13 January 1956, Volume 123, Number 3185 SCIENCE

Farther Experiments and Observations in Electricity

Benjamin Franklin

§1. There will be the same explosion and shock if the electrified phial is held in one hand by the hook, and the coating touch'd with the other, as when held by the coating, and touch'd at the hook.

2. To take the charg'd phial safely by the hook, and not at the same time diminish its force, it must first be set down on an electric *per se*.

3. The phial will be electrified as strongly, if held by the hook, and the coating apply'd to the globe or tube; as when held by the coating, and the hook apply'd (*1*).

4. But the *direction* of the electrical fire being different in the charging, will also be different in the explosion. The bottle charged through the hook, will be discharged through the hook; the bottle charged through the coating, will be discharged through the coating, and not otherways; for the fire must come out the same way it went in.

5. To prove this, take two bottles that were equally charged through the hooks, one in each hand: bring their hooks near each other, and no spark or shock will follow; because each hook is disposed to give fire, and neither to receive it. Set one of the bottles down on glass, take it up by the hook, and apply its coating to the hook of the other; then there will be an explosion and shock, and both bottles will be discharged.

6. Vary the experiment, by charging two phials equally, one through the hook, the other through the coating: hold that by the coating which was charged through the hook; and that by the hook which was charged through the coating: apply the hook of the first to the coating of the other, and there will be no shock or spark. Set that down on glass which you held by the hook, take it up by the coating, and bring the two hooks together: a spark and shock will follow, and both phials be discharged.

In this experiment the bottles are totally discharged, or the equilibrium within them restored. The *abounding* of fire in one of the hooks (or rather in the internal surface of one bottle) being exactly equal to the *wanting* of the other: and therefore, as each bottle has in itself the *abounding* as well as the *wanting*, the wanting and abounding must be equal in each bottle. See §. 8, 9, 10, 11. But if a man holds in his hands two bottles, one fully electrified, the other not at all, and brings their hooks together, he has but half a shock, and the bottles will both remain half electrified, the one being half discharged, and the other half charged.

7. Place two phials equally charged on a table at five or six inches distance. Let a cork-ball, suspended by a silk thread, hang between them. If the phials were both charged through their hooks, the cork, when it has been attracted and repelled by the one, will not be attracted, but equally repelled by the other. But if the phials were charged, the one through the hook, and the other (*2*) through the coating, the ball, when it is repelled from one hook, will be as strongly attracted by the other, and play vigorously between them, fetching the electric fluid from the one, and delivering it to the other, till both phials are nearly discharged.

8. When we use the terms of *charging* and *discharging* the phial, it is in compliance with custom, and for want of others more suitable. Since we are of opinion that there is really no more electrical fire in the phial after what is called its *charging*, than before, nor less after its *discharging*; excepting only the small spark that might be given to, and taken from the non-electric matter, if separated from the bottle, which spark may not be equal to a five hundredth part of what is called the explosion.

For if, on the explosion, the electrical fire came out of the bottle by one part, and did not enter in again by another, then, if a man, standing on wax, and holding the bottle in one hand, takes the spark by touching the wire hook with the other, the bottle being thereby *discharged*, the man would be *charged*; or whatever fire was lost by one, would be found in the other, since there was no way for its escape: But the contrary is true.

9. Besides, the phial will not suffer what is called a *charging*, unless as much fire can go out of it one way, as is thrown in by another. A phial cannot be charged standing on wax or glass, or hanging on the prime conductor, unless a communication be formed between its coating and the floor.

10. But suspend two or more phials on the prime conductor, one hanging on the tail of the other; and a wire from the last to the floor, an equal number of turns of the wheel shall charge them all equally, and every one as much as one alone would have been. What is driven out at the tail of the first, serving to charge the second; what is driven out of the second charging the third; and so on. By this means a great number of bottles might be charged with the same labour, and equally high, with one alone, were it not

---

In recognition of the 250th anniversary of the birth of Benjamin Franklin, we reproduce Letter IV from his book, *Experiments and Observations on Electricity*. The complete title of the letter was "Letter IV. from Benj. Franklin, *Esq*; in *Philadelphia*, to Peter Collinson, Esq; F.R.S. *London. Farther* Experiments *and* Observations *in* Electricity." Letters III and IV were concerned with the Leyden jar. Letter III told of the discovery that the jar has a plus charge on the outside and a minus charge on the inside. Letter IV shows the theoretical usefulness of Franklin's concepts plus and minus.

Letter IV was published in the first edition of *Experiments and Observations on Electricity, made at Philadelphia in America, by Mr. Benjamin Franklin, and Communicated in several letters to Mr. P. Collinson, of London, F.R.S.* (E. Cave, London, 1751). The text given here is reprinted by permission of the publishers from *Benjamin Franklin's Experiments, a New Edition of Franklin's Experiments and Observations on Electricity*, edited, with a critical and historical introduction, by I. Bernard Cohen, published by Harvard University Press, Cambridge, Mass., copyright 1941 by the President and Fellows of Harvard College. The text is based on the fifth English edition (F. Newbery, London, 1774).

that every bottle receives new fire, and loses its old with some reluctance, or rather gives some small resistance to the charging, which in a number of bottles becomes more equal to the charging power, and so repels the fire back again on the globe, sooner in proportion than a single bottle would do.

11. When a bottle is charged in the common way, its *inside* and *outside* surfaces stand ready, the one to give fire by the hook, the other to receive it by the coating; the one is full, and ready to throw out, the other empty and extremely hungry; yet as the first will not *give out,* unless the other can at the same instant *receive in*; so neither will the latter receive in, unless the first can at the same instant give out. When both can be done at once, it is done with inconceivable quickness and violence.

12. So a strait spring (though the comparison does not agree in every particular) when forcibly bent, must, to restore itself, contract that side which in the bending was extended, and extend that which was contracted; if either of these two operations be hindered, the other cannot be done. But the spring is not said to be *charg'd* with elasticity when bent, and discharg'd when unbent; its quantity of elasticity is always the same.

13. Glass, in like manner, has, within its substance, always the same quantity of electrical fire, and that a very great quantity in proportion to the mass of glass, as shall be shewn hereafter.

14. This quantity, proportioned to the glass, it strongly and obstinately retains, and will have neither more nor less though it will suffer a change to be made in its parts and situation; *i.e.* we may take away part of it from one of the sides, provided we throw an equal quantity into the other.

15. Yet when the situation of the electrical fire is thus altered in the glass; when some has been taken from one side, and some added to the other, it will not be at rest or in its natural state, till it is restored to its original equality. – – – And this restitution cannot be made through the substance of the glass, but must be done by a non-electric communication formed without, from surface to surface.

16. Thus, the whole force of the bottle, and power of giving a shock, is in the GLASS ITSELF; the non-electrics in contact with the two surfaces, serving only to *give* and *receive* to and from the several parts of the glass; that is, to give on one side, and take away from the other.

17. This was discovered here in the following manner: Purposing to analyse the electrified bottle, in order to find wherein its strength lay, we placed it on glass, and drew out the cork and wire which for that purpose had been loosely put in. Then taking the bottle in one hand, and bringing a finger of the other near its mouth, a strong spark came from the water, and the shock was as violent as if the wire had remained in it, which shewed that the force did not lie in the wire. Then to find if it resided in the water, being crouded into and condensed in it, as confin'd by the glass, which had been our former opinion, we electrified the bottle again, and placing it on glass, drew out the wire and cork as before; then taking up the bottle, we decanted all its water into an empty bottle, which likewise stood on glass; and taking up that other bottle, we expected, if the force resided in the water, to find a shock from it; but there was none. We judged then that it must either be lost in decanting, or remain in the first bottle. The latter we found to be true; for that bottle on trial gave the shock, though filled up as it stood with fresh unelectrified water from a teapot. – – – To find, then, whether glass had this property merely as glass, or whether the form contributed any thing to it; we took a pane of sash-glass, and laying it on the hand, placed a plate of lead on its upper surface; then electrified that plate, and bringing a finger to it, there was a spark and shock. We then took two plates of lead of equal dimensions, but less than the glass by two inches every way, and electrified the glass between them, by electrifying the uppermost lead; then separated the glass from the lead, in doing which, what little fire might be in the lead was taken out, and the glass being touched in the electrified parts with a finger, afforded only very small prickling sparks, but a great number of them might be taken from different places. Then dextrously placing it again between the leaden plates, and compleating a circle between the two surfaces, a violent shock ensued. – – – Which demonstrated the power to reside in glass as glass, and that the non-electrics in contact served only, like the armature of a loadstone, to unite the force of the several parts, and bring them at once to any point desired: it being the property of a non-electric, that the whole body instantly receives or gives what electrical fire is given to or taken from any one of its parts.

18. Upon this we made what we called an *electrical-battery,* consisting of eleven panes of large sash-glass, armed with thin leaden plates, pasted on each side, placed vertically, and supported at two inches distance on silk cords, with thick hooks of leaden wire, one from each side, standing upright, distant from each other, and convenient communications of wire and chain, from the giving side of one pane, to the receiving side of the other; that so the whole might be charged together, and with the same labour as one single pane; and another contrivance to bring the giving sides, after charging, in contact with one long wire, and the receivers with another, which two long wires would give the force of all the plates of glass at once through the body of any animal forming the circle with them. The plates may also be discharged separately, or any number together that is required. But this machine is not much used, as not perfectly answering our intention with regard to the ease of charging, for the reason given, *Sec.* 10. We made also of large glass panes, magical pictures, and self-moving animated wheels, presently to be described.

19. I perceive by the ingenious Mr. *Watson's* last book, lately received, that Dr. *Bevis* had used, before we had, panes of glass to give a shock (*3*); though, till that book came to hand, I thought to have communicated it to you as a novelty. The excuse for mentioning it here is, that we tried the experiment differently, drew different consequences from it (for Mr. *Watson* still seems to think the fire *accumulated on the non-electric* that is in contact with the glass, p. 72) and, as far as we hitherto know, have carried it farther.

20. The magical picture (*4*) is made thus. Having a large metzotinto with a frame and glass, suppose of the KING (God preserve him) take out the print, and cut a pannel out of it near two inches distant from the frame all round. If the cut is through the picture it is not the worse. With thin paste, or gum water, fix the border that is cut off on the inside of the glass, pressing it smooth and close; then fill up the vacancy by gilding the glass well with leaf gold, or brass. Gild likewise the inner edge of the back of the frame all around, except the top part, and form a communication between that gilding and the gilding behind the glass: then put in the board, and that side is finished. Turn up the glass, and gild the fore side exactly over the back gilding, and when it is dry, cover it, by pasting on the pannel of the picture that hath been cut out, observing to bring the correspondent parts of the border and picture together, by which the picture will appear of a piece, as at first, only part is behind the glass, and part before. Hold the picture horizontally by the top, and place a little moveable gilt crown on the king's head. If now the picture be moderately electrified, and another person take hold of the frame with one hand, so that his fingers touch its inside gilding, and with the other hand endeavour to take off the crown, he will receive a terrible blow, and fail in the attempt. If the picture were highly charged, the consequence might perhaps be as fatal (*5*) as that of high treason, for when the spark is taken through a quire of paper laid on the picture by means of a wire communication, it makes a fair hole through every sheet, that is, through forty-eight leaves, though a quire of paper is thought good armour against the push of a sword, or even against a pistol

bullet, and the crack is exceeding loud. The operator, who holds the picture by the upper end, where the inside of the frame is not gilt, to prevent its falling, feels nothing of the shock, and may touch the face of the picture without danger, which he pretends is a test of his loyalty. – – – If a ring of persons take the shock among them, the experiment is called, *The Conspirators.*

21. On the principle, in *Sec.* 7, that hooks of bottles, differently charged, will attract and repel differently, is made an electrical wheel, that turns with considerable strength. A small upright shaft of wood passes at right angles through a thin round board, of about twelve inches diameter, and turns on a sharp point of iron, fixed in the lower end, while a strong wire in the upper end, passing through a small hole in a thin brass plate, keeps the shaft truly vertical. About thirty *radii* of equal length, made of sash glass, cut in narrow strips, issue horizontally from the circumference of the board, the ends most distant from the center, being about four inches apart. On the end of every one, a brass thimble is fixed. If now the wire of a bottle electrified in the common way, be brought near the circumference of this wheel, it will attract the nearest thimble, and so put the wheel in motion; that thimble, in passing by, receives a spark, and thereby being electrified is repelled, and so driven forwards; while a second being attracted, approaches the wire, receives a spark, and is driven after the first, and so on till the wheel has gone once round, when the thimbles before electrified approaching the wire, instead of being attracted as they were at first, are repelled, and the motion presently ceases. – – – But if another bottle, which had been charged through the coating, be placed near the same wheel, its wire will attract the thimble repelled by the first, and thereby double the force that carries the wheel round; and not only taking out the fire that had been communicated to the thimbles by the first bottle, but even robbing them of their natural quantity, instead of being repelled when they come again towards the first bottle, they are more strongly attracted, so that the wheel mends its pace, till it goes with great rapidity twelve or fifteen round in a minute, and with such strength, as that the weight of one hundred *Spanish* dollars with which we once loaded it, did not seem in the least to retard its motion. – – – This is called an electrical jack; and if a large fowl were spitted on the upright shaft, it would be carried round before a fire with a motion fit for roasting.

22. But this wheel, like those driven by wind, water, or weights, moves by a foreign force, to wit, that of the bottles. The self-moving wheel, though constructed on the same principles, appears more surprising. 'Tis made of a thin round plate of window glass, seventeen inches diameter, well gilt on both sides, all but two inches next the edge. Two small hemispheres of wood are then fixed with cement to the middle of the upper and under sides, centrally opposite, and in each of them a thick strong wire eight or ten inches long, which together make the axis of the wheel. It turns horizontally on a point at the lower end of its axis, which rests on a bit of brass cemented within a glass salt-cellar. The upper end of its axis passes through a hole in a thin brass plate cemented to a long strong piece of glass, which keeps it six or eight inches distant from any non-electric, and has a small ball of wax or metal on its top, to keep in the fire. In a circle on the table which supports the wheel, are fixed twelve small pillars of glass, at about four inches distance, with a thimble on the top of each. On the edge of the wheel is a small leaden bullet, communicating by a wire with the gilding of the *upper* surface of the wheel; and about six inches from it is another bullet, communicating in like manner with the *under* surface. When the wheel is to be charged by the upper surface, a communication must be made from the under surface to the table. When it is well charged it begins to move; the bullet nearest to a pillar moves towards the thimble on that pillar, and passing by electrifies it, and then pushes itself from it; the succeeding bullet, which communicates with the other surface of the glass, more strongly attracts that thimble, on account of its being before electrified by the other bullet; and thus the wheel encreases its motion till it comes to such a height as that the resistance of the air regulates it. It will go half an hour, and make one minute with another twenty turns in a minute, which is six hundred turns in the whole; the bullet of the upper surface giving in each turn twelve sparks to the thimbles, which makes seven thousand two hundred sparks: and the bullet of the under surface receiving as many from the thimbles; those bullets moving in the time near two thousand five hundred feet. – – – The thimbles are well fixed, and in so exact a circle, that the bullets may pass within a very small distance of each of them. – – – If instead of two bullets you put eight, four communicating with the upper surface, and four with the under surface, placed alternately; which eight, at about six inches distance, completes the circumference, the force and swiftness will be greatly increased, the wheel making fifty turns in a minute; but then it will not continue moving so long. – – – These wheels may be applied, perhaps, to the ringing of chimes (*6*), and moving of light-made orreries.

23. A small wire bent circularly, with a loop at each end; let one end rest against the under surface of the wheel, and bring the other end near the upper surface, it will give a terrible crack, and the force will be discharged.

24. Every spark in that manner drawn from the surface of the wheel, makes a round hole in the gilding, tearing off a part of it in coming out; which shows that the fire is not accumulated on the gilding, but is in the glass itself.

25. The gilding being varnished over with turpentine varnish, the varnish, though dry and hard, is burnt by the spark drawn through it, and gives a strong smell and visible smoke. And when the spark is drawn thro' paper, all round the hole made by it, the paper will be blacked by the smoke, which sometimes penetrates several of the leaves. Part of the gilding torn off is also found forcibly driven into the hole made in the paper by the stroke.

26. It is amazing to observe in how small a portion of glass a great electrical force may lie. A thin glass bubble, about an inch diameter, weighing only six grains, being half filled with water, partly gilt on the outside, and furnish'd with a wire hook, gives, when electrified, as great a shock as a man can well bear. As the glass is thickest near the orifice, I suppose the lower half, which being gilt was electrified and gave the shock, did not exceed two grains; for it appeared, when broken, much thinner than the upper half. – – – If one of these thin bottles be electrified by the coating, and the spark taken out through the gilding, it will break the glass inwards, at the same time that it breaks the gilding outwards.

27. And allowing (for the reasons before given, § 8, 9, 10.) that there is no more electrical fire in a bottle after charging, than before, how great must be the quantity in this small portion of glass! It seems as if it were of its very substance and essence. Perhaps if that due quantity of electrical fire so obstinately retained by glass, could be separated from it, it would no longer be glass; it might lose its transparency, or its brittleness, or its elastivity. – – – Experiments may possibly be invented hereafter, to discover this.

27. We were surprised at the account given in Mr. *Watson's* book of a shock communicated through a great space of dry ground, and suspect there must be some metalline quality in the gravel of that ground; having found that simple dry earth, rammed in a glass tube, open at both ends, and a wire hook inserted in the earth at each end, the earth and wires making part of a circuit, would not conduct the least perceptible shock, and indeed when one wire was electrified, the other hardly shewed any signs of its being in connection with it (*7*). Even a thoroughly wet packthread sometimes fails of conducting a shock, though it otherwise conducts electricity very well. A dry

cake of ice, or an icicle held between two in a circle, likewise prevents the shock, which one would not expect, as water conducts it so perfectly well . – – – Gilding on a new book, though at first it conducts the shock extremely well, yet fails after ten or a dozen experiments, though it appears otherwise in all respects the same, which we cannot account for (*8*).

28. There is one experiment more which surprises us, and is not hitherto satisfactorily accounted for; it is this: Place an iron shot on a glass stand, and let a ball of damp cork, suspended by a silk thread, hang in contact with the shot. Take a bottle in each hand, one that is electrified through the hook, the other through the coating: Apply the giving wire to the shot, which will electrify it *positively,* and the cork shall be repelled: then apply the requiring wire, which will take out the spark given by the other; when the cork will return to the shot: Apply the same again, and take out another spark, so will the shot be electrified *negatively,* and the cork in that case shall be repelled equally as before. Then apply the giving wire to the shot, and give the spark it wanted, so will the cork return: Give it another, which will be an addition to its natural quantity, so will the cork be repelled again: And so may the experiment be repeated as long as there is any charge in the bottles. Which shews that bodies having less than the common quantity of electricity, repel each other, as well as those that have more.

Chagrined a little that we have been hitherto able to produce nothing in this way of use to mankind; and the hot weather coming on, when electrical experiments are not so agreeable, it is proposed to put an end to them for this season, somewhat humorously, in a party of pleasure, on the banks of *Skuylkil* (*9*). Spirits, at the same time, are to be fired by a spark sent from side to side through the river, without any other conductor than the water; an experiment which we some time since performed, to the amazement of many (*10*). A turkey is to be killed for our dinner by the *electrical shock,* and roasted by the *electrical jack,* before a fire kindled by the *electrified bottle*: when the healths of all the famous electricians in *England, Holland, France,* and *Germany* are to be drank in (*11*) *electrified bumpers,* under the discharge of guns from the *electrical battery.*

Notes

1. This was a Discovery of the very ingenious Mr. *Kinnersley,* and by him communicated to me.
2. To charge a bottle commodiously through the coating, place it on a glass stand; form a communication from the prime conductor to the coating, and another from the hook to the wall or floor. When it is charged, remove the latter communication before you take hold of the bottle, otherwise great part of the fire will escape by it.
3. I have since heard that Mr. *Smeaton* was the first who made use of panes of glass for that purpose.
4. Contrived by Mr. *Kinnersley*..
5. We have since found it fatal to small animals, though not to large ones. The biggest we have yet killed is a hen. 1750.
6. This was afterwards done with success by Mr. *Kinnersley.*
7. Probably the ground is never so dry.
8. We afterwards found that it failed after one stroke with a large bottle; and the continuity of the gold appearing broken, and many of its parts dissipated, the electricity could not pass the remaining parts without leaping from part to part through the air, which always resists the motion of this fluid, and was probably the cause of the gold's not conducting so well as before; the number of interruptions in the line of gold, making, when added together, a space larger perhaps than the striking distance.
9. The river that washes one side of *Philadelphia,* as the *Delaware* does the other; both are ornamented with the summer habitations of the citizens, and the agreeable mansions of the principal people of this colony.
10. As the possibility of this experiment has not been easily conceived, I shall here describe it.—Two iron rods, about three feet long, were planted just within the margin of the river, on the opposite sides. A thick piece of wire, with a small round knob at its end, was fixed on the top of one of the rods, bending downwards, so as to deliver commodiously the spark upon the surface of the spirit. A small wire fastened by one end to the handle of the spoon, containing the spirit, was carried a-cross the river, and supported in the air by the rope commonly used to hold by, in drawing the ferry-boats over. The other end of this wire was tied round the coating of the bottle; which being charged, the spark was delivered from the hook to the top of the rod standing in the water on that side. At the same instant the rod on the other side delivered a spark into the spoon, and fired the spirit. The electric fire returning to the coating of the bottle, through the handle of the spoon and the supported wire connected with them.

    That the electric fire thus actually passes through the water, has since been satisfactorily demonstrated to many by an experiment of Mr. *Kinnersley*'s, performed in a trough of water about ten feet long. The hand being placed under water in the direction of the spark (which always takes the strait or shortest course, if sufficient, and other circumstances are equal) is struck and penetrated by it as it passes.
11. *An electrified bumper* is a small thin glass tumbler, nearly filled with wine, and electrified as the bottle. This when brought to the lips gives a shock, if the party be close shaved, and does not breath on the liquor.

April 29, 1749.

Significance of "Heat-Activated" Enzymes

Morton N. Swartz, Nathan O. Kaplan, Mary E. Frech

The mechanism of regulation of metabolic routes in the intact cell has been a subject of much interest. It has, of necessity, assumed an even greater significance recently as studies with cell fractions have revealed alternative pathways of metabolism for a given normal metabolite. Mutation, suppressor genes, and new enzyme formation as in the phenomenon of adaptation have recently been explored intensively (*1*) and certainly could provide potent agencies of metabolic control. Another possible mechanism of cellular regulation, the synthesis by the cell of specific enzyme inhibitors, has also been suggested by many workers (*1*). It is this latter concept that we propose to emphasize in this paper (*2*).

Dr. Swartz is a research fellow, U.S. Public Health Service–National Cancer Institute. Dr. Kaplan is a staff member, and Miss Frech is a research assistant at the McCollum-Pratt Institute, Johns Hopkins University.

"Heat-Activated" Enzymes

In the course of assays on the pyridine nucleotide content of various microorganisms, it was noted that whereas trichloracetic acid extracts of *Proteus vulgaris* X-19 (strain No. 6380) contained considerable amounts of these nucleotides, extracts prepared from boiled cells showed predominantly nicotinamide riboside and very little diphosphopyridine nucleotide (DPN) or nicotinamide mononucleotide (NMN). Subsequent investigation revealed the presence, in sonic extracts of this organism, of two enzymes (a DPN pyrophosphatase and a 5′-nucleotidase) that were ordinarily present in an inhibited state. Only after these extracts were placed in a boiling water bath for several minutes could any significant activity be shown. The strik-