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Title: Experiments on the Nervous System with Opium and Metalline Substances

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Release date: November 7, 2014 [EBook #47309]

Language: English

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EXPERIMENTS

ON

THE NERVOUS SYSTEM,

WITH OPIUM AND METALLINE SUBSTANCES;

MADE CHIEFLY WITH THE VIEW OF DETERMINING THE

NATURE AND EFFECTS

OF

ANIMAL ELECTRICITY.

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EDINBURGH:

PRINTED BY ADAM NEILL AND COMPANY,
FOR BELL & BRADFUTE, AND T. DUNCAN;
AND J. JOHNSON, LONDON.

M.DCC.XCIII.

CONTENTS.

	<i>Page</i>
INTRODUCTION,	5
Observations on the Circulating and Nervous Systems of Frogs,	6
Experiments with Opium,	9
Corollaries from the above Facts and Experiments,	12
Summary of Experiments made on Animals with Metalline Substances,	17
Summary of Facts proved by the foregoing Experiments,	35
Resemblance of the Fluid put in Motion by the foregoing Experiments to the Electrical Fluid,	38
The Nervous Fluid or Energy not the same with the Electrical, nor with the Fluid put in Motion by the foregoing Experiments,	40
General Conclusions,	42

INTRODUCTION.

WHEN, in November last, I began to make Experiments on Animal Electricity, of which I read some account to the Royal Society on the 3d of December; I was not only much hurried with business, but could not procure a sufficient number of Frogs for the purpose. During the last winter and spring, I prosecuted the subject more fully and with greater attention; and, on the third day of June, I read a second paper to the Royal Society, to which I have, since that time, made additions. I shall now state a summary of the chief circumstances I have observed, with a few Remarks.

OBSERVATIONS ON THE CIRCULATING AND NERVOUS SYSTEMS OF FROGS.

As my Experiments with Opium, as well as those on Animal Electricity, have been performed on Frogs chiefly; I shall premise some observations on their Circulating and Nervous Systems.

THEIR Heart consists of one Auricle and one Ventricle only, their Aorta supplying their Air Vesicles or Lungs, as well as all their other Organs; and, of course, their Venæ Cavæ return the Blood from all parts to the Heart. The Ventricle of their Heart contracts about sixty times in a minute; and the purple colour of the Blood which is seen within it, disappears after each contraction, or the Blood is entirely expelled by its contraction. For upwards of an hour after cutting out its Heart, a Frog can crawl or jump; and, for upwards of half an hour longer, it contracts its Legs when the Toes are hurt, though not with sufficient force to move its Body from the place where it is laid. [7]

THEIR Encephalon consists of Brain and Cerebellum, each of which, on its upper part, is divided into two Hemispheres; and, below, they are conjoined by thick Crura, which form the Medulla Oblongata and Spinal Marrow, both of which are proportionally larger than in Man, and more evidently consist of two Cords. There are nine true Vertebræ; and at the sixth of these, the Spinal Marrow terminates in the Cauda Equina. The Sciatic Nerves are formed by three pairs of Nerves, sent out below the seventh, eighth and ninth Vertebræ, and by one pair from the Os Sacrum. A Nerve, resembling our great Sympathetic Nerve, passes downwards from the Abdomen into the Pelvis.

Two days after cutting off the Head of a Frog at its joining with the first Vertebra, I found it sitting with its Legs drawn up, in their usual posture; and when its Toes were hurt, it jumped with very considerable force. Its Heart likewise continued to beat about forty times in a minute, and so strongly as to empty itself and circulate the Blood.

IN several Frogs, after cutting off the back part of the six undermost true Vertebræ, I took out all that part of the Spinal Marrow with the Cauda Equina which they cover. The lower Extremities were rendered insensible to common injuries, and lay motionless, yet the Frogs lived several months thereafter, and the wounded parts of their Backs cicatrised; and the Bones of their Legs, which I fractured, were re-united, the Blood circulating freely in their Vessels. [8]

It is universally known, that if, after amputating the Limb of a warm blooded Animal, we repeatedly irritate the Nerves which terminate in Muscles, repeated Convulsions of the Muscles are for some time produced; and that in Frogs, and other cold blooded Animals, the Nerves retain this power still longer.

BUT it has been commonly supposed, that, after irritating the Nerve a given number of times, the effect ceases, Authors conceiving that there is lodged in the Nerve some fluid, or other energy which is exhausted by repeated explosions. Instead of this, I have found that the time the Nerves preserve their power is the same, whether we irritate them or not; or that their energy is not exhausted by irritation, unless the irritation be such as sensibly alters their texture. [9]

EXPERIMENTS WITH OPIUM.

I CUT one hole in the fore and upper part of the Cranium and Dura Mater of a Frog, and another in the back part of the lowermost Vertebræ, and then injected, from the one hole to the other, a small syringe full of water, in five ounces of which one ounce of Opium had been infused for three days. The infusion, by this means brought into contact with the whole surface of the Encephalon and Spinal Marrow, produced almost instantly universal convulsions; and, in less than two minutes thereafter, the Animal was incapable of moving its body from the place where it was laid. A quarter of an hour thereafter, I found the Heart beating twenty-five times only in the minute; and so feebly, that it could not entirely expel the Blood. When, half an hour thereafter, the Sciatic Nerves were pinched, a light tremor only was excited in the Muscles of the Leg; and Animal Electricity produced but feeble twitchings of the Muscles.

[10]

THE infusion of Opium, injected in the same manner in Rabbits and in a Pig, produced similar effects.

I HAD long ago^[1] observed, that an infusion of Opium, poured into the Cavity of the Abdomen of a Frog, after cutting out its Heart, occasioned, in a few minutes, convulsions of its hind Legs. I have since found, that, after cutting off the Head, and cutting out the Heart of a Frog, its hind Legs are considerably weakened by pouring an infusion of Opium into the Cavity of its Abdomen.

ALTHOUGH an infusion of Opium poured into the Auricle and Ventricle of the Heart of a Frog, instantly renders that Organ incapable of contraction, and, even after the Aorta has been previously cut, occasions convulsions of the Legs, yet I have not found that by Opium applied to the Brain, the Spinal Marrow, the Heart, or Abdominal Viscera, the Muscles of the Legs were so entirely killed as not to perform some motion when their Nerves were pinched, or when they were acted on by Animal Electricity.

[11]

AFTER taking out the lower half of the Spinal Marrow, and likewise cutting transversely all the parts at the Pelvis, except the Crural Arteries and Veins and Lymphatics, which probably accompany them, I found that an infusion of Opium, applied to the Skin and Muscles of the Legs, affected the superior parts of the Body^[2]: more probably, in my opinion, by absorption, than through any minute remanent branches of the Nerves, especially as I do not find, on laying the Vessels so prepared over a gold probe, and touching with it Zinc laid under the Spine, that convulsions of the Legs can be excited. At the same time, the quantity of Opium absorbed is so small, that I could not distinguish its smell or taste in the Blood; nor did I find these distinguishable, in other Experiments, in which the Frogs were violently convulsed after applying the infusion to the surface of their Skin.

ANIMAL Electricity or different metals applied to the Head of a Frog, or to any part of its Spine above its sixth Vertebra, do not occasion convulsions of its hind Legs.

[12]

COROLLARIES FROM THE ABOVE FACTS AND EXPERIMENTS.

FROM the above Facts and Experiments, it appears,

1. THAT the Frog, after its Head is cut off, feels pain, and, in consequence of feeling, moves its Body and Limbs.

2. As the Nerves of the hind Legs are not affected by Animal Electricity, unless it be applied lower than the fifth Vertebra, these Nerves do not seem to be derived solely or chiefly from the Brain or Cerebellum.

3. As Opium, after the Circulation ceases, affects Organs distant from those to which it is applied, it is beyond doubt, that the latter suffer in consequence of Sympathy of Nerves.

4. IT appears that, in this Animal, there is Sympathy of Nerves after the Head is cut off; or that Sympathy of Nerves does not, in this Animal, depend entirely on the connection of Nerves within the Head. [13]

5. As, after cutting off the Head, this Animal is susceptible of pain, and, in consequence of that, performs voluntary motion, it appears that, in it, the Brain is not the sole seat of the *Sensorium Commune*.

6. SEVERAL weeks after I had taken out the lowermost half of the Spinal Marrow, and with it the Cauda Equina, I daily applied, for four days running, Animal Electricity to the Sciatic Nerves, by passing a gold Probe between them and the Os Sacrum, and excited several hundreds of convulsions of the Thighs and Legs, and yet found that, on laying bare the Femoral Nerves, and pinching them, the Muscles were slightly convulsed.

HENCE, I apprehend, additional force is given to an opinion I ventured many years ago to propose^[3], that the Nerves do not receive their energy wholly from the Head and Spinal Marrow, but that the texture of every branch of a Nerve is such as to furnish it, or that the structure of each Nerve is similar to that of the Brain.

7. FROM the above Experiments, it appears probable, in the highest degree, that Opium may be absorbed in such quantity as to produce fatal symptoms. [14]

8. THE following circumstances concur in rendering inadmissible an opinion lately proposed by M. FONTANA, that Poisons operate by changes they produce on the mass of Blood, or on some unknown principle connected with the Blood.

a. IF his opinion was just, Poison introduced into a Vein of the extremities, so as to be in contact with this unknown principle, should operate as quickly, and in the same manner as when the Poison is mixed with the Blood near the Heart, which he admits is not the case^[4].

b. CUTTING the Spinal Marrow in Frogs, before applying the Poison of the Viper to their Legs, prevents it from killing them^[5]; which should not happen, if the Poison acted on the Blood alone.

c. HE acknowledges that an Animal bit in its Leg by a Viper, instantaneously feels acute pain^[6]; and it, in like manner, feels instantly great uneasiness when the Poison is mixed with its Blood^[7]. We know for certain, that, through the medium of the Nerves, we are instantly rendered sensible of injury done to the most distant parts of our Bodies. [15]

ARE we not, therefore, in the last mentioned Experiment, to conclude, that the uneasiness was produced because the Poison acted upon the Nerves of the Vessels?

d. IN like manner, Animals were convulsed as soon as they were wounded, or received the Poison into a Blood-vessel; and long before the Blood could have reached the Muscles in action^[8].

e. As soon as the distilled Water of Lauro-cerasus was poured into the Stomach of a Pigeon, it was convulsed, died instantly^[9], that is, before the Poison could have entered the Mass of Blood. [16]

f. MANY years ago, I found, after cutting the Venæ Cavæ and Aorta of a Frog, that a watery solution of Opium poured into the Heart, occasioned, in a few minutes, convulsions in its Legs; and, after cutting out the Heart, that the Opium poured into the Cavity of the Abdomen affected the Legs in like manner; although, in these Experiments, the Circulation was not only interrupted, but the greater part of the Blood evacuated.

I THEREFORE then concluded^[10], and now conclude, that Opium and other Poisons, even after they are mixed with the Mass of Blood, produce their fatal effects, chiefly and almost solely, by acting on the Nerves of the Heart and Vascular System, and, through these, affecting the whole of the Nervous System.

SUMMARY OF EXPERIMENTS MADE ON ANIMALS WITH METALLINE SUBSTANCES.

I SHALL now proceed to state the several circumstances I have observed, in my Experiments, which more directly lead us to judge of the Nature and Cause of Animal Electricity.

1. WHEN two Plates of different Metalline Substances, particularly of Zinc and Gold, between which a living Frog is placed, are brought into contact with each other, those Muscles, which are farther from the Brain and Spinal Marrow than the Metals, are convulsed: and this effect follows, although the Animal and Metals are placed on an inverted glass jar, and that a stick of sealing wax is interposed between the hand of the Operator and the Metals; that is, although the Animal, with the Metals, be insulated.

I HAVE further observed, that the Metals, disposed as above described, excite convulsions in the Legs, after all the parts of the Frog have been divided transversely at the Pelvis, providing only that they are, thereafter, laid in contact with each other. [18]

2. WHEN all the parts of a living Frog, except the large Nerves called Sciatic, are cut transversely at the Pelvis, and the fore part of the Animal is laid on a plate of Zinc, supported by glass, and the hind Legs on glass; if a gold Probe be applied so as to touch the Zinc and one of the Legs; or a piece of Metal put under one of the Legs; the Muscles of both Legs will be convulsed.

THE event is the same, after the Body of the Frog has been cut transversely about the middle of the Spine: or when the Legs are laid on the Zinc and the Spine on Glass.

IF a piece of perforated dry Paper is placed between the gold Probe and the Muscles, there will be no convulsions; but wet Paper interposed does not prevent the convulsions.

ON separating the gold Probe from the Muscles there are no convulsions.

3. IF, after the Animal and Metals are placed as above described, the joining of the two Legs at the Ossa Pubis is cut, that Leg only will be convulsed with which the gold is in contact. [19]

4. THE Spine of the Frog with the Zinc being placed on one glass, and the Legs on another glass, if the gold, supported by one hand, which we shall call the Right Hand, be applied to the Zinc alone, and not to the Legs, these are not convulsed. But if the Operator applies his left hand to the Legs, or if a bystander, communicating with the Operator by the medium of the floor only, touches them, they are convulsed. If a stick of sealing-wax be interposed between his right hand and the gold, or between his left hand and the Legs; or, if the bystander, touching the Legs, is insulated, by standing on a stool supported by glass feet, the Legs will not be convulsed. If the insulated bystander touches the Legs with one hand, and the Operator with his other hand, the Legs are immediately convulsed.

5. AFTER cutting the Spine transversely under the fifth Vertebra, and all the parts of the Pelvis, except the Sciatic Nerves, and laying the Spine on Zinc supported by glass, and the Legs on glass; if gold be applied to the Zinc, and then to one of the Sciatic Nerves, both Legs, if they have not been separated from each other at the Ossa Pubis, will be convulsed^[11]. And this happens although a stick of sealing-wax be interposed between the hand of the Operator and the gold Probe, and although no Metalline Substance touches the Legs. [20]

THIS Experiment succeeds after denuding the Sciatic Nerves for the length of an inch, and wiping them dry; and it continues to succeed for an hour or more, and till the Nerves are evidently discoloured and shrunk in their size. And, after that, although we wet the Nerves, their powers are not restored; shewing that the influence had been conveyed not by wetness on the surface of the Nerves, but by the particular matter of which Nerves are composed. [21]

THE event is the same, when the upper ends of the Sciatic Nerves are cut away from the Spine, and laid on the Zinc.

6. AFTER preparing the Frog and placing the Metals as in last Experiment, if a piece of thin dry Paper, pierced with a number of small holes, be interposed between the gold Probe and the Sciatic Nerves, the Legs will not be convulsed. But, if the Paper be wetted, although it is not perforated, the Legs will be convulsed.

AFTER preparing a Frog, as in last Experiment, and laying the Spine on one glass, and the Legs on another, if the Zinc be laid on a third glass, and the gold Probe applied to it and to the Sciatic Nerves, the Legs will not be convulsed.

8. IF the Spine and hind Legs, connected by the Sciatic Nerves, are all laid on the same plate of Zinc, supported by glass, the Legs are not convulsed on touching the Zinc with the gold Probe held in the right hand, although the left hand is applied to the Legs. [22]

9. IF several Frogs, prepared as above described, are laid upon glass, in a straight line touching each other, and that the first Frog is supported on Zinc, and the last upon Gold; if one end of a brass wire is applied to the Zinc, and the other end of it to the Gold; the Muscles of all the Frogs will be convulsed. The event is the same, although a stick of sealing-wax be interposed between the hand of the Operator and the brass wire: that is, although the Frog with the Metals be insulated.

10. WHEN Frogs are prepared as in last Experiment, and the Spine of the first of them laid on Zinc, and the last supported by the left hand of the Operator, if with a gold Probe, held in his right hand, he touches the Zinc, the Muscles of all the Frogs will be convulsed. But if the hind Legs, as well as the Spine, of the first Frog be laid on the Zinc, the Muscles of that Frog will not be convulsed.

11. AFTER a Frog was prepared as before described, I cut the Sciatic Nerves where they are about to enter the Thighs, and laid their cut ends in contact with the Muscles, and then touched the Zinc and Nerves with a gold Probe, without exciting convulsions in the Thighs or Legs. [23]

12. AFTER cutting the Sciatic Nerves, I tied together their divided parts, and then touched the Zinc and Nerves above the Ligature, with the Gold, without finding that the Legs were convulsed, when the Zinc supporting the Spine was laid on one glass and the Legs on another: but when the Metals and parts of the Frog were laid on a wet Table, the Muscles of the Leg were convulsed.

13. WHEN the Sciatic Nerves have been cut and rejoined by Ligature, if while the Gold is, with one hand, applied to the Zinc and Nerves, above the Ligature, the other hand touches the Feet, the Legs are convulsed.

14. IF the two hind Legs of a Frog are separated from each other, and their Sciatic Nerves afterwards tied to each other; if one of the Legs be laid on Zinc supported by glass, and the other Leg on glass, when, with one hand, the Toes of one of the Legs are touched, whilst with the other hand a gold Probe is applied to the Zinc and Nerve of the Leg which it supports, this Leg only will be convulsed. But if the gold Probe touching the Zinc be applied to the Nerve of the most distant Leg, both Legs will be convulsed. [24]

15. I FOUND it was not necessary, in order to excite convulsions, that either of the Metals should be in contact with the living Nerve or living Flesh of the Frog; for if, after separating from each other the hind Legs of a Frog, and cutting transversely the upper part of their Sciatic Nerves, I laid a piece of putrid or boiled beef between their Sciatic Nerves, and two other pieces of putrid or boiled beef between their Toes and a plate of Zinc; if, with the point of a gold Probe, the side of which was applied to the piece of beef placed between the Sciatic Nerves, I touched the Zinc, both Legs were convulsed.

16. IN like manner, when I placed alternately, in a straight line, a number of dead and living Frogs touching each other, and in the living Frogs cut, at their Pelvis, all the parts but the Sciatic Nerves; if, with my left hand I touched a dead Frog at one end of the line, and with a gold Probe, held in my right hand, I touched a plate of Zinc, on which a dead Frog was laid at the other end of the line or chain of Frogs, the Muscles of all the living Frogs were convulsed.

17. WHEN a chain of living and dead Frogs was formed, as in the two last Experiments, but without cutting at their Pelvis all the parts but the Nerves; on applying the gold to the Zinc, convulsions of the [25]

Muscles were not excited.

18. IT has been found, that, if a plate of Zinc is applied to the upper part of the point of the Tongue, and a plate of Silver to its under part, on bringing the two Metals into contact with each other, a pungent disagreeable feeling, which it is difficult to describe, is produced in the point of the Tongue. And if a plate of Zinc is placed between the upper lip and the gums, and a plate of gold applied to the upper or under part of the Tongue, on bringing these two Metals into contact with each other, the person imagines that he sees a flash of lightning, which, however, a bystander in a dark room does not perceive; and the person performing the Experiment perceives the flash, though he is hoodwinked.

IT has been alleged, that the Flash happens before the two Metals touch each other, and is repeated on separating them; but these facts appear to me very doubtful, as I do not find that a Flash is produced when a piece of Cambric-paper, in which a number of holes is pierced with a pin, is interposed between the Zinc and Silver, although the Paper does not in thickness exceed 1/1500 part of an inch.

[26]

AFTER performing this Experiment repeatedly, I constantly felt a pain in my upper jaw at the place to which the Zinc had been applied, which continued for an hour or more: And in one Experiment after I had applied a blunt Probe of Zinc to the Septum Narium, and repeatedly touched with it a Crown piece of Silver applied to the Tongue, and thereby produced the appearance of a Flash, several drops of Blood fell from that Nostril; and Dr FOWLER, after making such an Experiment on his Ears, observed a similar effect^[12].

I HAVE farther observed, that although the previous application of a second plate of Silver to one half of the plate of Zinc, does not prevent the Flash when the other half of the plate of Zinc, touching the Tongue, is brought into contact with the first piece of Silver placed between the lip and the gum; yet if the Zinc and Silver are in the first place applied to each other, then placed between the lip and gum, and, after this, touched with the Tongue, there is no appearance of a Flash, although some degree of pungency and a disagreeable sensation is perceived by the Tongue: and a mixed mass, composed of one part of Zinc and two parts of Quicksilver, or a mass composed of three parts of Zinc and one of Silver, incorporated in a furnace, have not the effect, when they are applied to Nerves, of exciting convulsions of the Muscles in which the Nerves terminate.

[27]

I HAVE also found, that two thick pieces of raw or boiled flesh, one between the Zinc and Tongue, and the other between the Silver and Tongue, do not prevent the disagreeable pungent sensation when the two Metals touch: and, in like manner, that the interpolation of two pieces of flesh between the Zinc and Tongue, and between the Silver and the upper Lip, does not prevent the appearance of a flash, on bringing the two Metals into contact.

19. I PUT a very thick plate of Zinc into a vessel with water, and placed, near to it, in the water, the under part of the Spine and the hind Legs of a Frog, after cutting all the parts at the Pelvis except the Sciatic Nerves. I then touched the Zinc with a gold Probe, and found, that, when I touched that part of the Zinc which was above the water, the Legs of the Frog were not affected; but when I touched that part of the Zinc which was below the surface of the water, the Legs of the Frog were convulsed^[13].

[28]

I NEXT put into the water one of the hind Legs of a dead Frog, and its other Leg into an adjoining vessel with water. Into the opposite side of the second vessel, I put one of the hind Legs of a living Frog, in which all the parts at the Pelvis, except the Sciatic Nerves, were cut; and into a third glass vessel with water, I put its other Leg. When I now touched that part of the Zinc, which was below the surface of the water with a gold Probe, the Legs were not convulsed; but, if I, at the same time, dipped the finger of my other hand into the water contained in the third vessel, they were convulsed: when, instead of my finger, I dipped into the water a stick of sealing-wax, held in my other hand, the Legs were not convulsed.

I FOUND, by the three following Experiments, that the Muscles are convulsed, whether the Influence, produced by the application of the Metals, passes upwards or downwards along the Nerves.

[29]

20. I CUT four living Frogs transversely at the middle part of their

Spines, and threw away the fore parts of their Bodies and their Abdominal Viscera.

I NEXT cut, at their *Pelves* all the Parts but the Sciatic Nerves; and at their Knees, I cut all the Parts but the Crural Nerves; and, in all of them, I cut asunder the joining of the two hind Legs at their Ossa Pubis. I then laid the Legs of all of them in a straight line, supported on different Glass Vessels inverted, in such a manner that the Foot of one Frog touched the Foot of the next to it.

HAVING then placed a Plate of Zinc under the Foot of the first Frog, and holding in my left hand the Foot of the fourth or last Frog, I touched the Zinc with a gold Probe which I held in my right hand; and found that all the Muscles of the Loins, Thighs and Legs of the four Frogs were convulsed.

21. WHEN I placed the two Frogs in the middle, with their Spines contiguous to each other, and the Feet of both touching the Spines of the other two Frogs forming the Extremities of the Chain, and of course the Feet of one of these resting on the Zinc, and the Feet of the other supported by my left hand: On touching the Zinc with the gold Probe held in my right hand, all the Muscles of the Frogs were, as before, convulsed.

[30]

22. WHEN I now turned aside the right Legs of all the Frogs, so that they did not form a Chain by touching the next Frogs; the right Legs were not convulsed.

It is evident, that in whatever direction we suppose the influence to have passed in its Circle, it must, in Experiment 20th, have passed up one Leg and down the other in the same Frog: And, in Experiment 21st, if it passed from one end of the Chain to the other end of it, it must have passed upwards in two of the Frogs, and downwards in the other two; or if the influence passed from the two ends of the Chain towards its middle, where the Spines of the two middlemost Frogs were contiguous, it must have passed upwards in all of them.

23. WHEN after cutting four living Frogs transversely at the middle of their Spines, but without cutting at their Pelves all the Parts but the Sciatic Nerves, I placed the hind Parts of them in a Chain, as in Experiments 20th, 21st and 22d, the Muscles were not convulsed on applying the Gold to the Zinc.

[31]

I NEXT found, that after placing in contact with each other the several Muscles which had been cut transversely in Experiments 20th, 21st and 22d, allowing the Nerves to remain undivided, the muscles were not convulsed when I touched the Plate of Zinc with the gold Probe held in my right hand, although I touched the other end of the Chain of Frogs with my left hand.

THE reason why the Muscles were convulsed in Experiments 20th, 21st and 22d, and not in Experiment 23d, evidently is, that in the former, the influence was concentrated in the Nerve, in the latter the influence was diffused; that is, was in part conveyed by other Organs, as well as by the Trunks of the Nerves.

24. AFTER finding that I could readily excite Convulsions in the hind Legs of a Frog, without cutting it, by laying its Back on a Plate of Zinc, and introducing a gold Probe within its Intestinum Rectum and touching the Zinc with the side of the Probe, I produced two or three hundred Convulsions, succeeding each other quickly, and observed that its Legs were, by these means, so much weakened, that it could not jump, and crawled with difficulty, but in a few minutes it recovered nearly the full force of its Muscles.

[32]

IN other Frogs I passed a gold Wire between their Sciatic Nerves and Os Sacrum, and twisted together the two ends of the Wire over the Backs of the Animals. I then put them into a Zinc Vessel filled with Water, or into a Glass Vessel filled with Water, in the bottom of which I laid a large Plate of Zinc: So that every time the Animals by moving separated the Gold from the Zinc, and again brought them into contact, their hind Legs were convulsed. I allowed them to remain three or four days in this situation, and found that their Limbs were weakened considerably, but not exhausted of their Power of Motion; and, after removing the gold Wire, the Limbs by degrees recovered their strength.

I MADE the same Experiment on those Frogs in which I had, six weeks before, cut out, from behind, all that part of their Spinal Marrow which is covered by the six undermost Vertebræ, and found, several days after the Frogs had been subjected to the Experiment, that, by pinching their Sciatic and Femoral Nerves, and still more readily by the application of the Gold and Zinc, weak

[33]

convulsions of the Muscles were excited.

25. AFTER Frogs were prepared as above described, by cutting their Spines transversely, and then all the parts of their Pelves, except their Sciatic Nerves, I found that slight Electrical Shocks, or a Leyden Phial discharged directly through the Limbs of a Frog, or indirectly by the medium of water, produced convulsions in their Muscles, exactly resembling those excited by the Metals. And when, after moderate Electrical Shocks had been passed repeatedly through their Legs, the Metals were applied to their Nerves, in the manner before mentioned, the Muscles were convulsed. I found, likewise, that after cutting the Nerves transversely, and tying them together, Electrical Shocks were conducted by the Nerves, and occasioned convulsions of the Muscles.

[34]

WHEN I had killed Frogs, by discharging through them, from their foreheads to their hind feet, large Leyden Phials highly charged, I found their Nerves or Muscles, or both, so much deranged, that feeble convulsions only could be excited by pinching the Nerves, or by applying the Metals to them.

[35]

SUMMARY OF FACTS PROVED BY THE FOREGOING EXPERIMENTS.

ON reviewing the foregoing Experiments, we shall find the following Facts fully proved.

1. ON forming a Circle by means of the parts of a living Animal and of two different metallic Bodies, especially Gold and Zinc, in contact with each other, if a Nerve makes part of the Circle, the Muscles in which the Nerve terminates are convulsed.

2. ALTHOUGH the Nerve making part of such a Circle has been cut transversely, yet, if the divided parts of the Nerve are laid in contact with each other, or tied together, the Muscles, in which it naturally terminates, are convulsed.

3. IF the Metals, composing parts of the Circle, are kept steadily in contact with each other, the convulsions of the Muscles cease. But, if they are separated from each other and again rejoined, the convulsions are repeated.

[36]

4. THE effects are the same, although the dead parts of an Animal or pure water make parts of the Circle.

5. ALTHOUGH the dead parts of an Animal, making part of such a Circle, are in contact with the Metals, the effects are the same.

6. A MUSCLE making part of such a Circle may be convulsed whilst the matter put in motion is passing in the direction from the Muscle to the Nerve.

7. THE Muscle may be convulsed although it makes no part of the Circle in which the matter put in motion passes, as appears from comparing Experiment 5th with Experiments 13th and 14th. From Experiment 13th, it appears, that the Fluid put in Motion by the Metals passes readily along a Nerve, after it has been cut, providing the divided Parts of it are brought into contact with each other. Yet in Experiment 14th, in which the left hand of the Operator was not applied to the Foot of the Frog, the Muscles in which the Nerve, lower than the Ligature, terminated, were not convulsed, because the Fluid put in motion did not descend lower than the place at which the gold Probe touched the Nerve above the Ligature. We may therefore presume that when a Nerve which has not been cut, as in Experiment 5th, is touched with the gold Probe, the Fluid put in motion does not pass lower in the Nerve than the place of the Probe. Hence we perceive the error of those who suppose that the moisture on the surface of the Nerve conduces the Fluid put in motion to the Muscles, and that their action is in consequence of the direct operation of this Fluid upon their Fibres.

[37]

8. THE effects are the same when the Animal and the Metals are insulated, by being placed on Glass, whilst Sealing-wax is interposed between the hand of the Operator and the Metals.

9. IF any part of the Circle is composed of Sealing-wax or Glass, the Muscles are not convulsed.

10. CONVULSIONS are not excited unless the Metals are in contact with each other; and unless both Metals are also in contact with the Animal Substances or the Water making part of the Circle.

[38]

**RESEMBLANCE OF THE FLUID PUT IN
MOTION BY THE FOREGOING EXPERIMENTS
TO THE ELECTRICAL FLUID.**

THE Fluid set in motion by the application of the Metals to each other, and to Animal Bodies or to Water, agrees with or resembles the Electrical Fluid in the following respects.

LIKE the Electrical Fluid, it communicates the sense of pungency to the Tongue.

LIKE the Electrical Fluid, it is conveyed readily by Water, Blood, the Bodies of Animals, the Metals; and is arrested in its course by Glass, Sealing-Wax, &c.

IT passes, with similar rapidity, through the Bodies of Animals.

LIKE the Electrical Fluid, it excites the activity of the Vessels of a living Animal, as the Pain it gives and Hemorrhagy it produces seem to prove. Hence perhaps it might be employed with advantage in Amenorrhœa.

IT excites Convulsions of the Muscles in the same manner, and with the same effects as Electricity.

WHEN the Metals and Animal are kept steadily in contact with each other, the Convulsions cease, or an Equilibrium seems to be produced, as after discharging a Leyden Phial.

[39]

[40]

THE NERVOUS FLUID OR ENERGY NOT THE SAME WITH THE ELECTRICAL NOR WITH THE FLUID PUT IN MOTION BY THE FOREGOING EXPERIMENTS.

THAT the Nervous Fluid is the same with the Electrical, or with the Fluid which is put in motion by the foregoing Experiments, is, I apprehend, disproved by the following circumstances.

1. WITHOUT stating the difficulty there is in conceiving how the Electrical Fluid can be accumulated by or confined within our Nervous System, we may observe that where the Electrical Fluid, or Fluid resembling that put in motion by the foregoing Experiments, is accumulated by an Animal, such as the Torpedo or Gymnotus, a proper apparatus is given to the Animal, by means of which it is enabled to collect and to discharge this Fluid.

2. THE Nervous Power is excited by chemical or by mechanical Stimuli; and, on the other hand, is destroyed by Opium and other Poisons, which cannot be imagined to act on the Electrical Fluid. [41]

3. I HAVE, I apprehend, refuted the theory of DOCTORS GALVANI, VALLI and others, which supposes that the Nerve is electrified *plus* and the Muscle *minus*, resembling the Leyden Phial, by shewing that the Muscles are convulsed where there is no communication between them and the Metals, but by the medium of the Nerve; or when the Metals are applied to different parts of the Nerve alone, without touching the Muscles which are convulsed, and when the Muscle which is convulsed makes no part of the Circle in which the Matter that is put in motion passes.

4. I HAVE proved, that the Muscles are convulsed whilst the current of the Electrical Matter is passing from them and from the smaller Branches of the Nerves into their Trunks; and as a Muscle is never thrown into Action by the Nervous Energy, except when this passes from the Trunk of the Nerve into its Branches, and from these into the Muscle, it appears that when, in these Experiments, the Muscles were convulsed, the Nervous and the Electrical Fluids were moving in opposite Directions; from which we may infer, that, in their Nature, they differ essentially from each other. [42]

5. THE Nervous Energy is stopped by a tight Ligature or by the transverse Incision of a Nerve, although its divided Parts are thereafter placed in contact with each other; whereas the Electrical Fluid or the Fluid excited by the Metals, passes readily, downwards or upwards, along a Nerve which has been tied or cut.

6. AFTER the Limb of a living Animal has been amputated, frequent Convulsions of the same Muscles may be excited by applying Mechanical or Chemical Stimuli to its Nerves; whereas Electrical Matter discharges itself suddenly.

HENCE I conclude,

1. THAT the Fluid, which, on the application of Metalline Bodies to Animals, occasions Convulsions of their Muscles, is electrical, or resembles greatly the Electrical Fluid.

2. THAT this Fluid does not operate directly on the Muscular Fibres, but merely by the Medium of their Nerves. [43]

3. THAT this Fluid and the Nervous Fluid or Energy are not the same, but differ essentially in their Nature.

4. THAT this Fluid acts merely as a Stimulus to the Nervous Fluid or Energy.

5. THAT these Experiments have merely shown a new mode of exciting the Nervous Fluid or Energy, without throwing any farther or direct Light on the nature of this Fluid or Energy.

FINIS.

FOOTNOTES:

- [1] See Edin. Phys. Ess. Vol. III.
- [2] See Edin. Phys. Ess. Vol. III.
- [3] See Observations on the Nervous System, 1783, Chap. x. and xi.
- [4] See FONTANA sur les Poisons, 1781, p. 267.
- [5] See FONTANA, p. 293.
- [6] FONTANA, p. 244.
- [7] FONTANA, p. 259.
- [8] FONTANA, p. 112. p. 259.
- [9] FONTANA, p. 142.
- [10] Edin. Phys. Ess. published in 1771, p. 363.
- [11] Very small portions of different metals, applied as above described, have astonishing effects; and although I have found that large portions of the metals produced convulsions, when smaller had failed, or that they produced stronger convulsions; yet the effects are by no means proportioned to the weight of the metals employed, nor to the extent of their surfaces which are suddenly brought into contact. In most of my Experiments, I employed a plate of Zinc, about five inches long, three inches broad, and about one-third of an inch thick; and a gold Probe, somewhat thicker and longer than the Probes Surgeons commonly use.
- [12] See Dr FOWLER'S Book, p. 85.
- [13] After reading to the Royal Society, on the 3d of June, an account of this Experiment, which I had made in the beginning of May, I found, from an ingenious publication of my Pupil Dr FOWLER, which I received that evening, that the same Experiment had been performed by him.

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