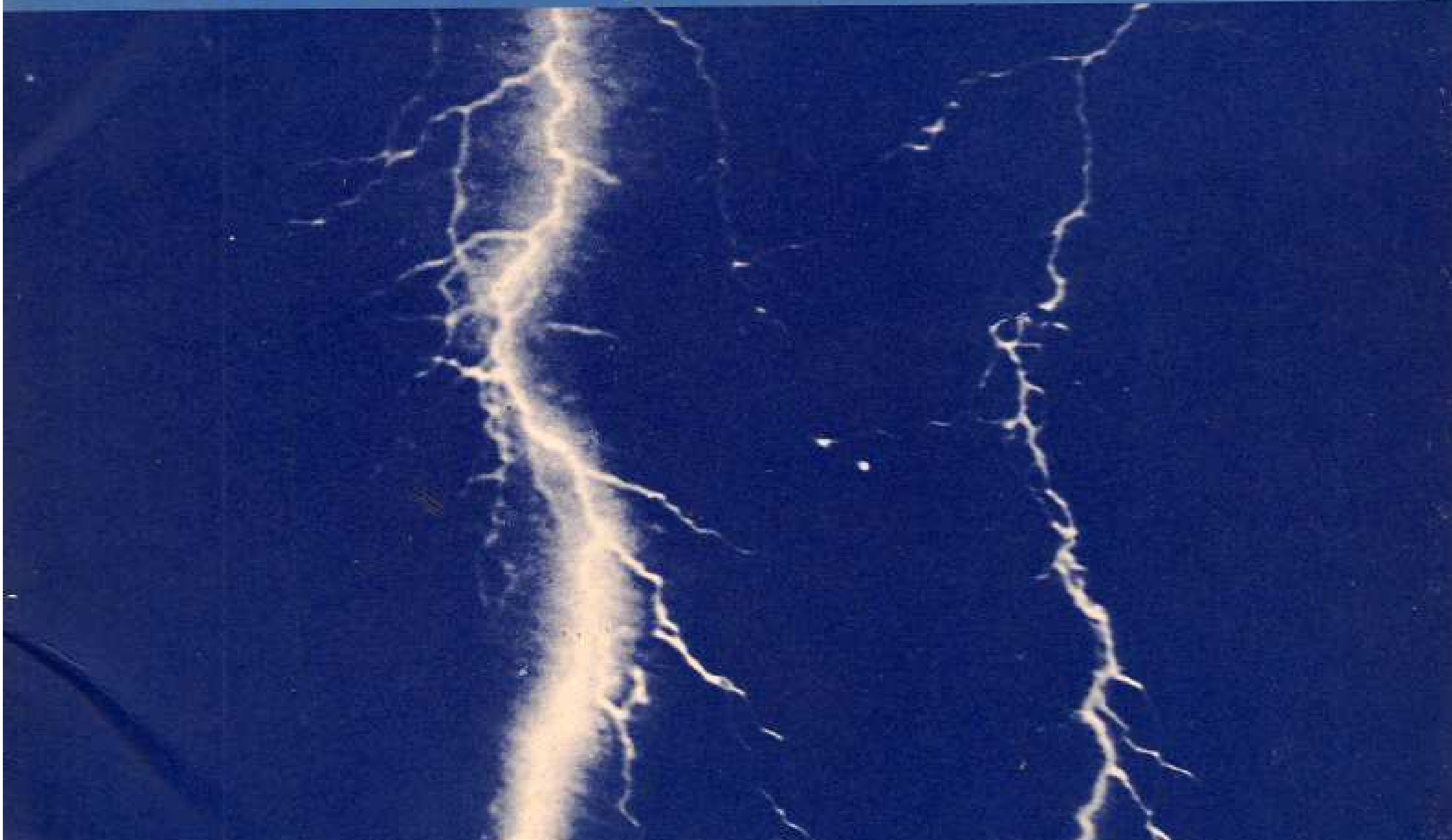
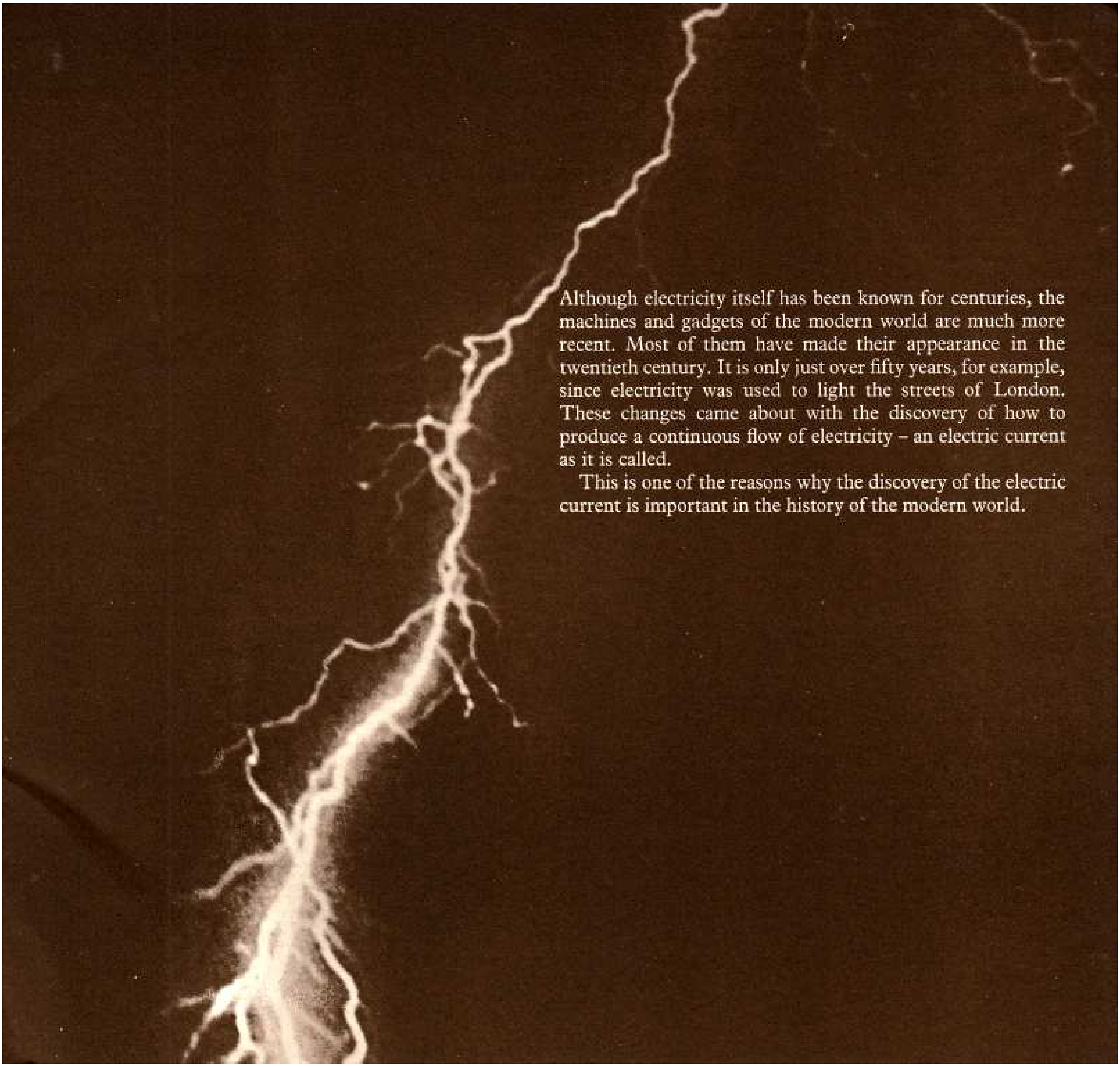
Chemistry Background Books

The Discovery of the Electric Current



Davy demonstrates in 1809 the arc light formed between two pieces of charcoal attached to the poles of his battery, and the audience witnesses electric lighting for the first time.
From 'An Illustrated History of Science' by F. Sherwood Taylor

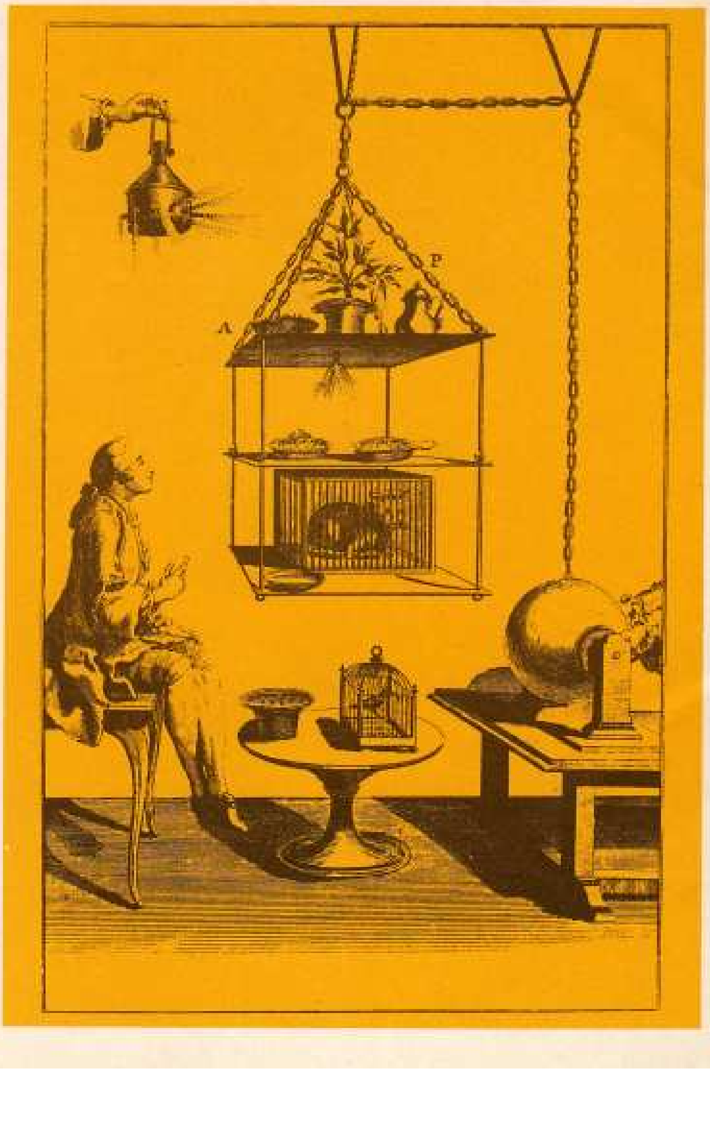


Although electricity itself has been known for centuries, the machines and gadgets of the modern world are much more recent. Most of them have made their appearance in the twentieth century. It is only just over fifty years, for example, since electricity was used to light the streets of London. These changes came about with the discovery of how to produce a continuous flow of electricity – an electric current as it is called.

This is one of the reasons why the discovery of the electric current is important in the history of the modern world.

The first electrical machine – a sulphur ball rotating on a shaft – which was constructed in 1660 by Otto von Guericke.
Institute of Electrical Engineers

Early studies into electricity. Here the Abbé Nollet (1700 – 1770) tries out the effect of electricity produced by an electric machine (bottom right) on flowing water and on living things. Jets from the fountain (top left) spurted towards the electrified chain but only trickled from the spouts on the side away from the chain. Plants grew rapidly under the influence of electricity, but cats and pigeons lost weight.



part one Galvani

Luigi Galvani (1737–1798)
discoverer of current electricity.

Until the end of the eighteenth century, electricity was not much more than a curiosity. More than 2000 years ago the Greek scientist Thales discovered that lumps of amber, when rubbed with silk, could attract small pieces of straw. Amber was called an 'electric' (from the Greek *elektron*: amber), and in the sixteenth century Dr William Gilbert, an English scientist at the court of Queen Elizabeth, listed several others: diamond, sapphire, amethyst, rock crystal, glass, silver, and sealing wax. All these substances became 'electrified' when rubbed with silk or a dry cloth, and could then attract small pieces of straw and other materials.

In 1660 Otto von Guericke, who lived at Magdeburg in Germany and who is better known for his invention of an air pump, designed the first electrical machine. It consisted of a ball of sulphur rotating on a shaft. When a dry hand was laid on the turning sulphur, the ball became electrified and gave off small sparks and crackling noises. Von Guericke noticed that the electrified ball would agitate nearby drops of water as well as attract small objects. His machine was later improved by various people (especially Benjamin Franklin in the United States), and the work led to machines with rotating glass spheres or discs similar in many ways to the Wimshurst machines which are to be found in physics laboratories. But none of these machines could produce a continuous flow of electric charge, or an electric current as we now call it. That was not possible until after the work of Luigi Aloisio Galvani.

Galvani's first experiments on the effect of electricity on frogs' legs. On the left of the bench is Galvani's electrical machine. On the right is an old-fashioned condenser, a Leyden jar, filled with lead shot and used for storing electrical charge. This and the other two engravings of Galvani's experiments appeared in Galvani's original publication of his discoveries in 1791. The letters and figure numbers in the engravings referred to Galvani's text and should here be ignored.
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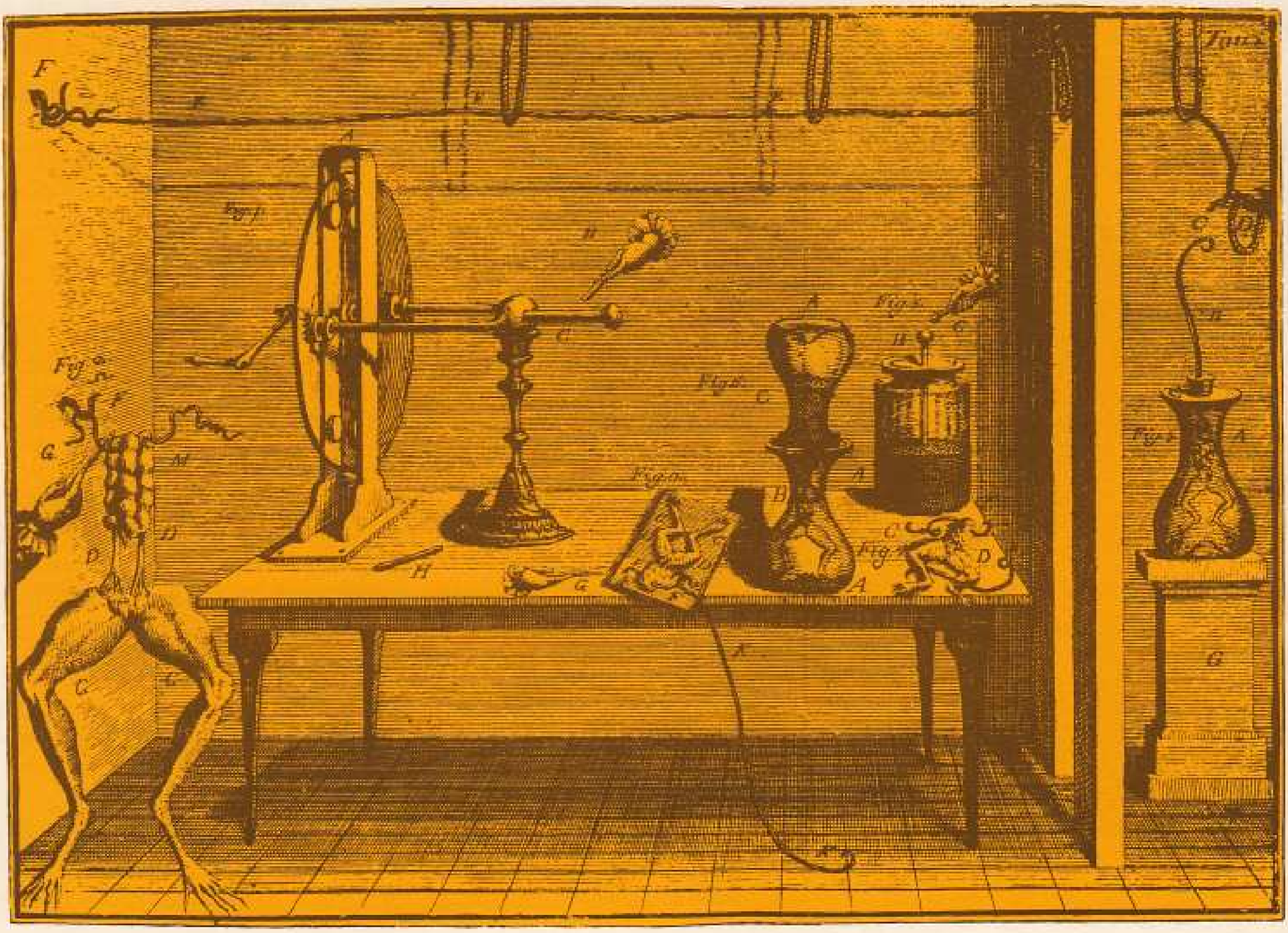
Galvani was a professor at Bologna in Italy. His discoveries sprang from an occasion, in 1786 or one of the years immediately before, when he was working in his laboratory with his wife and an assistant. One of them noticed that the legs of a dead frog gave a sudden kick when touched with the blade of a scalpel.

An account of this observation is given by Galvani himself in the following way: 'I had dissected a frog and placed it upon a table on which there was an electric machine. While one of those who were assisting me touched lightly the point



of a scalpel on the nerves of the frog, suddenly all the muscles of its limbs were seen to be violently contracted.'

Naturally, Galvani was excited by this observation. The leg muscles appeared to contract repeatedly 'just as though they had been seized with a violent cramp'.

At first, Galvani thought that frogs' legs would only be affected when the electric machine was being used. The next step was to study the effect of lightning, or atmospheric electricity, on muscles. Galvani fixed some frogs' legs with brass hooks to an iron lattice outside his house, and then

Galvani's experiments on the effect of lightning on frogs' legs. The scene shown here – with one pair of legs on a table and another suspended in a bottle – is not the one described in the text in which the legs were fixed to an iron lattice.
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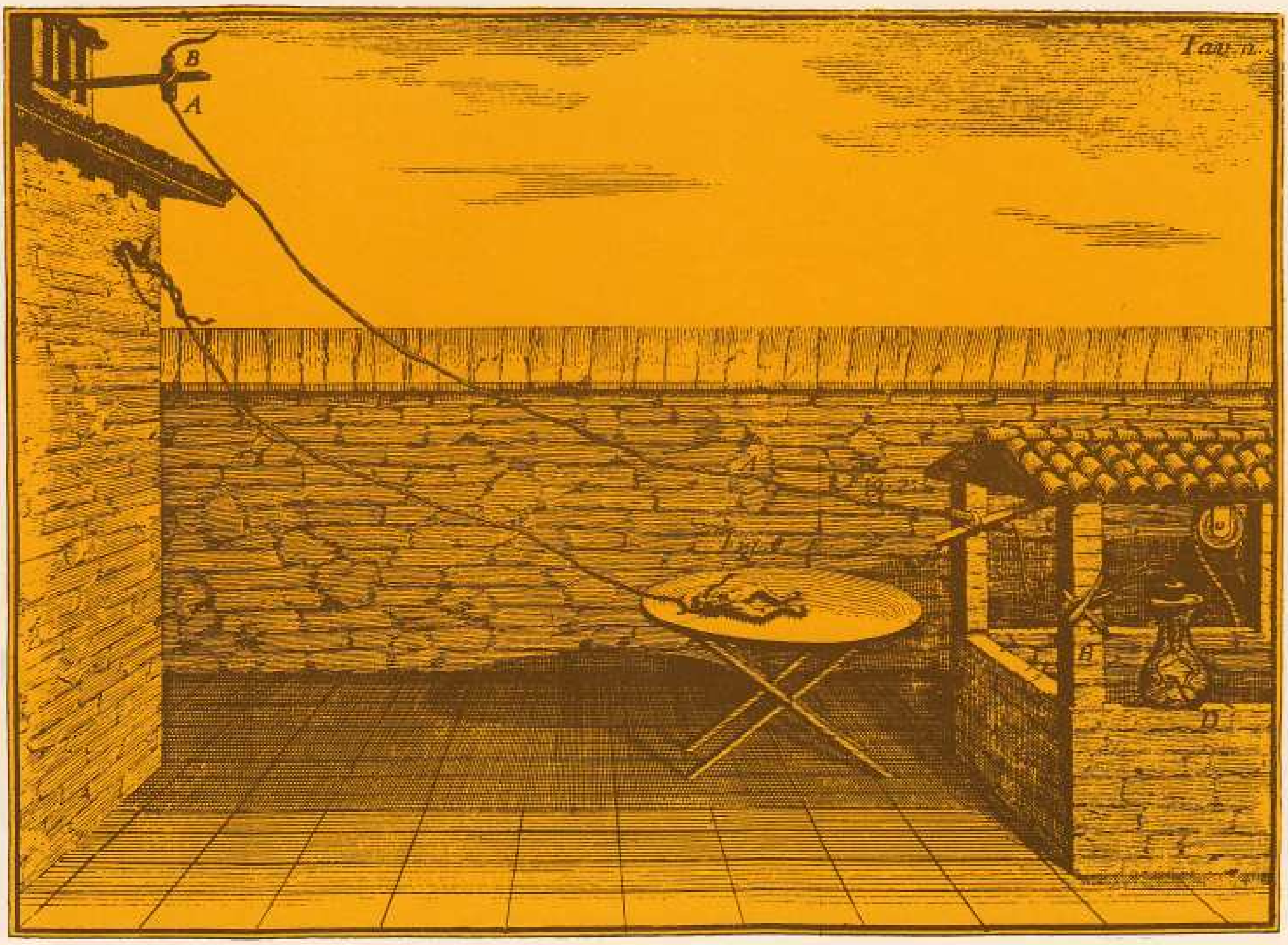

Galvani's metallic arc – consisting of copper and silver rods, either welded or held in each hand. This engraving shows that Galvani later extended his experiments from frogs to warm-blooded animals: on the left of the bench is a sheep and above it is a chicken's leg.
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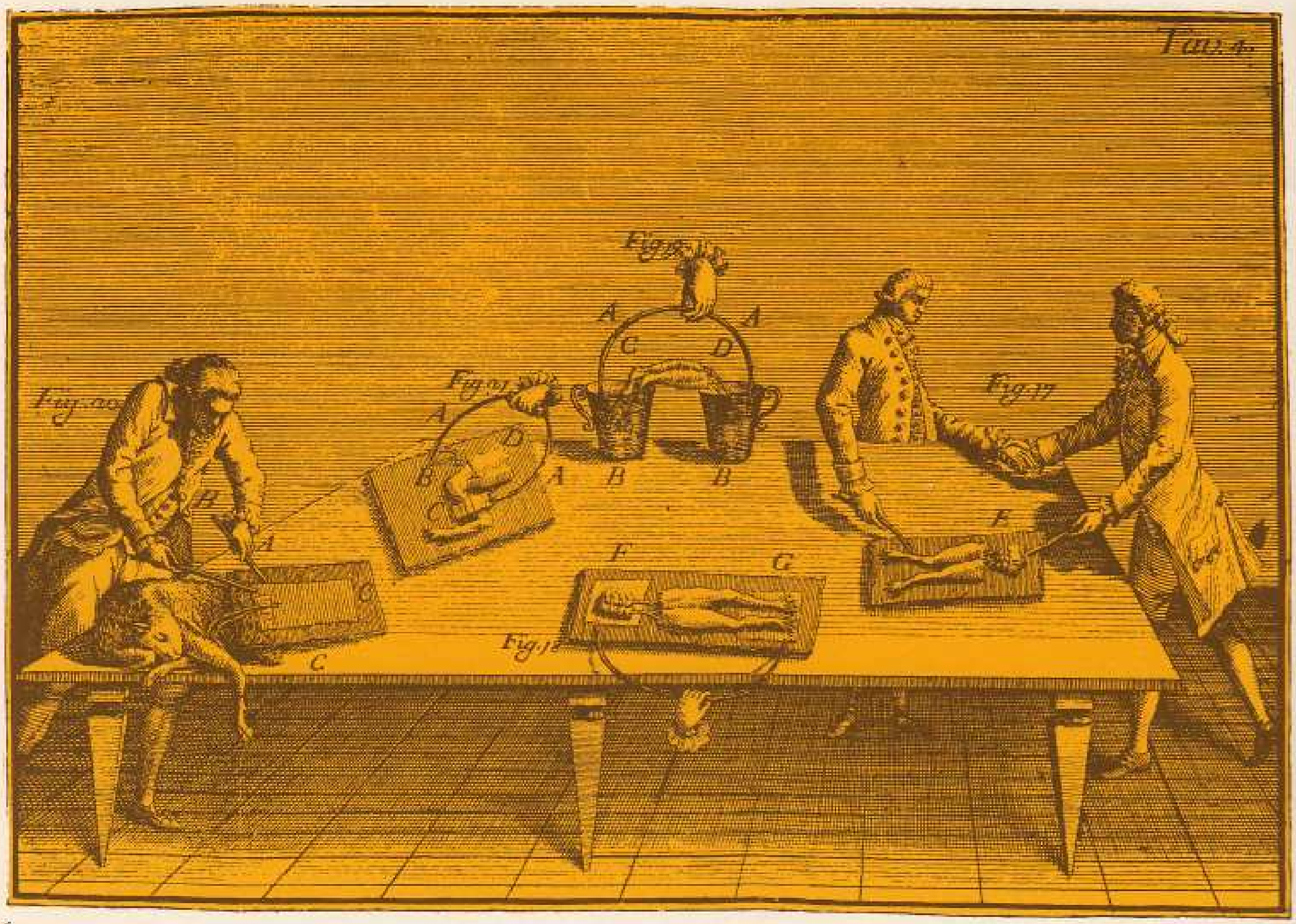

connected the legs to the ground with long iron wires. This arrangement was meant to be a kind of lightning conductor by means of which electricity would be forced to pass through the frog's leg on its way into the ground. When lightning flashed from the sky the leg muscles convulsed and twitched as he had hoped.

Galvani continued his experiments with lightning, but in Italy the days are generally sunny and often he had a long time to wait for lightning. On 20 September 1786 the sun shone brightly from a clear sky and Galvani was getting impatient. He looked at the frog's leg which his wife and he had freshly prepared and hung on the iron lattice. This is what happened:

'The frog's leg, fastened by brass hooks to the iron lattice round the garden wall of my house, exhibited convulsions not only during thunderstorms, but sometimes when the sky was quite serene. Once, weary of waiting in vain, I pressed the brass hooks, which were driven into the spinal marrow of the frog, against the iron lattice and observed contractions of the muscles tolerably often. I came very near to adopting the theory that the contractions were due to atmospheric electricity, which, having slowly entered the animal and accumulated in it, is suddenly discharged when the hook comes into contact with the iron lattice, for it is easy in experimenting to deceive ourselves, and to imagine we see things we wish to see. So I took the animal into a closed room and placed it on an iron plate. When I pressed the hook, which was fixed still in the spine, against the plate, behold! the same muscular contractions as before. I tried other metals at different hours on various days, in several places, and always the same result, except that the contractions were more violent with some metals than with others.'

After a great many experiments of this kind, Galvani arrived at an explanation. At first, he was tempted to think that the contractions were due to the storage of atmospheric electricity in frogs' legs. But then he had convinced himself that the twitching would occur indoors, simply by touching the nerves and muscles with metallic objects. Galvani concluded that the bodies of dead animals must contain electricity – 'animal electricity' as he called it.

This is how Galvani explained what happened in his experiments. He knew that when he touched the muscle of a frog's leg with a copper rod, and the nerve of the same leg with a rod of zinc, and when he made the ends of the two rods touch, the leg would give a kick. Galvani thought this happened because the two metals allowed the 'animal electricity' to jump from nerve to muscle.

But this explanation was incorrect. Galvani did not realize that the cause of the electrical twitching of the muscles was not some mysterious store of animal electricity but a quite unsuspected source of electricity – the touching of two different metals. What Galvani had done, without quite knowing it, was to make a very crude electric battery.

part two Volta

Alessandro Volta (1745 – 1827) inventor of the electric battery. *Burndy Library*

The correct explanation of Galvani's experiments was first put forward by a countryman of his – Alessandro Volta, Professor of Physics at the University of Pavia. Volta repeated many of Galvani's experiments, and at first agreed with his explanation that electricity originates in animal tissues. But he quickly shifted his attention to the metal rods.

Volta began with an observation by the Swiss J. G. Sulzer in 1780. Sulzer 'happened to place his tongue between pieces of lead and silver whose edges were in contact, and thereupon noticed an unpleasant, pungent taste'. When he placed the metals separately on his tongue he failed to produce the taste. Sulzer did not follow up this experiment, but Volta tried it out and got the same results. At the risk of blinding himself, he even included his eye in the circuit, and observed the sensation of light which electricity created.

Volta then carried out a large number of experiments, and after two years' hard work he published his new theory. The electric current responsible for Galvani's observations was not 'animal electricity' but what Volta called 'metallic electricity'. He maintained that two different kinds of metal, when brought into contact with a moist body, will produce an electric current, and that if this electricity is passed through a nerve, the muscle controlled by the nerve will move. He also discovered that the strength of the current depended on the kinds of metals used. He arranged metals in a series, so that pairs of metals which were further apart in the series produced the greater electric currents. Volta's series was: zinc, lead, tin, iron, copper, silver, gold.

By the time Galvani had published his work, Volta had already made a name for himself as a physicist. In 1791, he was elected a Fellow of the Royal Society in London – a very high distinction seldom given to foreigners. In presenting the

Volta's earliest pile – pairs of zinc discs (Z) and silver discs (A) are separated by paper strips soaked in salt water. Thirty such pairs give a continuous flow of electricity to a person placing a finger in each of the two cups.
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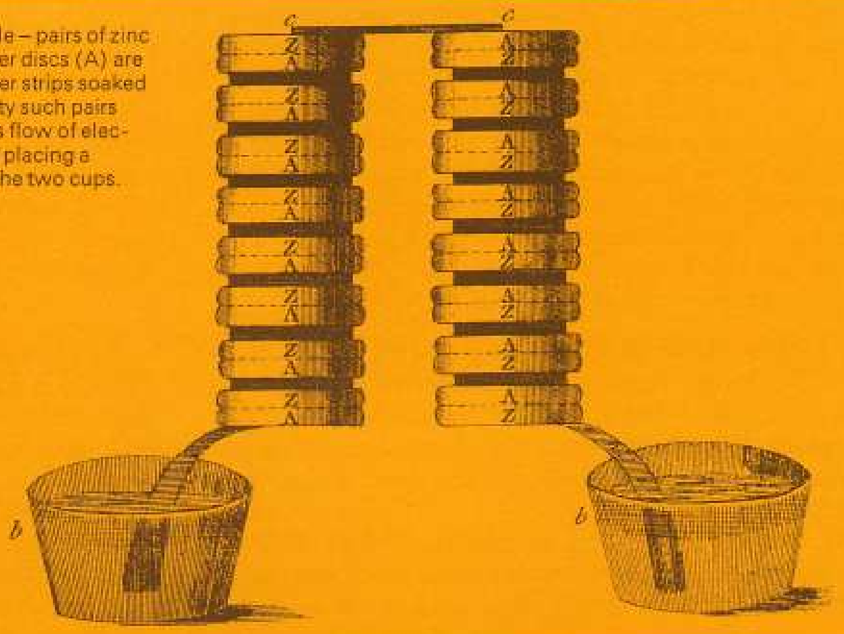

Another arrangement of the Voltaic pile – as described in Volta's letter to the Royal Society in 1800. The cups are filled with weak acid or salt water into which zinc (Z) and silver (A) plates, connected by metal rods, are dipped.
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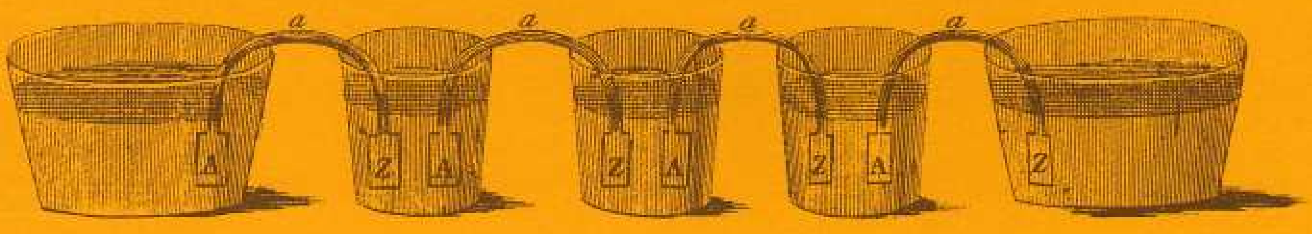


Royal Society Medal to Volta; the President of the Royal Society, Sir Joseph Banks, said: 'To Professor Volta is reserved the merit of bringing the experiments of his fellow countryman, Dr Galvani, to the test of sound reasoning and accurate investigation. He has explained them to the whole of Europe.'

Volta continued with his researches, and in 1800 he published details of one of the most fruitful of all inventions – the Voltaic 'pile' or the electric battery. This device could provide a steady flow of electric current. It was a great step forward in the development of electrical science and technology.

Volta's pile consisted of pairs of discs of zinc and silver stacked in a pile, each pair being separated by a moist cloth or paper. With about 60 discs in the pile, a person could feel a distinct electric shock when touching the upper and the lower discs with the fingers.

In 1800 Volta described his invention of the pile in a letter to Sir Joseph Banks. Written in Italy, the letter had to cross France, which, at that time, was at war with England. When the letter eventually arrived, Volta's description aroused great interest.

Two English scientists, William Nicholson and Anthony Carlisle, were the first to make practical use of a Voltaic pile. They constructed their own from the description in Volta's letter to Sir Joseph Banks. It consisted of thirty-six silver half-crowns alternating with thirty-six zinc discs, separated by paper soaked in salt water. They connected the pile to platinum wires dipped in water and obtained bubbles of gas – oxygen at one end and hydrogen at the other. For the first time water had been broken down by an electric current into the substances of which it is formed.

Sir Humphry Davy seized on this experiment because he thought it would help to break down other substances into the elements of which they are made. His instinct was right, and Davy made many important discoveries. But he gave credit to the first experimenters when he said: 'The origin of all that has been done in electro-chemical science was the discovery by Nicholson and Carlisle of the decomposition of water on 30 April 1800.'

Davy suggested a second explanation of how electricity may be produced in Voltaic piles. He said that the electricity could result from chemical changes in the metals rather than from contact between them. Both theories were valuable in finding out more about electric current. And after the invention of the electric pile, scientists began to see all sorts of ways in which its electric current could be used.

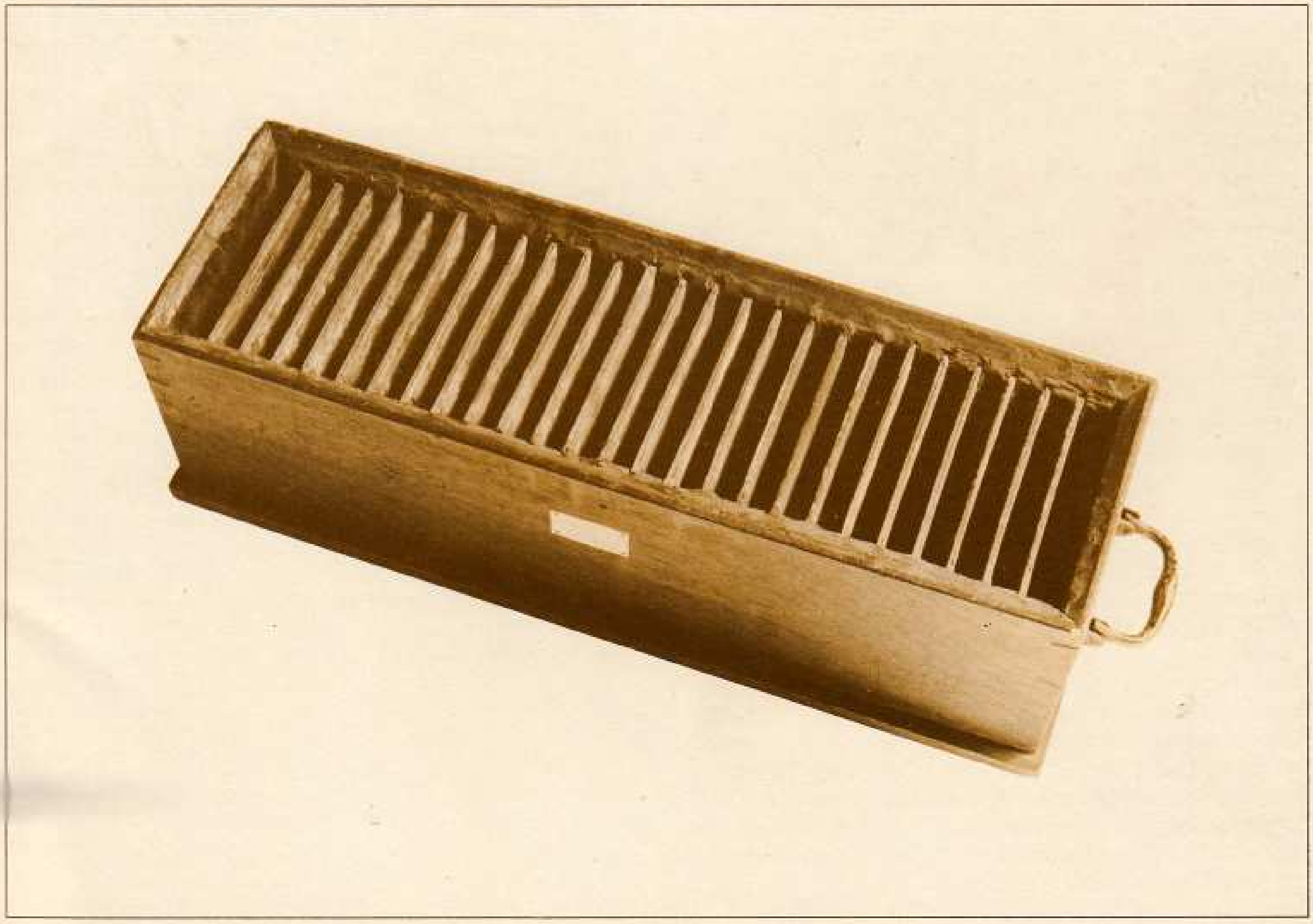
Davy himself improved the design of the Voltaic pile and then, by passing an electric current through different substances, he discovered several new metals. In 1809 he assembled in the vaults of the Royal Institution in London the largest Voltaic pile ever made. It consisted of 2000 pairs of plates eight inches square, and Davy used it to produce a brilliant arc light. (See the Background Book, *Humphry Davy*.)

The battery with which Sir Humphry Davy (1778–1829) carried out some of his electro-chemical experiments. It was designed by Dr William Cruickshank. The putting of the metal plates in a specially-prepared wooden box enabled the battery to be carried about, and was a great improvement on earlier versions of the Voltaic pile.
Royal Institution photograph

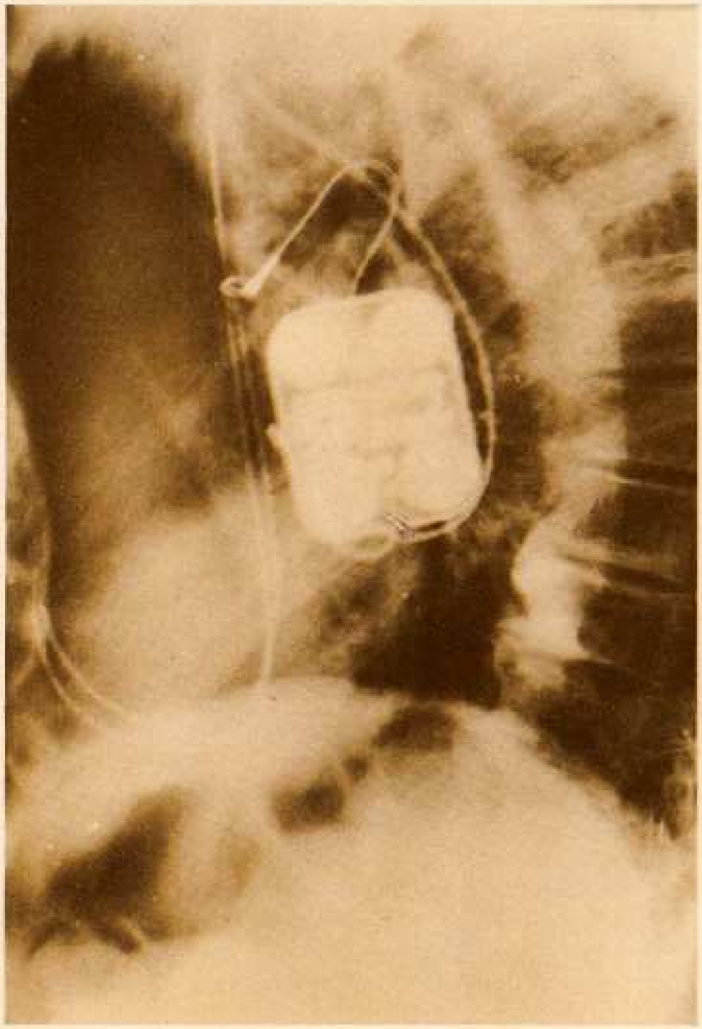
That feat was a promise of things to come.

Since the beginning of the nineteenth century, there have been a great many improvements in methods of making electricity, and a great many uses for it have been developed. But the principle of the Voltaic cell is still widely used. There are the dry batteries which are used to operate electric torches or transistor radios. When larger electric currents are required, as for lighting the headlamps of motor cars, it is possible to use bigger batteries which contain acid and which, at first sight, resemble some of the devices which Davy used. In practice, however, batteries such as those used in motor cars (accumulators as they are called) differ from ordinary batteries in that, when their electricity has been used up, they can be recharged by connecting them to the mains.

To supply the daily needs of factories and houses, however, batteries are too cumbersome and too expensive. This is why the electricity generating stations are important, and they operate on a different principle from that of the Voltaic cell. In power stations, electricity is made by machines called dynamos, or alternators. These are complicated drum-



Even today, electricity is used to stimulate muscles – reminiscent of Galvani's experiments on frogs' legs. Here a small battery, called a 'pacemaker', is implanted near the heart to stimulate the heart muscles.



shaped networks of wire made to spin rapidly between the poles of a powerful magnet. All the electricity in the National Grid is made by dynamos.

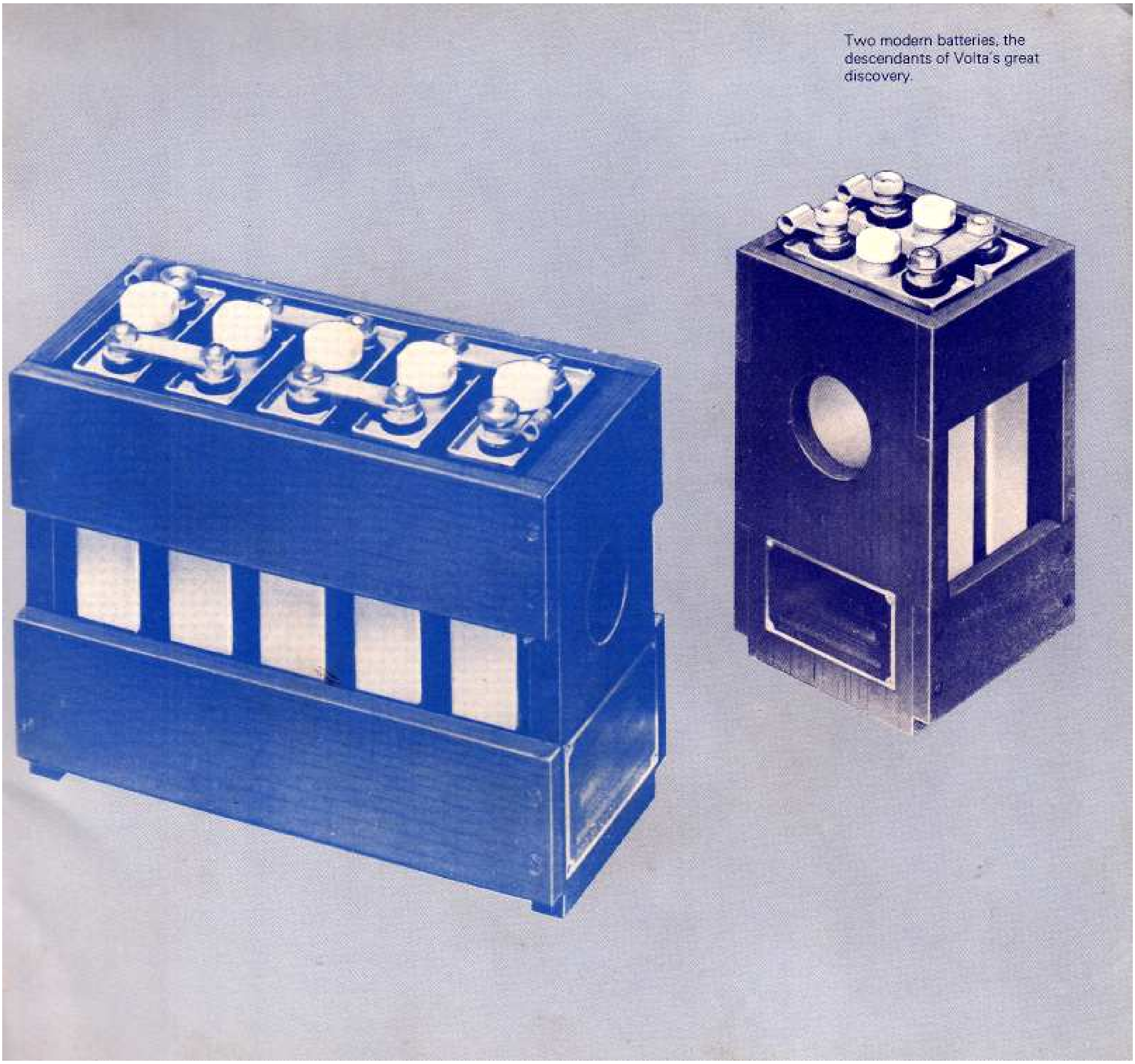
The great industry which makes electricity in Britain is a proof of how important electric current has become. A great deal has happened since Galvani and Volta first showed how it might be possible to exploit this source of power, but there is no forgetting the importance of what they did.

Questions

1. One electrical measuring instrument is named after Galvani, and another after Volta. What are they?

2. The electric battery provides a very useful way of 'storing' electric current, and it is easily carried about – as, for example, in a car or a torch. But batteries are no longer used to provide electricity on a large scale for power and lighting. Instead there is another way of producing electric current, discovered by Davy's assistant, Michael Faraday. Describe this other way.

3. With what part of Volta's work does the following statement of Galvani link up: '. . . the contractions were more violent with some metals than with others?'



Two modern batteries, the descendants of Volta's great discovery.

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