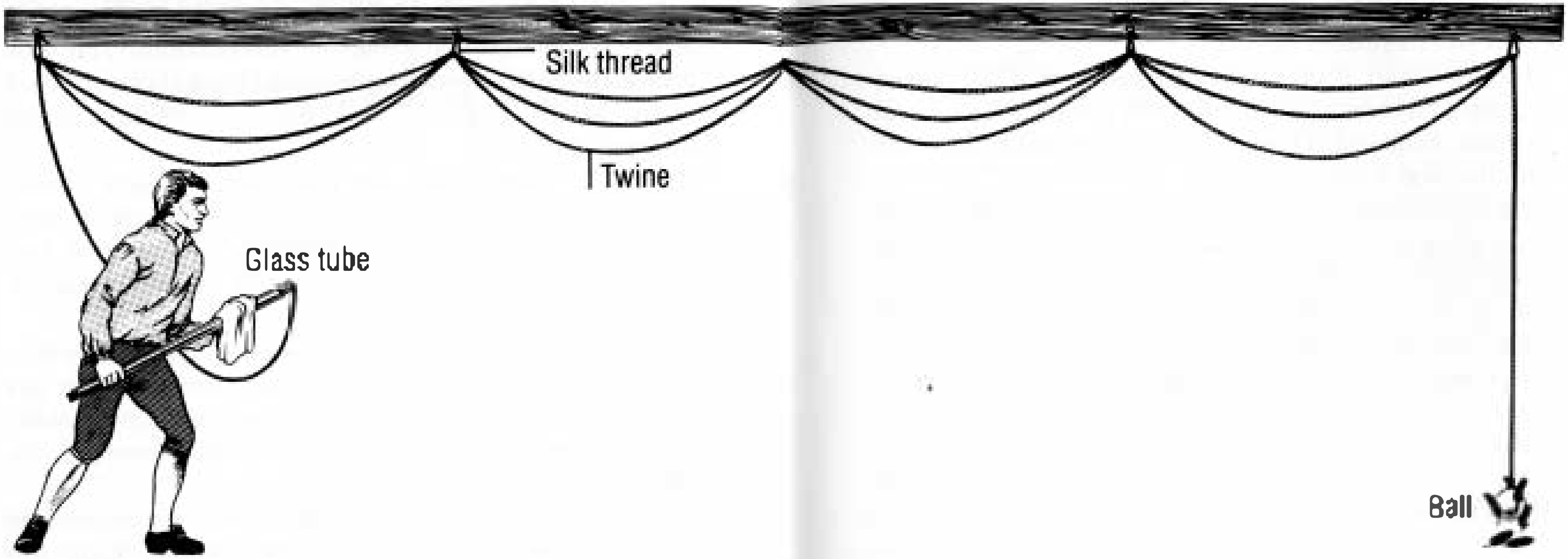
What Gray had shown, therefore, was that electricity could flow through objects. It was also a fluid. From this time on, people began to speak of "electric fluid".

Next Gray tried to see how far he could make the electricity travel. He let the ivory ball dangle from some string attached to the cork at the end of his glass tube. The ivory ball still attracted feathers when he rubbed the glass tube. He used longer and longer stretches of string till he had the ivory ball dangling at the end of 9 metres of string. It still attracted feathers.

Gray wanted to try still longer distances, but by the time he was using 9 metres of string, he had to stand on the roof of his house. He had another idea. He would stretch string across the ceiling of his workshop. He would attach the string to the ceiling by nails.

He stretched over 100 metres of string back and forth, back and forth. The two ends dangled down from the ceiling. To one end he attached his glass tube, to the other

Gray's experiment with silk thread and twine



end his ivory ball.

But now the ivory ball would *not* attract feathers, no matter how long he rubbed the glass tube. Suddenly the electricity seemed to have stopped travelling. Was it because the string was too long? Had he finally found a length too great for the electricity to flow through?

No, that couldn't be it, because even the glass tube stopped attracting feathers after being rubbed. It wasn't that the electricity wasn't flowing. The electricity wasn't there at all. Something he was doing was spoiling the experiment—something that he hadn't been doing before. What could it be?

Up until now he had simply let the string dangle. Now, however, he had nailed the string to the ceiling. Could it be the nails? Maybe the electric fluid escaped through the nails and went into the ceiling and then out into the open air. Perhaps it did this because the nails were so thick that it was easy for the electricity to pass through them. Perhaps he should use something thinner?

Gray had some silk thread. It was thin but strong. He tied a piece of silk thread to each nail. Then he tied the other end of each piece of silk thread to the string. Now the electric fluid passing through the string couldn't reach the nails unless it passed through the very thin silk thread first. If the silk was too thin to pass through, the electric fluid would have to stay in the string and the experiment would work again.

He tried and it *did* work. The electric fluid passed through 30 metres of string from end to end. If he rubbed the glass at one end of the string, the ivory ball at the other end attracted feathers.

He kept using more and more string and finally the string grew so heavy that the silk thread holding it up broke. Gray decided to use brass wire instead of silk to hold up the string. But now the electric fluid was gone again. The fluid must have escaped through the brass wire. Gray decided that what the wire was made of must be more important than how thin it was.

He tried further experiments and found that electricity flowed better or could be "conducted" more easily through metal than through anything else. For that reason metal or any other material that electricity can pass through easily is called a "conductor". Something that electricity can pass through with difficulty is a "non-conductor" like silk.

Gray could now understand why amber, glass, sulphur, and other materials were electrified by rubbing. They were all non-conductors. Once they were rubbed, they filled up with electricity that couldn't go anywhere.

If a conductor like a piece of metal was rubbed, electric fluid would travel into almost anything that touched it. It would travel so quickly and easily that none would be left in the metal. If metal touched a non-conductor, it would take away any electric fluid the non-conductor might contain.

In 1731, Gray tested his theory by placing pieces of metal on blocks of resin. This is a substance much like amber and is a non-conductor. Instead of rubbing

the metal by hand, he rubbed it with a silk handkerchief. Silk is also a non-conductor. Only resin, silk, and air touched the metal and these were all non-conductors.

The rubbing produced electricity in the metal which couldn't escape through the non-conductors. It stayed in the metal which then attracted feathers.

Gray even tied a boy to the ceiling by strong silk threads and rubbed his arm with silk. After a while, feathers clung to the boy and his clothing.

Gray was able to show that *anything* can be filled with electric fluid if it is rubbed.

3. Fluids and jars

News of Gray's experiments soon reached other parts of Europe. In France, a man named Charles Francis Du Fay started some experiments of his own.

In 1733, he took a tiny piece of cork and covered it with a very thin layer of gold. Then he hung it from the ceiling by a silk thread. If he electrified the bit of cork by touching it with an electrified rod, the electricity spread evenly to the gold on the surface since cork was a good conductor. As the cork and gold were only touched by the silken thread and by air, the electricity could not escape.

If Du Fay wanted the electricity to escape after the bit of cork was electrified, all he had to do was touch it with a piece of metal. The electric fluid would instantly pass into the piece of metal and the cork would be discharged.

Du Fay then took another piece of cork, treated it the same way and hung it from the ceiling near by. Now there were two pieces of cork side by side, dangling just a few centimetres apart. He made sure there were no draughts in the room, so that the two pieces of cork hung straight

down. He thought one piece of cork, if electrified, might attract the other.

He rubbed a glass rod with silk until it was filled with electric fluid. He touched it to one of the pieces of cork and some of the fluid travelled into the gold-covered cork.

What happened was exactly what he expected. There was an attraction between the electrified cork and the one that hadn't been touched. Instead of the two pieces of cork hanging straight down they leaned towards each other. The electrical attraction was pulling them together.

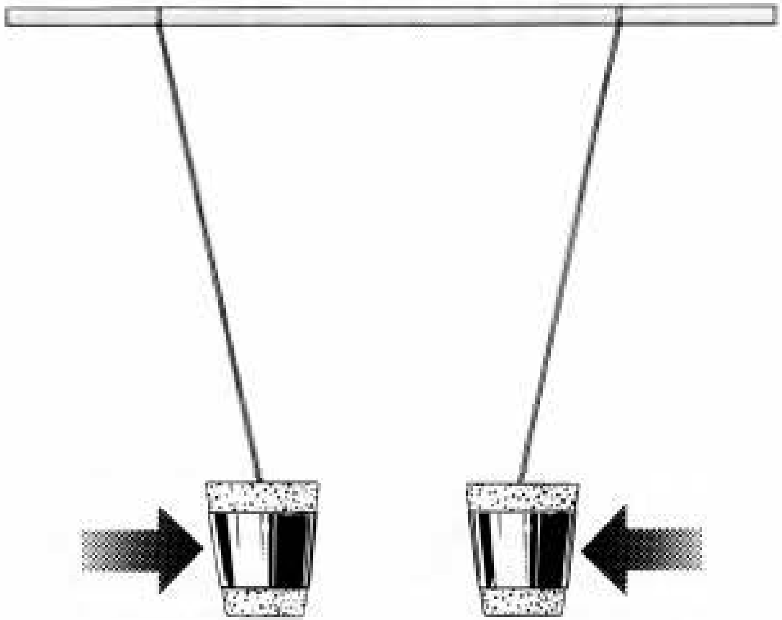
But suppose *both* pieces of cork were electrified. Then each one would be attracting. It seemed to Du Fay that this would make the attraction twice as strong, so that the pieces of cork would pull more closely to each other and hang at a greater angle.

Du Fay tried that. He started with two pieces of cork hanging straight down. Then he rubbed his glass rod and touched first one piece of cork and then the other. To his astonishment, the attraction between the pieces of cork was *not* stronger. The pieces of cork were hanging at an angle but were pushing *away*, or "repelling", each other.

This was puzzling. Was this the way electricity acted? Or was there something wrong with the glass he was using? Maybe he should use a different material altogether. He began with a resin rod and rubbed it with wool because wool works better on resin than silk does. Once the resin was electrified, he touched it to the two bits of cork. At once they pushed away from each other. They were repelling each other.

There was one more thing Du Fay could try. He rubbed a glass rod with silk and touched one piece of cork with it. Then he rubbed a resin rod with wool and touched the other piece of cork with it. This time there was an attraction. The two pieces of cork, each filled with electric

Electrified cork attracting non-electrified cork

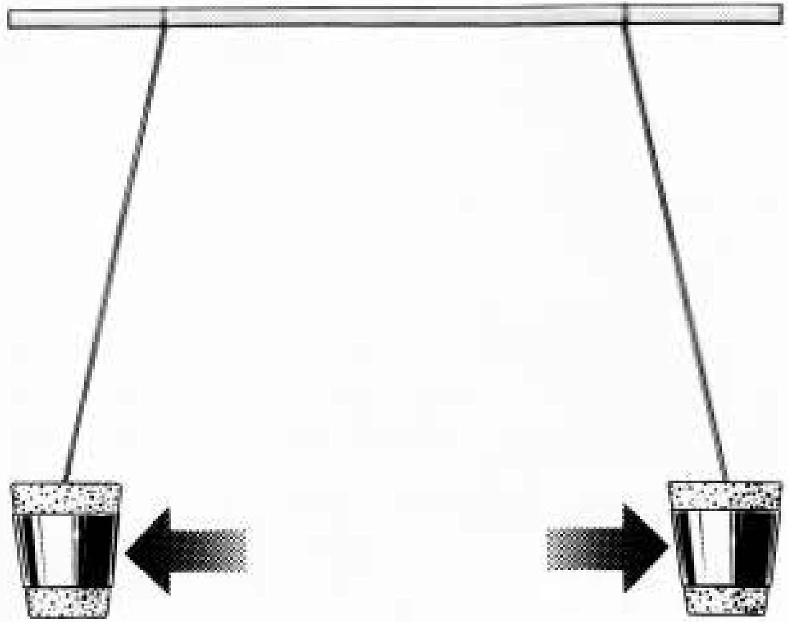


fluid, pulled towards each other.

Du Fay decided there were two kinds of electric fluid. One was the kind of fluid that filled glass when it was rubbed. Suppose we call that glass-electric fluid. The other was the kind of fluid that filled resin—resin-electric fluid. If two pieces of cork were each filled with the same fluid, they repelled each other. If they were each filled with a different fluid, they attracted each other.

Du Fay experimented further to see if this was so. He touched an electrified glass rod to a bit of cork and let the cork fill with glass-electric fluid. Then he took the glass rod away and brought it back very slowly, making it come closer and closer to the cork. Sure enough the glass rod

Electrified corks repelling each other



and the cork, which were now filled with the same fluid, repelled each other. The bit of cork pulled away from the glass rod.

If he brought over an electrified resin rod, however, the cork was attracted. It leaned towards the resin rod.

If he filled a piece of cork with electric fluid from a resin rod in the first place, everything was the opposite. The resin rod repelled the cork and the glass rod attracted it.

Du Fay went on to try other materials. He found that whenever he electrified an object, that object always acted as though it was filled with glass-electric fluid or with resin-electric fluid. There were only those two kinds of electric fluid. There was no third kind.

Meanwhile some experimenters were discovering ways of packing large amounts of electricity into small objects.

About 1745, for instance, people began to work with glass jars partly coated inside and outside with a thin coating of metal. There was a cork in the open mouth of the jar. A brass rod with a brass chain at the bottom was struck through the cork. The brass chain made contact with the metal which coated the glass at the bottom of the jar.

If an electrified glass rod was touched to the brass rod sticking out of the jar, some of the electric fluid would pass into the metal inside the jar. Once it was there it couldn't escape because the cork and the glass were non-conductors.

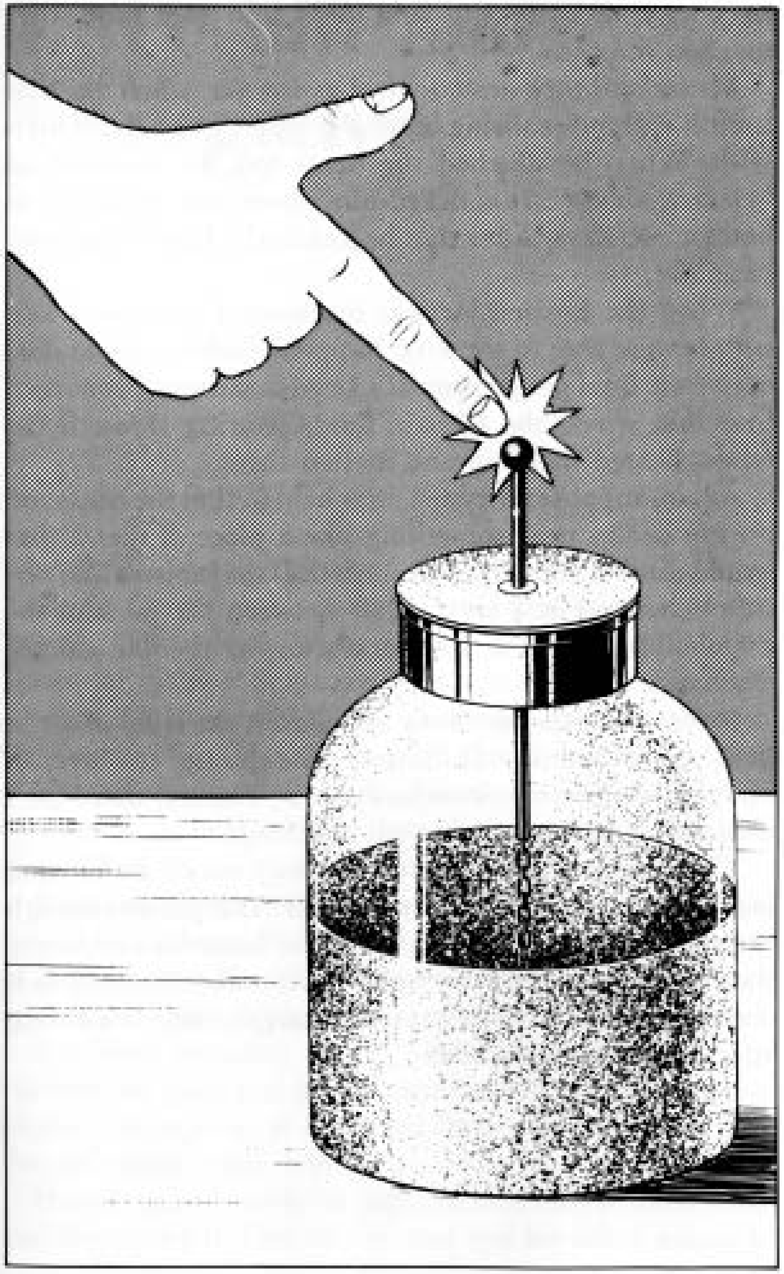
If the glass rod was electrified again, more electric fluid could be passed into the jar. Eventually, enough electric fluid could be passed into the jar to make it very highly charged with electricity.

One of the inventors of this kind of jar was a Dutch professor named Peter van Musschenbroek. He worked at the University of Leyden in the Netherlands, so the new device came to be called a "Leyden jar".

The more electric fluid you squeeze into a Leyden jar, the more it is likely to be pushed out again. It is like packing more and more clothes into a trunk. The more you put in, the greater is the push of those clothes against the trunk-lid. If the latch flies open some of the clothes tumble out. The same thing happens in the Leyden jar. The more you charge it with electricity, the more easily something might happen to discharge it and let the electric fluid come pouring out.

The first people who worked with the Leyden jar found that once it was fully charged, it could be dangerous. A careless touch to the brass rod on top would allow all the

Receiving an electric shock from a Leyden jar



electricity to come out and pass into the hand that touched it.

Musschenbroek tested his Leyden jar when he first built it without realising how large a charge he could fill it with. When he touched the brass rod, he received an "electric shock". It knocked him down and he stayed in bed for two days. After that he handled a Leyden jar very carefully.

When the Leyden jar was discharged in other ways, people were able to see what happened when a great deal of electric fluid poured out. If a Leyden jar was discharged into thin wires, the electric fluid, pouring through the wires, heated them up and melted them.

Again, suppose a Leyden jar is held so that the brass rod on top comes near something like a piece of metal that would discharge it if it was touched. If the jar isn't allowed to touch, there is a layer of air between the jar and the metal. The air is a non-conductor so the jar cannot discharge.

If you bring the jar closer and closer, the layer of air in between is thinner and thinner. The thinner the layer of air, the less of a non-conductor it is. Finally, there isn't enough air present to prevent discharge.

The electric fluid then forces its way out of the Leyden jar through the air and into the metal. As it passes through the air, it heats it so that it glows. The heated air expands, then comes back together again, and makes a sound as it does so. When the Leyden jar discharges, there is a strong spark and a sharp crackle.

4. Positive and negative

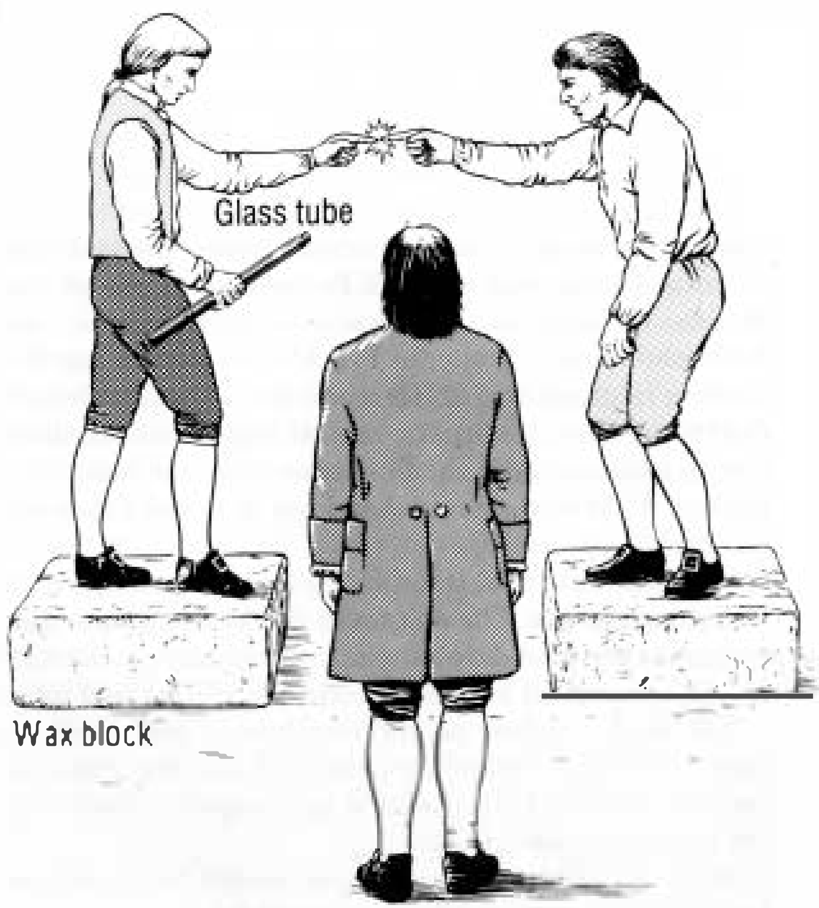
The news about electrical experiments crossed the Atlantic Ocean and reached Pennsylvania, one of the British colonies in America. In Pennsylvania, an American named Benjamin Franklin received a Leyden jar from England in 1747. He wondered where the electric fluid came from. If someone rubbed a glass rod and filled it with electricity, did the fluid come from the hand that rubbed it? Where did the hand get it from? From the ground?

Franklin decided to test this. He had a man stand on a large block of wax. The wax was a non-conductor, so that as long as the man didn't touch anything except the wax and the air around him, no electricity could get into him.

The man standing on the wax held a glass rod. He rubbed the glass rod in the usual way and the glass rod became electrified. It attracted light objects. Where did the electricity come from?

It must have come from the man himself. He must have had electricity in him all the time but for some reason it

Benjamin Franklin's experiment with men on wax blocks



didn't show up. When he rubbed the glass rod, some of the electricity entered the rod. But then what about the man himself? He had lost the electric fluid that had entered the rod. What was the result of that?

To test the matter further, Franklin had another man stand on a second block of wax. The first man touched the second man with the electrified glass rod. The electric fluid poured into the second man. The second man was electrified. Feathers stuck to him. If he placed a finger near a conductor, there was a spark and then he wasn't electrified any longer. He was discharged.

But what about the first man who had lost the electric fluid to the second? He was electrified also. He, too, could attract feathers. He, too, could be discharged, forming a spark when this happened.

What's more, the two men had different electric charges. The second man who had been electrified by the glass rod had what Du Fay would have considered glass-electric fluid. The first man had resin-electric fluid. (This could be checked by preparing little pieces of cork, some of which were electrified by a glass rod and some by a resin rod. Then you could see which ones would be attracted to which man and which would be repelled.)

It seemed to Franklin this was what happened: every object already contains a certain amount of electric fluid but behaves as though it is unelectrified. It doesn't attract anything.

Through the act of rubbing, some electric fluid is rubbed away from an object or rubbed into it. The object then has either *more* than the normal amount of electric fluid, or *less* than the normal amount. In either case, it acts as though it has an electric charge. If it had more than the normal amount of electric fluid, Franklin said it was "positively charged". If it had less than the normal amount, it was "negatively charged". If two objects each have a positive charge, they repel each other. Each object already has more than enough electricity and has no use for the electricity in the other. If two objects each have a negative charge, they repel each other. Each object has less than enough electricity and neither will give up any to the other.

If one object has a positive charge, however, and another a negative charge, then things are different. The object with the positive charge has extra electric fluid that it can give up, while the other has some missing electric fluid which it needs. The two objects therefore attract each other and when they touch, electric fluid goes from the positively charged object into the negatively charged object. After that, each object has the proper amount of electricity and neither one is charged. The two opposite charges have "neutralised" each other.

Franklin checked this. He had one man rub a glass rod and touch the other man with it. Now one man had too much electric fluid and one too little. Both were electrically charged—one with a positive charge and one with a negative charge.

He had the two men hold out their hands and place their fingers close together. When they did that, electric fluid jumped from one to the other. There was a bright spark between the two fingers. Both men felt their fingers tingle. Then neither man was electrified any more.

The question now was: which type of electric charge was positive and which type was negative? When glass was rubbed with silk, did the glass end up with more than the normal amount of electric fluid or less than the normal amount? There was no way Franklin could tell, so he guessed.

He decided that glass had less than the normal amount

of electric fluid after it was rubbed and that it was carrying a negative charge. This meant that a resin rod, which had the other kind of charge, carried a positive charge. All other electric charges were compared with those on resin and on glass and were described as either positive or negative, depending on whether they behaved like one or the other. (Many years later, when scientists were able to go deeper into the matter using new facts and methods Franklin did not have, they discovered that Franklin had guessed wrongly. It was the glass that had more than normal amounts of the fluid and the resin that had less than normal amounts. However, that did not spoil Franklin's basic theory.)

Once Franklin had worked out the behaviour of the electric fluid, he could explain how a Leyden jar worked. An ordinary rod of some particular kind of material would pick up only a positive or negative charge when it was rubbed. The more electric charge was squeezed into it, the harder it became to squeeze in any more. After a while, it held all it could.

In a Leyden jar, however, the metal coat on one side of the glass was negatively charged and the metal coat on the other side was positively charged. The glass in between kept them from coming together and neutralising each other. The negative charge of one metal coat kept attracting the positive charge from the other metal coat, and vice versa. As a result the total charge on the metal coats could be greater than that in a piece of material of the same size.

Next Franklin considered the spark and the crackle that came when a Leyden jar was discharged. It reminded him of lightning in a thunderstorm.

How about real lightning and thunder? Perhaps when a thunderstorm was brewing, the clouds and the Earth acted like a huge Leyden jar. Perhaps the clouds developed a negative charge and the Earth a positive charge (or vice versa) with the air between acting as a non-conductor. When enough charge was piled up in the clouds and air, the push to discharge became so great that the electric fluid forced its way through the air. There was a gigantic spark we call lightning and then a gigantic crackle we call thunder.

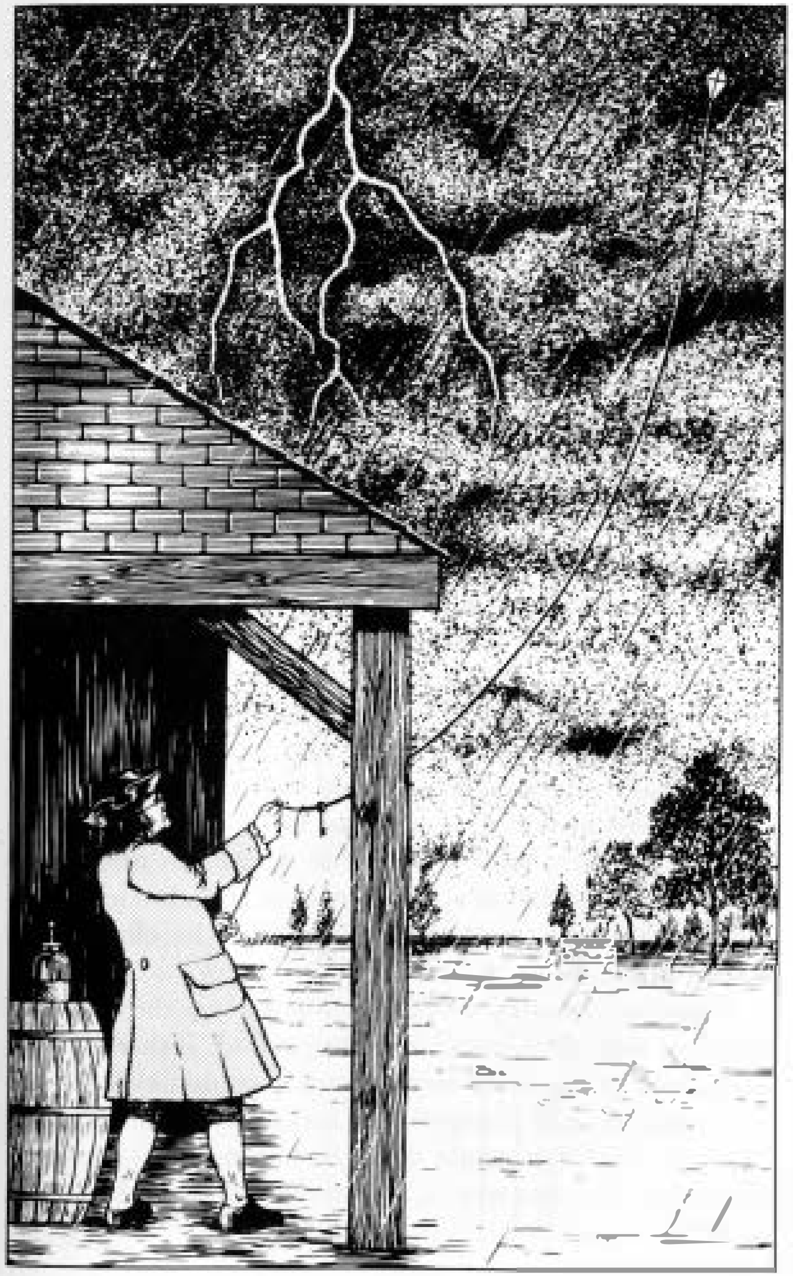
The amount of charge piled up before discharge took place was enormous. For that reason, the discharge was enormous, also. If a house discharged that quantity of electric fluid, the heat would set it on fire. If a human being discharged it, the effect might kill him or her.

In June 1752, Franklin thought he would test his idea by flying a kite during a thunderstorm. He tied a pointed metal rod to the wooden framework of the kite and attached a length of string to the metal rod. He attached a piece of cord to the twine that held the kite and at the bottom of the cord he attached a metal key.

If there was electricity in the clouds it would enter the metal rod on the kite and be conducted down the wet string to the cord and down the cord to the key. He didn't want to have it conducted into himself, since the electric shock might kill him. He therefore attached a silken string to the end of the cord holding the kite and he held the silk string. The electricity would not pass through the silk as long as he kept it dry. He was careful to stand under a shed while he was flying the kite. (Actually, flying a kite in a thunderstorm is very dangerous, and people have been killed doing it—so don't you try!)

The storm clouds gathered. After a while, Franklin noted that the fibres of the kite cord were standing apart as though all had gained the same electric charge and were repelling each other.

Franklin's kite experiment



Carefully, Franklin placed his finger near the key at the bottom of the string. There was a spark from the key to his finger and he felt the tingle. It looked just like the spark and felt just like the tingle when electric fluid was discharged in the laboratory.

He had brought an uncharged Leyden jar with him. He touched the brass rod to the key and then tested the jar. It was charged with electricity and behaved just as though the electricity had been produced by an electrified glass rod.

Franklin had proved that lightning was an electric spark. He had proved that the electricity formed in the clouds was the same electricity formed in the laboratory.

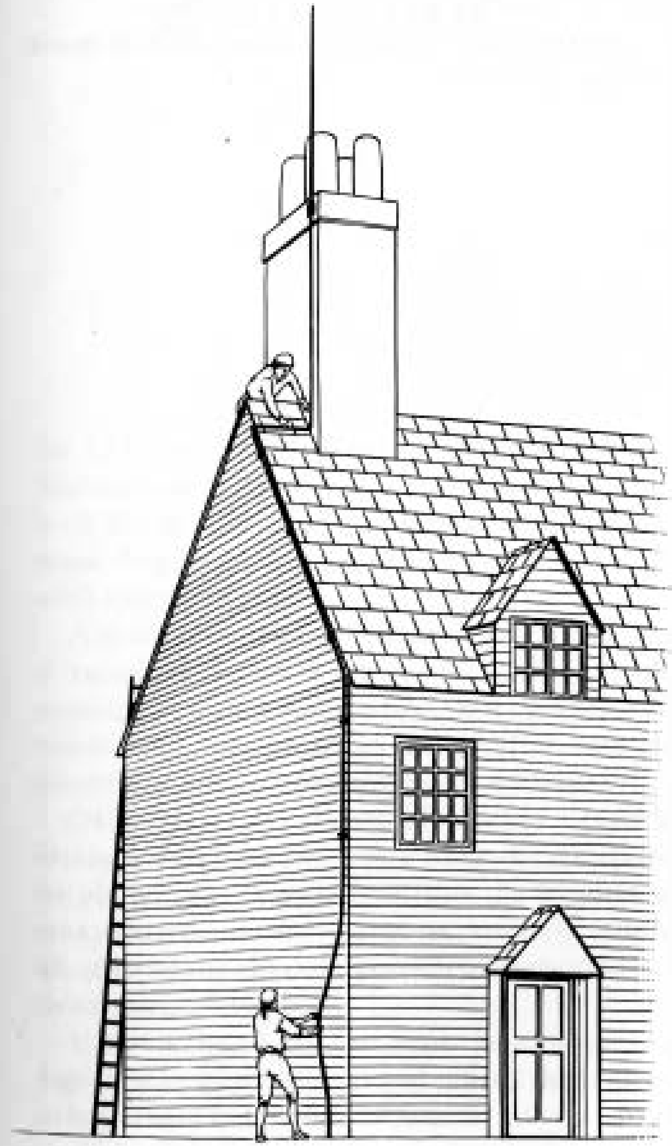
Franklin had done something else. In 1747, he had experimented with the first Leyden jar he had received. But instead of using a brass rod with a blunt end, he used a rod with a point.

He found that this made it easier for the Leyden jar to be discharged. In fact, a very sharp needle point made it so easy for the Leyden jar to discharge that it couldn't be charged in the first place. You could pump charge into a Leyden jar, but that charge would leak away through the needle point as fast as it was put in.

Once Franklin had showed that the clouds and Earth formed a huge Leyden jar during a thunderstorm, he thought a sharp point might discharge the clouds and Earth, also.

Suppose a pointed metal rod was put on the roof of a building and wires joined it to the ground. If that was the case, the house and the area around it would never pile up much charge. The charge would leak away as fast as it was built up and there would never be any need for a violent discharge. In other words, a house would never be struck by lightning.

Lightning rod on a chimney stack



In 1753, the year after his kite experiment, Franklin announced to the world how to install a "lightning rod" on a house. All over the American colonies and Europe people began to put lightning rods on buildings.

This was the first time electrical knowledge was made useful to people generally.

5. Batteries and generators

In 1771, electrical experiments took a new turn. An Italian biologist named Luigi Galvani was experimenting with Leyden jars. He also happened to be working with some frog legs in an experiment that had nothing to do with electricity.

A spark from the Leyden jar struck one of these legs and it twitched. Galvani was astonished because ordinary muscles contract only while they are alive. Electricity made dead muscles act as though they were alive. Could electricity have something to do with life?

Of course, Galvani knew of Franklin's experiments and he knew that lightning was a huge electric spark. Suppose he placed some frog legs outside the window when there was a thunderstorm in progress. With the storm filling the clouds and the air and the earth with electricity, would the dead muscles twitch?

When a thunderstorm came, he took some of the frog legs he was working with and placed them on brass hooks to keep them from being blown out into the street. Then he laid them across the iron grill-work outside his window.

Sure enough the muscles twitched and kept on twitching for quite a while.

But then he tried it again when there was no thunderstorm and when the weather was perfectly clear. The muscles *still* twitched. In fact, they twitched whenever they made contact with two different metals, such as brass and iron, at the same time.

Galvani decided that there must be a connection between electricity and life. Living things were full of electricity. He felt that this "animal electricity" didn't disappear all at once after death, so that muscles could still twitch when they touched two different metals.

Then another Italian scientist named Allessandro Volta began to wonder about this muscle twitching. He had worked quite a bit with electricity and he wasn't convinced that muscles had unusual amounts of electricity.

When muscles made contact with two different metals, maybe the electricity was produced by the metals, not by the muscles. If that was the case, perhaps the metals could be used to produce electricity without the muscles. Instead of putting a moist muscle across two different metals, suppose a piece of moist cardboard was put across them?

In 1794, Volta found that he could produce electricity without rubbing and without any kind of muscle tissue. Suppose two different metals were placed in salty water, which is a conductor. Suppose the metals underwent chemical change. These chemical changes somehow involved electricity. One of the metals would gain electric fluid and become positively charged, while the other would lose it and become negatively charged.

Volta continued to experiment, trying to build up as large a charge as possible. In 1800, he prepared a whole series of bowls of salty water. He bent a strip of copper from one bowl into a second bowl so that each end was in the salty water. This copper strip was connected to a tin strip in the second bowl. The strip of tin from the second bowl was bent over to a third, then a strip of copper from the third to a fourth, then a strip of tin, and so on. Each strip was connected to the strip in the next bowl.

All the copper strips developed a positive charge and all the tin strips a negative charge. All the charges seemed to add to each other so that the total charge for all the bowls together was much larger than it would have been if only one bowl was used.

Then Volta connected the tin strip at one end of the line of bowls to the copper strip at the other end with a metal wire. The excess electric fluid at one end ran through the metal wire to the other end where there was a shortage of electric fluid.

Because the chemical change involving the tin and copper continued to take place, a positive charge continued to be formed at one end and a negative charge at the other. The electricity kept running through the wire for as long as the chemical change continued.

Whenever you have a whole series of similar objects, you can call them a "battery" of objects. Volta had a whole series of metal strips in bowls of salty water that produced an electric charge. This was therefore called an "electric battery", and Volta had invented the first one.

Until Volta's time, all the electricity that had been experimented with had been electricity that stayed in a particular object. The electricity hardly moved. It was therefore called "static" electricity from a Latin word meaning "to stand still".

Volta's battery, however, produced electricity that ran through a wire steadily for a long time. He had produced the first "electric current".

At once people began to experiment with this new electric device. They constructed new and better batteries. They found that if chemical changes produced an electric current, an electric current could also be used to produce chemical changes.

In 1800, the very year in which the battery was invented, an Englishman named William Nicholson used an electric current to split water into two gases, hydrogen and oxygen. He showed that water was a chemical combination of those two gases.

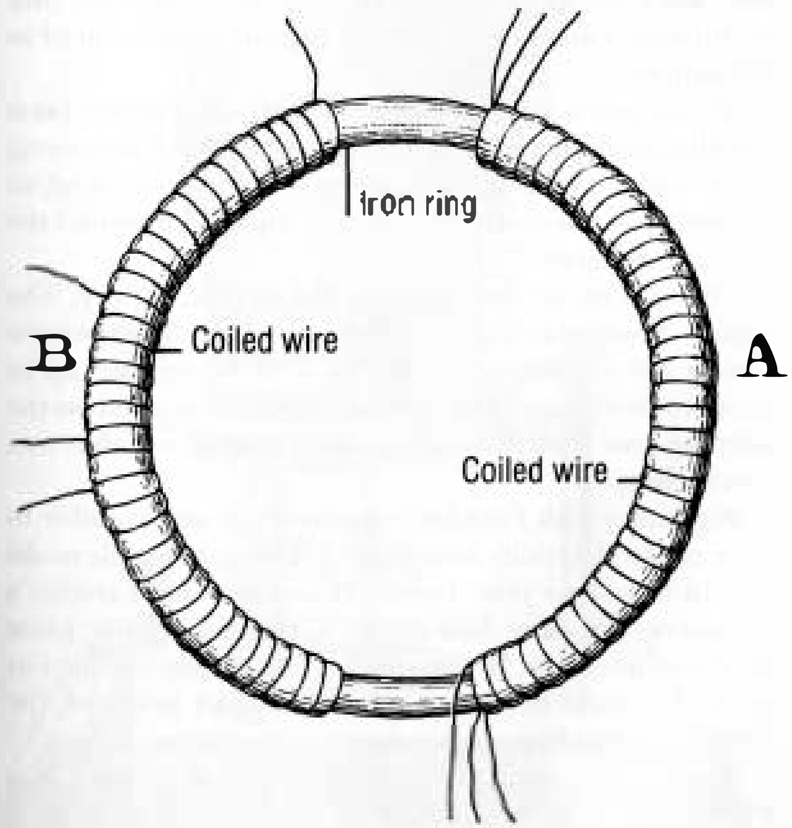
In 1807, another Englishman named Humphry Davy used an electric current to break up certain rocky substances that no one had ever been able to break up before. He obtained new metals that no one had ever seen before.

Then, in 1819, a Danish scientist, Hans Christian Oersted found that when a wire was carrying an electric current it acted like a magnet. The two attractions, electricity and magnetism, apparently had some connection after all.

At once, experimenters began to study the new fact. In 1829, an American scientist, Joseph Henry, showed that if wire carrying electric current was wound into coils, the magnetic attraction became stronger. Each coil of wire seemed to reinforce the next. It was important to wrap all the wire in silk, however, so that the current could not jump from one coil to the next but had to travel through the full length of the wire.

If the coils of wire were wrapped about a piece of iron, the magnetic pull became even stronger. It was far

"Electromagnet"



stronger than that of any ordinary magnet. What's more, this "electromagnet" could be easily turned on and off. If the wires were attached to a battery, the magnetic pull started. If the wires were pulled away from the battery, the magnetic pull stopped.

Henry used a small electromagnet to lift more than a tonne of iron. He could move the iron to where it was wanted and then he could release it.

An English scientist, Michael Faraday, showed that just as electricity could produce magnetism, magnetism could be used to produce electricity. In 1831, he showed that when a copper plate was made to turn round and round near a magnet, an electric current was produced in the copper.

If you use a steam engine to keep the copper plate turning, electric current can be led away from it for as long as the steam engine keeps working. Faraday produced, or "generated", electricity in this way and had invented the "electric generator".

This was an improvement on the electric battery. The battery produced electricity only while certain expensive metals like copper, tin, and zinc were being used up in chemical reactions. The electric generator worked on the burning coal that powered a steam engine and that was much cheaper.

Beginning with Faraday's discovery, it was possible to have cheap electricity in as large amounts as people could use. In that same year, Joseph Henry reversed Faraday's discovery. Faraday had made a turning copper plate produce electricity. Henry showed how an electric current could be made to turn a wheel. He had invented the "electric motor".

The electric motor could be started and stopped in a moment. A tiny electric motor could keep small objects

Alexander Bell's "telephone"
(transmitted first speech 1876)

Morse code

A	•—	S	•••
B	—•••	T	—
C	—•——	U	••—
D	—••	V	•••—
E	•	W	•——
F	•—•	X	—••—
G	——•	Y	—•——
H	••••	Z	——••
I	••		
J	•———	1	•————
K	—•—	2	••———
L	•—••	3	•••——
M	——	4	••••—
N	—•	5	•••••
O	———	6	—••••
P	•——•	7	——•••
Q	——•—	8	———••
R	•—•	9	—————

moving. A gigantic electric motor could keep enormous objects moving. It was possible to make electricity do most of the work that human and animal muscles had been doing all through history.

Little by little, inventors made use of the electric current to do amazing things.

The American inventor, Samuel F. B. Morse, built the first important electric "telegraph" in 1844. The electric current in a long wire could be started and stopped so as to send very short signals (dots) or somewhat longer ones (dashes). The dots and dashes were arranged in different ways for each letter of the alphabet.

This "Morse code" made is possible to send messages long distances at the speed of electricity, which is nearly 300,000 kilometres a second. A telegraph message can pass from New York to San Francisco in less than ⅟₆₀ of a second.

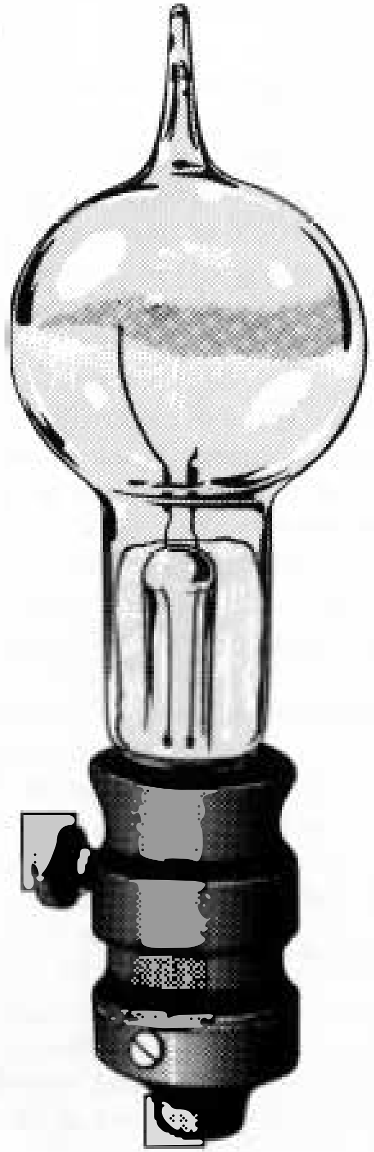
In 1876, a Scottish-American inventor, Alexander Graham Bell, worked out a method for making an electric current get weaker or stronger in such a way as to produce sound waves. He invented the "telephone".

In 1879, the American inventor, Thomas Alva Edison, found a way to run an electric current through a carbon thread in a closed gas container that held no air. The electric current heated the thread till it glowed white-hot. Since there was no air, it couldn't burn but just kept on glowing. Edison had invented the "electric light".

Many other inventions were made. Nowadays, we all use the electric current. We can use it for cooking, heating, cooling, freezing, lighting. We use it to run our record player, our radio, our television set. We use it for electric carving-knives, electric toasters and electric hairdryers.

There is no end to the many uses of electricity. Every

Thomas Edison's first electric light bulb 1879



year people are using more and more electricity. This makes our lives completely different from those of our ancestors.

The is all the result of the curiosity of many people who over many centuries kept wondering why things behaved as they did.