Contributions to experimental physiology : showing that the ligation of the trachea, the divisions of the spinal cord in the cervical and dorsal regions, the removal of the viscera ... do not prevent intelligence, sensation, and motions ... / by Bennet Dowler.

CONTRIBUTIONS

TO

EXPERIMENTAL PHYSIOLOGY,

SHOWING

That the ligation of the trachea, the divisions of the spinal cord in the cervical and dorsal regions, the removal of the viscera, the destruction of the ganglions and plexuses of the sympathetic nerve, the ligation, section, and removal of the brachial and ischiatic plexuses, including the nerves of the limbs, do not prevent intelligence, sensation, and motions which are accurate in design, perfect in execution, being simultaneous and altogether voluntarily in all parts of the body, even though connected only by the muscles; also experiments on the roots of the spinal cord, &c., &c.,

BY

BENNET DOWLER, M. D.

Corresponding Member of the Academy of Natural Sciences of Philadelphia; Fellow of the Medico-Chirurgical College of the same city, &c., &c.

May 6th,—3 *P. M. to* 6 *P. M.*,—1852.

VIVISECTION NO. 1.

—

By the politeness of Dr. Cartwright, I was called upon, by letter, this evening, to make arrangements for the vivisection of an alligator, which he placed at my disposal. I accordingly called at his house to inform him that I would attend on the following day; but after reflecting upon the matter, I thought it advisable to proceed in the vivisection

without delay, although unprovided with suitable instruments.* In a few minutes after the operation began, several medical gentlemen arrived, though not all at the same time : Drs. Greig, Coit, Reynolds, Mr. Gordon, and at a later period Dr. Weatherly.

1. The alligator, over 3½ feet long, was vigorous, and disposed to fight and resist.

2. It was secured by bandaging its muzzle and tying its body to a plank, the back down.

3. The trachea was firmly tied in the middle of the neck with a piece of tape.

4. In a few minutes the animal appeared to be dying. The cords were untied, those of the mouth excepted. Death appeared complete in thirty minutes. In the meantime, the viscera of the chest and abdomen had been exposed. One of the hind legs was dissected—the skin and faciæ removed—the muscles separated, and the sciatic nerve and its branches, to the popliteal region and down to the ankle, was pinched, disorganized and cut, without any signs of pain—without voluntary motions, and without convulsive action, excepting the usual twitchings, chiefly in the toes [which I have so often described as taking place in the apparently dead animal, for a period, sometimes, from one to three days, and even in amputated limbs. These twitchings do not appear, in any case to amount to complete extensions or flexions].

All of a sudden the alligator came to life. This was about half an hour after tying the trachea, the ligature still remaining. The limbs had been relaxed—the body motionless for some minutes. But in the twinkling of an eye it turned upon its abdomen—jumped from the table to the pavement, and without attempting to run away, faced the company—took an attitude of defence—struck at every one that came

* Since writing the above, I have performed some, and reviewed other experiments made with what would be regarded, at first sight, as suitable instruments—instruments which are probably the worst, as sharp knives, keen chisels, etc. In the present instance, the use of a dull case-knife, probably prevented, in a good degree, profuse hæmorrhage, which is always unfavorable to striking results. Franklin, who knew the unaffected simplicity of Nature, approached her portals, and learned her profoundest secrets, by means of a kite, a key, a flask, and a few plain instruments, which would make but a sorry appearance amid the glitter and magnificence of a mordern laboratory. With his kite—an object of ridicule to the ignorant--he discovered how to disarm the thunder-bolts of heaven.

nigh, as if intending to bite; though fortunately for its enemies, its jaws were still firmly bandaged together. It watched the vivisectors narrowly, and turned courageously upon any one who advanced nearest to it.

6. All signs of death having thus suddenly disappeared, it was determined, after ten or fifteen minutes' delay, to recapture it, and re-bind it to the plank for further experiment, the trachea being still tied, as at first.

7. After many attempts with a dull case-knife, used as a chisel, aided by a hammer, the spine with its cord was divided in the middle of the neck—several of the cervical vertebræ were broken so that a thumb could be passed between the ends of the cord. By this method of operation, some of the great muscles of the neck were bruised and even completely disorganized, thereby preventing, in a great degree, motion in the head and neck. Much blood was lost, though this animal has comparatively but little.

8. The viscera were more fully dissected. The ligature was at length removed from the trachea. The latter having been opened, the lungs throughout the subsequent stages of the vivisection were repeatedly inflated by Dr. Cartwright's black boy. In detaching the lungs, or from some other cause, a rent had been produced, from which the air escaped,* though this occurred at an advanced stage of the dissection.

At intervals the dissection of the legs was continued, by which the skin and fasciæ were removed, the muscles separated, the nerves exposed, pinched, crushed, cut and removed.

9. By means of a rusty wood saw, the spine, with the cord, was divided a second time, midway between the fore and hind legs in the lower third of the dorsal region, so that the body could have been doubled in three pieces like a pocket-rule, connected only by the skin and muscles.

10. Most of the viscera were removed from the body. The remaining nerves of the limbs were exposed, experimented on, and cut away.

---

* One of the medical gentlemen who was present informed me, that this rent was caused by the black boy, who inflated the lungs with undue violence. These organs, indescribably delicate and beautiful, consisting of small transparent bladders without parenchyma, are easily ruptured. When compressed so as to exclude the air, and dried upon glass, they form a fine microscopic object, but little thicker than paper in an animal from one to three feet long.

11. Finally, from the last division of the spine a punch was introduced into the canal, by which the cord was gradually but completely destroyed downwards to its caudal, and then upward to its cervical portions.

12. From the first to the last division of the cord—from the resuscitation to the close of the experiments, the threefold division of the body made by the two sections of the cord, displayed in all three of its parts, both sensation, volition, and accurately adapted muscular motion. The eyes winked or nictated. The head, towards the close of the experiments, attempted to bite Dr. Reynolds. The lumbar and caudal division gave the most unequivocal indications of pain, contrivance, and adaptative action. Thus the animal, on being suspended by the neck, so that the legs might hang down, was pricked with a scalpel in the groin, whereupon it raised one hind leg, (the other had been amputated) it carried the foot (the law of gravity opposing) instantly and accurately to the exact spot where the injury was inflicted, pushing strongly against the knife, slightly wounding its ankle in the attempt to remove the pain-giving instrument—a feat requiring extreme flexion—a complete doubling of the leg upon the thigh. Now this flexion, and several others performed near the close of the experiments by the remaining hind leg and by the fore legs, took place not only after two divisions of the cord, but after the removal of the individual nerves in the limbs themselves, and after the removal of the viscera and the principal portion of the sympathetic nerves, plexuses and ganglions. These motions indicated sensation and volition, as truly as those of the undivided normal animal. In the divided, eviscerated animal, with its limbs *deprived of its nerves*, clear indications of pain and combined motions took place, when, at the close of the experiments, the divided ends of the cord were touched. Thus, when the dorso-caudal part of the cord was irritated, the hind leg was strongly directed to that place. This it repeated until the entire cord was gradually destroyed by a punch reaching down to the tail. The same phenomena occurred when the punch pressed or disentegrated the cord, from the last, or dorsal division, upwards towards the head or cervical division.

13. In the dissection of the nerves of the limbs during and after the apparent death—after the first and second divisions of the cord, and after amputation, a certain peculiar kind of muscular twitching, particularly in the fingers and toes, took place from compressing or injuring the nerve-cords (as I have formerly described); slight compression produced many twitches—a strong disorganizing one, or a section gave one or two only, after which compression in the same place produced no

motion whatever. The motion could always be reproduced whenever a new portion of the nerve was selected, provided it was invariably upon the distal side of the disorganization or section. The proximal end, that is, the end connected with the cord, when thus treated, was not succeeded by any motion, while that of the distal portion rather augmented as the irritation approached the extreme distribution of the nerves upon the fingers and toes. When the nerves were uninjured in any way, these twitchings were no greater than after the section of the nerve or the amputation of the limb. These twitchings seem totally void of volition or adaptation, being equally independent of the cord and of the proximal end of the nerves.

It will be seen that in the preceding experiments numerals have been used, in conformity to the stages of the vivisection. These are prefixed to the paragraphs for the convenience of the witnesses, who may have arrived at different periods. It will be seen by the certificates, at the bottom of the page, that Drs. Coit, Reynolds and Greig saw all the material experiments, beginning with paragraph 7, and thence to the end. Dr. Weatherly does not mention particulars, as will be seen.* This report has not been changed or added to since it was read to, and examined by, these gentlemen, with the exception of two foot notes.

VIVISECTION NO. 2.

The following Programme was submitted to the gentlemen present before the vivisection was commenced. The answers to the interrogatories of this Programme, as given by this experiment, and by many former experiments incomparably more striking, varied, prolonged, and perfect, will be annexed in the categorical form of affirmative or negative, within brackets, unaccompanied by explanations, though prelusive of experimental details that follow. This animal lived, comparatively, a short time. The weather was hot. Judging from experiments made in the cool season, I suppose that it would have lived at least three or four times longer, had the vivisection been made in the

---

* We fully agree with Dr. Dowler as to the correctness of the experiments which we witnessed, from paragraph No. 7.

J. J. COIT, M. D.
D. ELLIOTT REYNOLDS, M. D.
ALEXANDER GREIG, M. D.

I saw a portion of these experiments, and so far as I witnessed them they are correct.

J. R. WEATHERLY M. D.

winter. The rapid hæmorrhage, for which no ligatures could be used, was another most unfavorable circumstance. I had never before divided the spinal canal with a sharp chisel, having generally used hatchets, saws, or dull instruments, whereby hæmorrhage was in a great degree prevented. In decapitating with a dull hatchet, the great carotid is sometimes, though rarely so contused or compressed by a sort of torsion, that a ligature is not required. Furthermore—The animal had been prepared for vivisection for four days before it took place; during this long delay it was constantly and strongly bound with numerous cords, from the tip of the muzzle to the tip of the tail, including the limbs. I found, upon subsequent dissection, that portions of the muscular tissue had been injured by the cords. This constant pressure for four days, doubtlessly, impaired its muscular activity.

I subjoin a small portion of the measurements: From the tip of the muzzle to the central interspace of the orbits, 5 inches; to the occiput, 7; interscapular, 11½; sacro-iliac, 25; caudal extremity, 56; circumference of the thigh, 7½; of the body, 21.

Programme of the Vivisection.

1. Divide the cervical cord: Will each division continue to manifest sensation and voluntary motion? Will each division act in concert or simultaneously on irritating either at, near, and remote from the line of division. [Ans. Yes.]

2. Divide the lower dorso-lumbar cord: Will all three parts afterwards manifest sensation and voluntary motion? Will two or three act simultaneously for a common end, where the middle or extremities are injured? [Ans. Yes.]

3. Dissect the brachial plexus of nerves from a fore-leg: Will voluntary motion and sensation still continue to manifest themselves on irritating the axilla, and the dorsal and cervical ends of the cord? Will the bare dissected muscles, if pinched or pricked, contract? [Ans. Yes.]

4. Destroy the principal trunks of the sympathetic: Will this dissection excite or destroy sensation and voluntary motion? [Ans. Dissection excites these, but the destruction of the ganglions and plexuses of the sympathetic does not appear to hasten their extinction. See Dr. Dalton's very interesting experiments accompanying this paper. Dr. Dalton must have cut away the chief part of the splanchnic nerve, together with the solar, cœlic, hepatic, gastric coronary, splenic, mesenteric,

renal, spermatic, aortic, and cardiac plexuses, as well as numerous ganglions.]

5. Dissect the spinal roots of that part of the cord which gives off the nerves to the hind legs: Will irritation of the posterior or the supposed sensory root not be wholly devoid of muscular action? [Ans. No.] Will irritation of the anterior or so called motor root, afford sensational or other phenomena like those of the posterior root? [Ans. Yes.]

6. After destroying the spinal roots, remove the corresponding portion of the cord: What effect will pricking and pinching at the groin produce? [Ans. Voluntary motion, if I remember rightly; but in former cases, this most certainly took place.]

7. Dissect, pinch, tie, cut, and disorganize the ischiatic or sciatic plexus, and trace the sciatic, the popliteal, anterior tibial and peroneal nerves. Prick and compress the isolated muscles: Will they not twitch equally with and without the nerves?—with and without connection with the cord? [Ans. Yes.]

8. Amputate a limb: Dissect away its nerves, prick and compress its muscles, will not the contractions be equally active as before? [Ans. Yes.]

For the following notes, written at the moment the events which they record took place, I am indebted to my learned friend, Albert Welles Ely, A. M., M. D. The portions which I have added are included within brackets.

Vivisection of Alligator at Dr B. Dowler's, on 13th May, 1852, at 9¼ A. M.

Present: Drs. S. A. Cartwright, Hale, McKinley of Tigerville, B. Dowler, Nutt, Ely, Copes, Bennedict, Coit, Reynolds and Weatherly.

Temperature of room, 79° F.; of the animal 75°. He is just from under the hydrant. [The hydrant water being 70°, the animal's heat has not yet reached that of the air, which it would soon reach, as former experiments prove.]

At 9 h. 20 min. A longitudinal incision just before the shoulders, about 3 inches long in the back of the neck [the muscles and skin thus divided were held asunder]; a half inch chisel was introduced, by which the cervical canal and cord were divided [at the 5th vertebræ]. The hæmorrhage was most profuse. All the gentlemen present having inserted their fingers into the wound, were satisfied that the spinal canal was divided; a piece of sponge was inserted between the vertebræ. [The copiousness of the hæmorrhage seemed to indicate a division of the great carotid, (which is single, and which lies close to the anterior surface of the vertebræ) but the subsequent dissection, which

was continued seven days, showed that no artery but the vertebrals had been cut.] This first division of the spine produced no change in the pupil of the eye [the iris being responsive to the light]. Eyes entirely natural, as before the operation. No change in the sensation of the parts below or above the division. The application of the point of a knife produced rapid motions in the head and all parts of the body, just as before the operation.

Division of the spinal cord in the dorsal region at 10 o'clock and 25 min., by means of a chisel. [The spinal canal was divided through the 14th dorsal vertebra, that is, at a distance of 7 vertebræ from the first lumbar.] Still the animal moved all parts of the body, even the head, eyes, and tongue. It tried repeatedly to bring the fore paw to the point where the chisel was inserted. Motion in all parts of the body was simultaneous. On inserting a probe into the canal, the animal moved all parts of his body as before. These motions were the same when the probe was inserted into the upper or lower portion of the divided spine. The application of heat caused motions in all parts, the animal always endeavoring to place his fore paws on the part heated. The pupils of the eyes began to dilate after making the second division of the spine. The animal closed his eyes at 10, 7 min., A. M.

At 5 minutes before 10, a long incision was made in the region of the spine, immediately between the hind legs, during which the fore legs continued to move, directed to the incision making. The pupil, during the dissection of the muscles, in this last operation, became enormously dilated. The narrow vertical slit or line of half an inch in length, naturally constituting the pupil in its contracted state, became a perfect circle. Some of the motions of the hind legs and tail were convulsive, while those of the fore legs and head were voluntary. At a quarter past 10 the head appeared to be perfectly dead, but the fore legs moved occasionally, [in a voluntary manner] as the dissection proceeded. On pinching the skin and muscles of the head, no motion followed; but on pinching or touching the shoulders immediately below the division of the cervical cord, the head moved to the side touched, and the fore legs both moved also. On making the touch on the opposite shoulder, the head invariably moved in the other direction, that is, towards the side touched or irritated.

The dissection was continued down so as to expose the spinal cord, and the posterior roots covered by the theca, which, in the alligator, is black. On touching the posterior root, motions took place in the hind legs on both sides, and in the fore legs. Also the tail moved with force from side to side, as when the animal was operated on. The motion

of the tail was evidently voluntary. [On touching the cord as well as posterior roots, both limbs usually twitched; this twitching occurred, too, in the right, as well as in the left leg, when the posterior roots of the left side were irritated. The opening of the cord, always difficult, often destructive to the posterior roots, and even to the texture of the cord, was in this case, after some delay, happily accomplished. Hey's saw, chisels and knives were used on both sides of the spinous processes, by which a narrow, vertical, but deep stratum or section of the muscles at their origin, was taken out from each side of these processes, and then, along with the spinous processes, a narrow longitudinal strip of the vertebræ themselves was removed, thereby exposing the cord, as covered by the dark, yet semi-transparent theca. This slit in the bony canal was, of necessity, too narrow for the perfect exposure of the anterior roots, but was, for this very reason, (as I had learned from experience, not from writers) all the better for the satisfactory experiments upon the posterior roots. The difficulties and disorganizing effects of this operation have not been properly estimated. To say nothing of the section of the muscles (the true motory organs) the posterior roots must suffer injury, and even sometimes complete disorganization, if a portion of the canal of considerable width be removed; for then the sawing and chiseling of the bones must take place at the very points where the posterior roots emerge! The narrower the portion of bone cut out, the greater the safety to these roots, and the less the chance of making experiments upon the anterior, particularly in small animals, the usual kind selected, as frogs, rabbits, kittens, etc. That a wide strip of the spinal canal can be cut out of small animals, so as to afford in the same case and at the same time a good view and a free manifestation of the cord and its nerves at their emergence, without injury to the posterior roots, may well be doubted! Here, I venture to think, lies much of the history, and not a little of the mystery, too, of the supposed absence of motory excitation by means of the posterior roots. The injury of these roots, the section of many muscles, and the like, are lost sight of, for a theory.*

In the present experiment, the two objects sought were achieved, or

---

[* I beg leave to suggest the following rule for operating on the spinal roots, namely—let two animals be always sacrificed for the double experiment. In the one, intended for the demonstration of the posterior roots, let the opening be narrow; in the other, wider. With even this precaution, the posterior roots will often be injured by concussion, etc., etc. I would like to see the operator who can cut the anterior roots without injuring the posterior.]

rather verified, namely—that of showing, uninjured, the posterior roots, and proving that they are motor, as fully as any other part of the nervous system. The twitchings of the limbs were as distinct when these roots alone were touched, or compressed, as when the cord was touched, and the anterior roots torn. After destroying and scraping away the cord, the twitchings were as great as ever; as when an instrument was scraped along the sides of the canal, so as to impinge against the remnants of both sets of roots, where they emerge from the canal; while on descending, peripherally, from the canal, after the destruction of the cord, the twitchings became more distinct with every removal from the centre. Still more: after destroying every visible nerve, the muscles on being compressed gave twitchings, precisely similar to those which had been excited through the nerves.]

At 25 minutes to 11, the sciatic nerve was exposed, the animal moving the hind legs as the knife divided the muscles. At the same time the two musk glands were dissected from the lower jaw, during which the fore legs moved voluntarily. Next the chest and abdomen were laid open, during which all parts, except the head, moved voluntarily, particularly the fore legs, which continued a pawing motion. The heart was slowly dilating and contracting. At 10 M., to 11, the lungs were artificially inflated, when the heart assumed a more powerful action, and the animal exhibited signs of coming to life. The throat dilated, the animal attempting to breathe of his own accord, and the head and legs moved. The sciatic nerve being tied, on pinching it gently *below* the ligature, the limb contracted as often as the experiment was made.

[In this, as in all other experiments, irritation or the pinching of a nerve in any part of its course, produced no effect upon the proximal or inner part of the nerve, nor on the muscles, whether the connection with the cord were preserved or severed, affording an invariable physiological law precisely opposite to that laid down in the most recent works on physiology: Messrs. Kirke and Paget, say for example, "that when the distal portion of the divided nerve is irritated, *no* effect appears." (Phys. 289.) "No muscular action follows irritation of the posterior roots." (Morton's Anat. 508.) In this, but far more in many other experiments, it is proved that sundry divisions of the cord and of the plexuses and ganglions of the sympathetic, do not prevent sensation and voluntary motion, all parts of the body acting in concert for a common end, simultaneously, intelligencially. Here, again, the newest and best works repeat, that "the cerebellum is the regulator of the locomotive

actions ;" (Todd on the Brain, &c.) a proposition quite incompatible with the phenomena already enumerated.]

Search being made for "lymphatic hearts," none were found. (Here Dr. Ely's notes end.)

A few minutes after noon, the gentlemen having gone up stairs to take some refreshments, I continued the experiments. I repeatedly inflated the lungs, for perhaps half an hour, without any marked effect. The death of all the tissues appeared to be going on with progressive but unusual rapidity. The action of the heart declined perceptibly. I ascertained that the swelling of the larynx, noticed in Dr. Ely's notes, was not owing to an effort of the animal to breathe, but was caused by a regurgitation of the air that had been forced through the artificial opening in the trachea, made for the inflating process, and which did not readily escape through the small glottidian slit of the larynx.

At 1, P. M., Dr. Ely rejoined me, at which time the twitching of the limbs, from irritation of the nerves and muscles, continued unimpaired. At half past 1, P. M., the experiments having ceased, the animal was placed under the hydrant, and irrigated for half an hour, and then it was immersed in a saturated solution of salt, for anatomical examination.

I regret that a want of space prevents me from inserting, *in extenso*, a recent communication, kindly sent me from the elegant pen of Dr. Dalton. The following extract will be read with interest: "Lieutenant, now Capt. John C. Casey, U. S. A., and myself were walking (I think it was in 1830) near the shore of Lake Pontchartrain, some half a mile westward of the Fort, when we saw an alligator, four or five feet long. We captured him, and then I proceeded to open and *eviscerate the entire contents of the thoracic and abdominal cavities* His heart, which we took to our quarters, continued its double action of systole and diastole for hours. From 24 to 26 hours after, I found the alligator alive, and when I approached him and touched him with a stick, he made a vigorous fight at me."

Having given a faithful detail of the two most recent experiments that I have made, may I not be indulged with a few remarks, more or less elucidatory of the general doctrines which they suggest?

It is admitted that alligators, from their anatomical conformation and psychical endowments, are better adapted for physiological experiment than any animal of the cold-blooded class—a class most relied on for these purposes, because their tenacity of life admits of a prolonged examination—a thorough analysis and separation of organs, and conse-

quently a satisfactory appreciation of functions. All that can be objected against these experiments, then, as illustrations of comparative physiology, applies *a fortiori*, to animals that are *less* analogous to man.* That a double section of the spinal cord, cervical and dorsal; that the removal of the nerve trunks of the limbs, and the destruction of the sympathetic nerve, would not remove all traces of sensation and voluntary motion in man, I am not prepared to deny. Nor am I fully prepared to take the affirmative, with all the assurance that precise experiment and careful observation could possibly supply. I have, indeed, observed in some warm-blooded animals, that the trunk, after decapitation, manifests for a short time both of these fundamental functions, while, I have observed for hours, in human subjects after apparent death, so many physiological phenomena, which I once thought impossible, that I am prepared to believe a good deal more. * * *

In man, paralysis of sensation and motion often rapidly follow certain lesions of the nervous system, while at the same time these same functions may survive, in other cases of injuries of a very extensive and destructive kind; moreover, in a very great number of instances, these functions are lost, without leaving any trace of disorganization discoverable by the morbid anatomist.

The prevalent theory of the nervous system is not only erroneous in itself, physiologically and pathologically considered, but it is, it may reasonably be supposed, mischievous in practice. Muscular diseases are called and treated as nervous, and although in many cases the treatment is right, the supposed cure of the nerves is probably referable to the muscular system, in which the morbid actions often are as evident as any facts can be, as in cramps, tetanus, hiccup, subsultus, chorea, convulsions, hydrophobia, hysteria, epilepsy, abortion, tenesmus, paralysis, stricture, rigidity, spasmodic contractions, strabismus, wry-neck, &c. How all these, and many other kindred diseases, which present

---

* The psychical and personal history of alligator No. 2, familiarly called Zip Coon, for two years, I may on a future occasion publish, showing his habits, passions, seeming power of fascination, and most of all, his apparent foresight of, and new contrivances against, the two extraordinary cold spells of the last winter. Happier than the *Crocodilæ* of the sacred Ganges, the classic Nile, or the turbid Mississippi, instead of dragging a useless life for centuries in the swamps, he died in the cause of physiology.

> Happy! to whom this glorious death arrives,
> More to be valued than a thousand lives!
> On such a theatre as this to die,
> For such a cause. WALLER.

material phenomena or symptoms in the muscular organs, can be seen in the nervous centres, or in the periphery, especially in those multitudinous cases where no changes can be detected, either symptomatically or anatomically, before or after death, would seem a more extravagant pretension than that of *clairvoyance* itself, as the latter only affects to see what is. The neurologists of our day, not satisfied with the Cullenian nosology, which assigns to the class of Neuroses, or nervous diseases, a formidable host of species ("quel nombre prodigieux d'enemis!"), but they would add even our epidemics, as yellow fever, to the catalogue!

HAMLET. Nothing is
But what is not.

It is not intended, however, to dwell, in this place, upon the pathological method of illustrating physiology.

Revenons à nos Crocodiles. As to the above mentioned vivisections, especially No. 1, it may be safely affirmed that so far as the natural language of brutes can be accredited as defining consciousness, feeling, volition, purpose, and self-determining motions, nothing is dubious—nothing unsatisfactory—nothing to be desiderated. Explanation may exhaust itself—expositors may dread and reject unwelcome consequences. The central sensorialist may rail at all parts of the system except the nervous, as being unfit for the soul's seat—as unfit for knowing, willing, feeling and acting. He can believe most steadfastly in an unknown, unfelt spot in brain, which he calls the sensorium, to which all the residue of the system, even the nervous, is but a mere passive conductor; he finds no difficulty in believing in a nervous circle, in *four* distinct, yet wholly hypothetical sets of nerves, a double set, the sensori-volitional, and yet another double set, the excito-motor! But on the other hand, how obstinately can he disbelieve that the mind, or psychical entity, can, by any possibility, occupy the muscles, or take even a temporary refuge in them, after the destruction of the nerves, although the former surpass the latter in delicacy and exquisiteness of organization, in adaptational contrivance, and in well developed finality, almost as much as a race horse surpasses an oyster in the locomotive apparatus!

It may be further remarked, that the analogies of Nature—developmental, progressive, comparative, physiological and anatomical, so far from teaching that the nervous skeleton is the sole starting point, the fundamental type of life and voluntary motion, teach just the contrary. Nature travels far, surmounts innumerable physiological obstacles,

mounts high in the scale of organization, and achieves motiferous and sensiferous systems, before she admits a nervous system at all. In plants, and in certain animals wholly destitute of nerves, both motion and sensibility exist in various degrees.

Plants sleep, wake, move, contract, and possess a kind of sensibility, without having a nervous system. Irritation, pinching, pricking, a drop of acid, an unaccustomed heat, or the slightest touch, will suffice to cause some plants to move. In a word, says Dutrochet, they will comport themselves as animals would in like case: "En un mot, la feuille se comporte comme le ferait, en pareil cas, un animal qui serait averti par ses sensations de l'actuelle d'une cause excitante sur ses organes." (*Mém. sur les Végétaux.* Tom. 1. 538. Art. xi. De l'excitabilité végétale et des mouvemens dont elle est la source.) The *mimosa pudica*, (Lin.) or sensitive plant, affords an example of vegetable, analogous to animal contractility, being wholly independent of nerves. A violent impression produces greater contraction of the plant, and a more rapid exhaustion of its contractile force than a slight one. During the repose of the plant, this force is renewed. Some plants are easily poisoned. Here identity, rather than mere analogy, is obvious.

A greater error in physiology never prevailed than that now almost universally recognized as a fundamental truth, namely, that the whole of man, his entire *Ens* is but a bundle of conducting nerves, or rather a minute unknown sensorial spot or centre. If teleology, or the doctrine of final causes, as explained by exquisite organization, by unmistakable adaptation, by the harmonious union of means and ends, and by physiological anatomy, be regarded, then the muscular may, in at least several respects, claim precedence over the nervous system. The latter is not, as it has been seen, even the essential condition of life, much less is it life itself, its entire ontology. Nor is it proved to be the whole of man; nor his sole psychical entity and instrument. In the human subject recently dead, the nerves exercise no influence for or against muscular contraction. The latter being both active and independent.

The motions above described, be it remembered, had not a single characteristic strictly "automatic," the pertinacious and pernicious assertions of celebrated book-makers (and certain automatic critics, who always think with the celebrated) to the contrary notwithstanding. Even though an author were a *Nardac* of the Empire, (the highest and most celebrated of all titles known in Lilliput) this would not give validity to opinions in physiology, while direct experiments prove these

opinions to be erroneous. The Academician who proposed to build houses from above downwards, would be a fit companion for those theorists who thrust in the words "automatic," "reflex," "instinctive," and so on, as a good explanation of the phenomena which I have so often described as occurring in animals after decapitation—after sections of the cord—after the removal of the nervous trunks—after the destruction of the sympathetic system—after the removal of the viscera. Not only so; the word "automatic" is as much applicable to the composition of the Iliad, or the movements of a dancer, as it can be to those functional contractions, flexions, and extensions, which I have observed in an almost countless number of experiments, made directly upon *human subjects*, soon after the infallible signs of ordinary, not physiological death, had taken place. These, more numerous, curious and instructive, than any I have observed in vivisection properly so called, are the very reverse of "automatic" or mechanical motion, and clearly overthrow the received theories of the nervous system—of the reflex action of the cord, and of the spinal roots.* Although I have published many of these experiments, and many of the purely physiological laws thence derived, the tenth part has not yet been told. The muscular system (not to name the co-ordinate functions, as the capillary, calorific, &c.) presents, in these experiments, many curious laws, in relation to the increment, decrement, temporary decline, regeneration, persistence, injuries and general conduct of its forces, which, though very variable, admit, nevertheless, of scientific classification into groups.

---

* Bell describes the motions produced by irritating the posterior or so called motory roots, as barely visible to the natural eye. Magendie says they are but slightly marked—"Ces contractions sont cependent peu marquées," being, as he says, infinitely weaker than those resulting from the touching of the cord itself. Neither of these experimenters appear to have known, that after the destruction of these roots, the motions augmented towards the periphery, from irritating the trunk of the nerve, and even from irritating the muscles after the removal of the nerves. Of course, these facts are completely subversive of the theories which these gentlemen have deduced from their experiments upon the spinal roots, not to name the reflex theory, more recently revived and advocated by others.

To refuse to publish facts because they will not be believed, was regarded by Dr. Samuel Johnson as downright meanness and cowardice. The facts related concerning the vivisection No. 1, upon the 6th of May, indicate results, (as clearly as experiments can do) which were as unexpected to me as they can be to any person whatsoever. But I relate facts only, regardless of their agreement or disagreement with received theories—regardless of my inability to explain them so as to form a system. The honest upbraidings and *naive* chidings of some of my correspondents, tend, in some degree, to make me think that possibly I may deserve the compliment, though intended as a censure, conveyed in the following passage in a recent letter from a friend: "I never could find what doctrine you want to establish—whether any or not." I certainly never expected to establish the doctrine that an eviscerated animal, having the spinal cord divided in the cervical and dorsal regions, and having, also, the nerves cut away from all its limbs, would still continue to manifest both sensation and voluntary motion! In former experiments, I had, with one or two exceptions noticed, that although mere sections of the cord did not destroy these fundamental functions, yet complete longitudinal destruction of that structure extinguished these phenomena almost instantly. The closing experiments in No. 1, consisted of this complete but gradual destruction of the cord, which the animal was fully aware of, following, as it did with its feet, the parts disentegrated! Now, although it is unwarrantable to assume anatomical structures in order to establish a doctrine upon a sure foundation, such provisional assumptions are sometimes allowable as hypotheses, several of which I suggest as possible explanations of the above mentioned experiments. Taking for granted, as proved by decapitation, that sensation can exist independently of the brain;* taking for granted that the sensorium is diffused, nay, even intensified in the periphery; admitting, provisionally, that the muscles are wholly devoid of sensation, still the spinal cord, though divided into segments, appears essential to sensation and self-determined motion. How then can these several spinal segments be connected with the periphery, in the absence of the great nervous trunks which go to the limbs? If we suppose the existence of anastomosing interlacements along the sides of the animal, originating with or implanted on the spinal nerves, and, perhaps, connected also with the great sympathetic system, here will be a communication of a very general character, though not visible to the naked eye. It is easy to decapitate; but it is not possible, in the short period to which a vivisection must be restricted, to remove all the ganglions, plexuses, and branches of the sympathetic system—a system that morbid action and vivisection prove to be endowed with sensation—a system, in which each ganglion is regarded by Bichat and most other physiologists as being a distinct centre. Hence, from the inextricable meshes of

* Sensation is no more the property of a special spot in the centre exclusively, than vitality is. Parts of the human body, as noses, ears, fingers, and so on, after having been separated from the general system for hours, have retained an independent vitality and been re-united; while, in other cases, particularly in Oriental countries, surgeons have restored lost parts in one person by taking parts from another.

this system, as well as from the spinal, countless numbers of nerves may pervade the substance of the muscles and become instruments of sensation, notwithstanding the destruction of the great nerve trunks sent to the limbs. Small portions of these nerves in the intervertebral foramina and a short distance beyond, were not removed. Hence, some branches may pass off laterally that would not be included in the plexuses.

The experiments in No. 1, differed in manner from, and extended beyond, former experiments, without contradicting them. But sciolists may exclaim —what has all this to do with human physiology? Are alligators like men? Not exactly. I have acknowledged the difference upon former occasions, perhaps to an unwarrantable extent.* I have a better right to the benefit of the objection than these gentlemen, because they profess to follow the celebrated Carpenter, Todd, Bowman, Hall, and others, who, in their latest and most elaborate works, insist that the cold-blooded animals are the most reliable ones for physiological experiments: Messrs. Todd and Bowman, in their most excellent work, now in the course of publication, namely, "Physiological Anatomy and Physiology of Man," say "*That the nervous force endures much onger in the cold-blooded animals*"—"*On this account the cold-blooded animals must be selected for exhibiting the phenomena*"—a proposition which Prof. Carpenter iterates and re-iterates, particularly in his learned work, "Physiology, General and Comparative," just republished in this country. Now, if dissenting gentlemen were more consistent in their objections, their logic would be none the worse for their philosophical reputation. If they can believe that European frogs and turtles illustrate human physiology, why should they reject the *Crocodilus Mississippiensis*, albeit, the wisest, biggest, and most perfect beast of the cold-blooded class, as the physiologists of the old world have the justice to acknowledge? Does the original curse against reptilians apply to the alligator only, so as to render it unfit for physiological experiments? It is evident that *it* was not the reptile which deceived Eve; for it does *not* "go upon its belly all the days of its life." It walks on four legs! The curse that clings to it is that of being a native American and not a European! Verily an Alligator "hath no honor in his own country,"† although anatomically and

---

* A foreign critic, in 1847, who intended to do me all possible damage, speaks on this wise: "Can any one, we ask, entertain a doubt that, the conditions being the same, the consequences would be the same in man, with a spinal centre constructed upon essentially similar principles to that of reptiles and animals? If such kind of evidence be rejected, physiology must return to its very infancy, for, with few exceptions, little or nothing can be learnt, strange as it may sound to some ears, of human physiology from observations restricted exclusively to man." A Dutch Governor tried to please all, but finding that impossible, determined to hear only one side of every case, as he found that hearing both sides not only confused his mind, but gave the trouble of changing the first opinion and forming a new one!

† Have the anti-crocodilians forgot that the classical history of this Reptilian is most honorable? That it was the symbol or hieroglyphical representative of the

physiologically he combines to a greater extent than any other single animal the essential types characterizing the vertebrata and articulata, approaching birds and mammals on the one side, and rising above the fishes, worms and mollusks on the other. Can the resistance-men prove that crocodilian digestion, absorption, sanguification, nutrition, secretion, circulation, volition, motion, hearing, seeing and feeling, are altogether different in nature, not simply in degree, from those functions in man? Take the strongest example of contrast, namely, the tenacity of life in the saurian: because life persists longer in the latter than in the former, after extensive injuries, does it follow that the vital actions of the one are essentially different in nature as well as in degree from the other?

Can any unprejudiced and enlightened mind, upon a careful review of the above mentioned experiments, and many others which I have made and published, reconcile them with the following statements?—statements founded almost entirely upon Sir C. Bell's experiments—which experiments Bell said were but very few, and even these few he had no confidence in, as he emphatically declares! Todd and Bowman say: "The anterior root of each spinal nerve is motor—the posterior sensitive. The irritation of the latter gives rise to no muscular action. Comparative anatomy confirms this conclusion among all classes of vertebrate animals. The origin of a double root denotes a double function. The union of the enchephalon with the spinal cord is necessary for voluntary motion and for sensation."

---

mighty Typhon, the slayer of the famous god Osiris, who was the brother and husband of Isis, and father of the "ever living, resplendent Horus, the beneficent deity?" At the city of crocodiles, Arsinoe, this sacred saurian was worshipped the most devoutly, whether living or dead, in the days of the Pharaohs.