

The little kingdom, or, The servants of the stomach : being a new series of letters to the young on the life of man and animals / by Jean Mace ; translated from the French by a lady.

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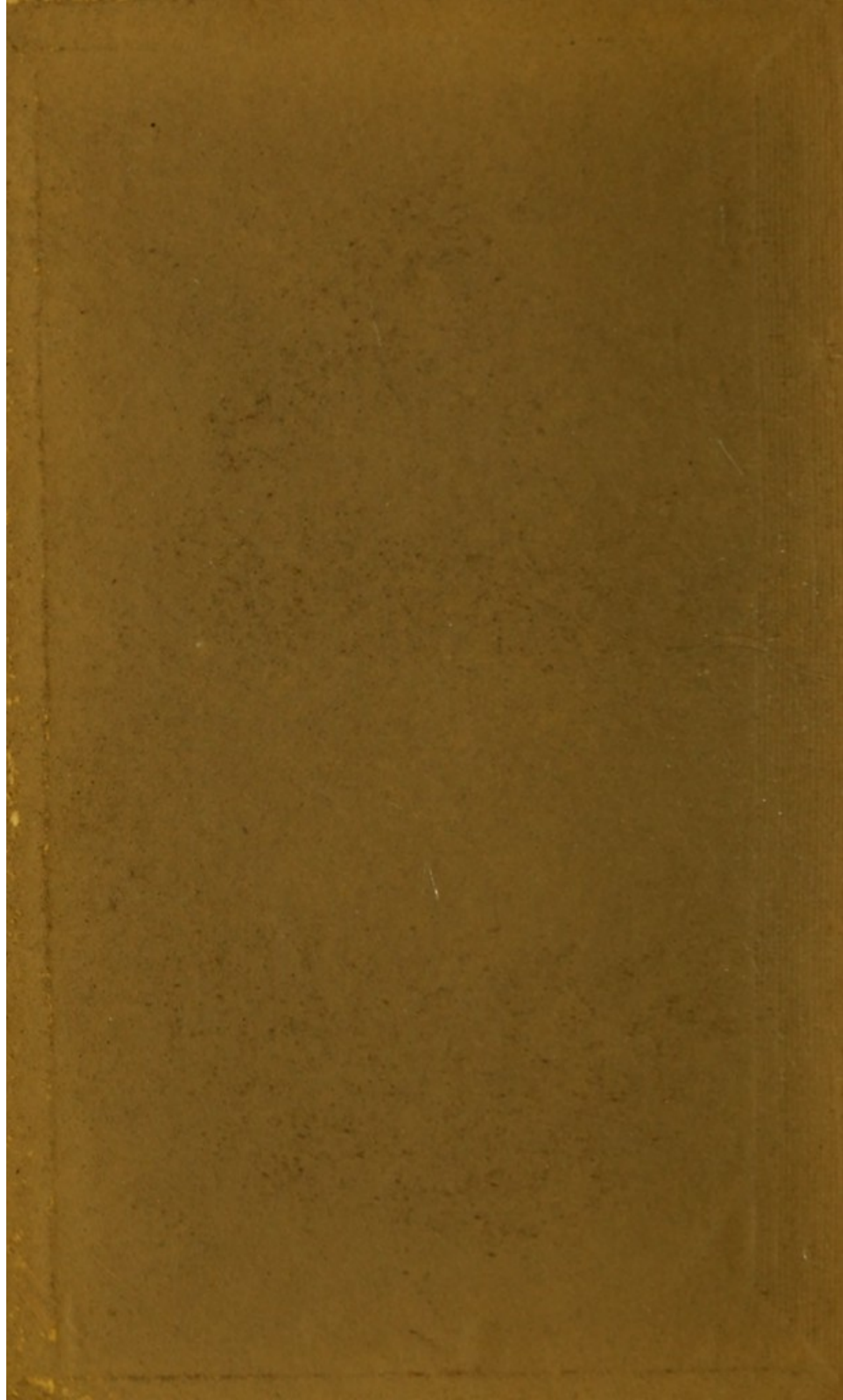
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THE LITTLE KINGDOM ;
OR,
THE SERVANTS OF THE STOMACH.

THE LITTLE KINGDOM;

OR,

THE SERVANTS OF THE STOMACH.

BEING A NEW SERIES OF LETTERS TO THE YOUNG
ON THE
LIFE OF MAN AND ANIMALS.

By JEAN MACE.

TRANSLATED FROM THE FRENCH BY A LADY.

IN TWO VOLUMES.

VOL. II.



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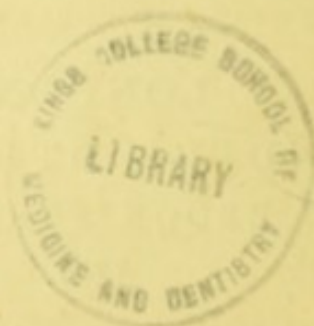
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THE LITTLE KINGDOM;

OR,

THE SERVANTS OF THE STOMACH.

LETTER I.

THE MOVEMENTS—(*Continued.*)

WHEN a drill-sergeant teaches his recruits to march, and gives the word of command, "Front, Forward," &c., at the word "Front" he makes them stand with the left foot carried well to the front, raised from the ground. This is called dividing the step. We are also going to do the same.

Stand perfectly upright, your two feet drawn together in line, as the unarmed soldier does, and remember you have to advance your left foot first. Your body imperceptibly balances itself, and your centre of gravity is immediately transported to the line of your right leg, which has for the moment to support your whole weight. The left leg, relieved

from duty, bends at first, thanks to the action of the flexors which raise it from the ground by contracting it; then the extensors straighten it and carry it forward. This is the first half of the movement.

At the word of command "Forward," the centre of gravity at once passes to the right leg, the body bends towards the extended foot, which falls to the ground, and you have made a step. You see it is a very simple affair.

The body, now balancing on the left foot, lifts up the heel of the right one, which, touching the ground only by the toes, is quite ready to move. The flexors raise it, the extensors throw it forward. The centre of gravity returns to it: it falls, and the whole process recommences. You can walk thirty miles in this way, provided your legs are sufficiently strong.

Thus you see, as I have already told you, that the flexors and extensors kindly divide the work, and you understand, do you not? how it is less fatiguing to walk than to stand still, a simple fact, which many people will hardly be convinced of. It is not, however, the less true, that every step we take is a fall, and that it is only by a succession of falls that we are able to advance. This is by no means flattering to our vanity, but what does that signify if we really make progress?

This continual oscillation of the centre of gravity, which perpetually changes, while walking, from one leg to the other, gives a regular motion to the body, especially observable in sailors, who, accustomed to walk upon movable floors, instinctively walk with

their legs considerably apart, so as to enlarge their basis of support. Consequently, on shore, they have a rolling walk, which is far from being graceful, and as by separating their legs their steps are shorter, the result naturally is, that sailors are in general bad walkers. But at sea they resume their superiority, and those who walk well on shore would be only too glad when on the deep, and the ship rolls with the waves, to possess the sailor's free step.

Another consequence of this oscillating movement is, that the right side of the body, being habitually stronger than the left, and thus at every step gaining an additional impulse in advance of the other side, if the eye did not guide us, we should, without knowing it, walk obliquely towards the left, to continue the language of the drill-sergeant, (language which does not require explanation.) For this reason, nicely would he be taken in, who, walking in the dark, fancied he was keeping in a straight line.

This brings to my mind a scene of my childhood. A long grass plat in the Park at Versailles, called the "tapis vert," (green carpet,) and which is in front of the lake known as "La pièce des Suisses," or "L'eau des Suisses." All who frequent the gardens at Versailles must be well acquainted with it. I do not know if the Parisians of the present day keep up this game of the golden age, but formerly it was not uncommon on fête days to see the good folks set off, with their eyes bandaged, from one end of the "tapis vert," with the intention of walking to the other end. And it was seldom, indeed, that any one succeeded.

The ignorant, going where the right side pushed them, found themselves all at once on the side walk to the left; the knowing ones, who had heard that the danger lay in going to the left, forcibly turned from that side, and arrived victoriously at the side walk to the right! So true it is that there is nothing like seeing clearly for keeping you on the straight path, and that a blind guide is always a bad one.

What I lately told you about the kindly division of labour between the flexors and extensors only holds good whilst walking upon level ground: the moment you begin to climb, this equality disappears; then it was only necessary for the body to proceed from one fall to another, now it has to be lifted up at every step, and of this the poor extensors have the whole burden.

Observe as you go up-stairs:—

As soon as you have placed one foot on the first step, the foot left behind, below its companion, does as you do when measuring your height with a friend who is taller than you are, it rises on the point, elevating its own side as well as it can, to put it on a level with the other. This work is performed by the extensors of the foot. They are in the calf of the leg, as you know, and their contraction draws up our old friend the calcaneum, (or heel-bone,) which in rising pushes the tibia before it, with all which it supports. At this moment the body is carried forward on the more advanced leg, which, by stiffening, (thanks to the extensors,) completely raises it up. On this occasion it is above the knee where the work is done, and if you will place your hand there at this moment,

you will feel how rigid the muscles of the fibres become, in order to replace the tibia and the femur on the same level.

What renders the effort more necessary is, that the centre of gravity must be drawn, cost what it may, on to this line, for it is the moment when the foot lowest down the stair is about to be raised from the ground to join its companion ; and the same thing takes place whether you ascend by single steps, or, as some big girls do, take two at a time. The same series of efforts recommences at every step ; and if your room happens to be on the sixth story, you will probably feel rather tired on arriving there. Now where do you feel this fatigue, if you please ? Even if you did not know by experience, you could guess it from what we have just told you. It is in the calf, and the knee, but more especially in the latter, since here the greatest strain is made on the centre of gravity. Moreover, the upper part of the body requires to bend well forward, to render the operation easier, and in ascending a mountain a person naturally assumes this position, without it being necessary to tell him to do so ; in fact, if the ascent is very long, he will at last almost bend himself double. Try to go up-stairs whilst holding yourself very upright—your knee will bitterly complain before you have reached the first story ; or, rather, be prudent—take my word for it—and do not try. The least accident which would retard the centre of gravity, after losing its support below, would make you fall backwards, and your mother would never forgive me.

Well ! you are up-stairs at last ; now you have to go down again. Here the extensors of the calf and knee have only playwork to do—it is a mere nothing that is required of them. It is gravitation that manages the whole, and, if allowed, the work would progress only too rapidly. One may truly say of this movement, that one advances by a series of falls, and the only effort necessary is to see that the centre of gravity does not advance further forward than the feet. You may have seen coachmen, when driving down a steep hill, pulling back the reins to hold in the horses. The coachman in this instance is the bundle of strong muscles we have in our loins ; they are placed just behind the steed, who would like nothing better than to break away ; and they contract right over him, to bring him back to them. The upper part of the body, which a short time ago bent forward, in order to assist the loins, now bends back, to aid them in taking its weight upon themselves. And I would still less advise you to try putting your head forward while descending the stairs, than leaning it back while ascending. I really do not know why I have spoken to you about this, as I am very sure you have never thought of doing such a thing.

You may, however, possibly have thought of running down-stairs ; if so, I beg of you never again to do it. Remember how very tyrannical are the laws of motion over bodies once on the move. Your own body, after it is set going, no longer belongs to you. You may have the misfortune to lose your equilibrium by a mere trifle, and, instead of stopping

to give you time to recover yourself, the motion within you, indifferent as to whether your arms or legs are broken, carries the little machine rolling down to the foot of the staircase, always accelerating its speed, like the ball falling to the ground; and if you are bruised on arriving at the bottom step, whose fault is it?

But we will not think of this any longer. A sensible girl, who knows the laws of motion and their pitiless rigour, will avoid trifling with them, or fail in paying the respect she owes to her centre of gravity, by making it gallop when it simply wishes to walk.

We say then that the work is performed by the loins when we descend. You cannot therefore wonder that the loins are tired when you have been walking down hill for a long time. The calves of the leg and knees, on the contrary, which have had nothing to do, are fresh and active, and a person who reaches the base of a mountain, worn out with fatigue, is quite surprised, if he does not know the reason, at finding himself rested as if by magic on the level road, although he is still walking. He has changed horses, like a post-chaise, and these are fresh steeds which carry him on.

One word more about the "step." If your papa has sometimes let you ride upon his knee, you must be acquainted with the three different paces, trot, canter, gallop. It is about the last of these three that I am going to speak. The gallop is done by lengthening the leg as much as possible. You will perhaps recollect that before long your knees and

calves grew very tired, just as if you were climbing. Do you know why this was ? It was simply because you were climbing the whole time.

Take your scissors, and make them go through the three steps, first the trot, opening the points a very little way, then the canter, opening them a little wider, then the gallop, opening them as wide as you can. In proportion to the separation between the two points, you will notice that the scissors descend. This is precisely what you do when you stretch out your legs ; you become very short, and as you take back your full height each time the legs are brought to the same level, the muscles have exactly the same duties to perform, as when you walk up-stairs.

I have taken a long time to teach a little girl, who can trot along so well as you can, how to walk. When you are older you will hear of a celebrated writer of comedies named Molière, who was also a great philosopher, although he used to philosophise in a jesting manner, which, after all, is not a bad way of doing. Whilst telling you all this, I am forcibly reminded of a character in one of Molière's plays, a Monsieur Jourdain, who is told how he pronounces *a* and *o* and *re* and *da* and *fa*, and he is delighted at the information, but, as his servant says, he speaks none the better for it, and I ask myself whether I have not been playing the part of this individual's master of philosophy towards you.

It is very certain that the first time you tumble, all the notions I have just given you about the centre of gravity, &c., &c., will be of little use in helping you,

but one would be very wrong if one only cared to see an immediate use for what we learn. Information is not tangible. We cannot eat it, it will not clothe us, we cannot put it in a shop for sale, nor can we shut it up in a box, and make a present of it; nevertheless, without it, what would become of us? To accustom one's-self to understand clearly what one does is one of the most useful things in the world. As I have already said, it is the true way to walk uprightly through life. You have not yet attained to this point, but you will do so some day; and, setting aside all other considerations, you will not be sorry, when you have little children of your own to teach to walk, that you understand how they learn to take their first steps.

LETTER II.

THE MOVEMENTS—(*Continued.*)

IF I had a scholar fifty years of age, I should scarcely require to proceed further with the history of the movements. The explanation of the step would no doubt be sufficient for his special use. But with a young lady, who jumps and runs perpetually, I can scarcely stop there. Running and jumping are both interesting subjects, of which it would be a pity not to speak.

Running is, properly speaking, merely a series of successive leaps. I must therefore begin by speaking of leaping.

Would you like to see with your own eyes how a leap is made? It is very easy. I will teach you a game which amused me when I was—well, I will not say how old.

Take a strip of rather firm paper, and roll it between your fingers into the form of a tube. This tube will be composed of a series of spiral rings which you can tighten or loosen at will. Leave them sufficiently loose to slip one within another, press the tube on the table, holding it by the top, and when it has become quite short, like a shut-up telescope, open your fingers suddenly; the tube will then jump into

the air, and rise pretty high, provided you have managed this cleverly.*

What renders it so active?

It is the elasticity of the spiral rings, which are like so many compressed springs. They make an effort to return to their former position, and when you open your fingers, which hold the tube captive, taking the table, which repels them, as the basis of support, they dart forth, carrying the plaything into the air.

Recollect now what you do, when you wish to jump with both feet together. You begin by bending your loins and knees as much as you can. This is the work of the flexors, and you represent the little shut-up tube. Then all at once the extensors come into play, the body draws itself up quickly while pressing the ground, and the motion thus given launches you into the air, exactly as if you were a strip of paper.

Only, as comparisons can never be exact between things so very different as your body and our little paper toy, the spring which carried you forward is much more complicated.

Bend one of the bits of whalebone (always to be found in a lady's dress) by the two ends, in the form of a bow, and then suddenly let go—the bone will dart forward, dragged on by the two ends, which hasten to resume their natural position.

We have a bow in us which straightens itself when we leap. It is the vertebral column. Mark well

* By drying the tube thoroughly, either near the fire or in the sun, it can be made to jump a far greater height.

what you do in this case. You not only bend your limbs, but also your body, and both straighten themselves at the same time, the moment you spring. The vertebral arch then makes a start, the rebound of which acts upon the loins, just behind the centre of gravity, which it propels forward.

But this is not all.

What do you do when you want to jump a little distance? You first balance your arms backwards and forwards several times, and then throw them forward with all your strength, at the very moment you make your spring.

What have you now done?

You have called to your assistance that terrible law of motion which smashes a railway train if stopped suddenly; you have developed in the upper part of your body, by balancing your arms, the germ of movement, if I may thus express myself. It becomes serious when you throw your arms forward, and all the body works together from head to foot—to carry itself forward below, by the stiffening and straightening of the legs; in the middle, by the vertebral column; in the upper part, by the jerk of the arms, which draw on the shoulders, as a pair of horses draw a carriage forward.

How many things are connected with a little leap of two or three feet! But, my dear child, this involves a fact of much more serious import than the act of walking. There you struggle, it is true, against that tyrannical love of the earth, which wishes to have you whether you will or no. But you struggle

whilst making the earth your support, and the feet are responsible for the rest of the body, of which they bear all the weight. Here you perform an absolutely independent act; you abandon every basis of support in effecting the movement, and it requires the unanimous concurrence of every member of a body as heavy as yours is, if you wish to shake off the yoke entirely. Try to jump while throwing your arms back, and you will see whether the lower part of your body could go far without the assistance of the upper part. I do not propose that you should try to jump by throwing the upper part of your body forward without taking any trouble about the lower part. It is quite clear one might manage in this way to break one's nose, and, in short, no one ever thought of trying it.

But we have not yet done with leaping.

Have you ever seen people dance on the tight rope? I ask you this question, because it is an art which is gradually disappearing, notwithstanding the feats of its latest performers; nor is this, in my opinion, to be regretted. These artists at all times enjoy a singular privilege. They spring in the air much higher than other people, their bodies straight as an arrow, without apparently owing anything to the vertebral arch or to the extensors. Still, assuredly, they are not sorcerers; besides, they no longer exist.

Another agent is here at work, as well as the body. The rope on which the dancer falls gives way with his weight, and then it also rights itself in its turn. The shock which it gives to the feet resting on it, when it

straightens again, sends the dancer back into the air, as it would throw back a beam that might fall upon it in place of him. Henceforth there is nothing more to do, and the springs succeed one another without further fatigue to the artist, except that of scrupulously maintaining the centre of gravity vertical with the cord. Besides, this is quite enough to attend to, when one considers the unpleasant prospect the poor man has before him, if he miss his mark. I do not sympathise with people who are pleased with this kind of amusement.

Whilst we are speaking of feats of strength, I must explain those wonderful springs to you that are made at the circus, to the great amazement of the simple, and by which a man can jump over a platoon of soldiers shouldering arms, with fixed bayonets. These are called the exercises of the springing board, and what then is a springing board? It is a flexible plank, elevated at one end, upon which the jumper falls from above, (when he wishes to astonish the spectators,) to make it rebound all the more. The plank acts like the dancer's tight rope, and all the honour of the feat would be due to it, if it were not also necessary that the human projectile should know how to make use of it. We must be just to every one.

You also, my little friend, without being one whit more knowing than the heroes of the circus, you make much less preparation for a jump, and you jump much further into the bargain, when you take a run before you spring, and the reason of this is quite simple. Gravitation and motion are, as I have often told you,

two rival powers which dispute the body, and, whenever one establishes itself, the other disappears, or, to speak more correctly, is annulled ; for it is a tenacious guest, and will not allow itself to be turned out of doors. In running, you put yourself in motion, and this motion would carry you on quite well alone if the feet stopped suddenly. You had some experience of this, when foolishly racing with your little friends through the beds of the kitchen garden ; your feet became entangled in the gardener's measuring-line, and your head, continuing its course, without asking your leave, popped into a bed of lettuces, which, happily for you, were newly weeded. He, then, who springs while in the act of running, already possesses an "acquired speed," as it is called, almost sufficient to effect the leap ; he has, as it were, only to strike the earth with his foot to enable him to take flight. And now see what is to be gained by bestirring one's-self. One gathers strength while journeying along.

After all, running is, as I have already told you, merely a succession of jumps. It essentially differs from walking, since, in the running step, the foot left behind leaves the ground before the one in front has secured its basis of support ; the body therefore finds itself, as in jumping, supported in the air by the power of motion alone. This rapid pace can naturally only be acquired by considerable effort. I have told you before, when speaking of the "work of the organs,"* how much the heart and lungs are engaged at such times, and how they will at last succumb to their task

* See "History of a Bit of Bread," p. 223.

when the race becomes too prolonged. It is on this account that good runners, when they wish to accomplish a long distance, throw their shoulders well back, and straighten the upper part of the body, so as to enlarge the chest by widening the ribs, and thus securing the action of their muscles, by rendering the basis to which they look for support as firm as possible.

There is also another reason for drawing back the shoulders, a reason which is instinctively felt by the greatest novice in the art of running. We have seen, in the chapter on "the Attitudes," the watchfulness which must be ever in exercise over the centre of gravity, always so imprudently inclined to cross the barrier beyond which lies a fall. This temptation is much stronger when the body, carried forward by its rapid career in the direction of danger, seems only, as one may say, to skim the ground with the ends of the toes. I beg you to notice, if you have not already done so, that we never place the foot flat upon the ground in running, as we do in walking; this would occupy too much time. It falls on the toes to rebound immediately. Those persons who in ordinary life feel that they are not well protected, redouble their precautions, and the body does the same in running. It throws itself backwards, and while I call your attention to these things, notice them yourself when you run. The faster you go, the more your head and shoulders bend backwards, to counterpoise the lower part of your body, whose chance of losing its equilibrium increases with the rapidity of the race.

It is also to act as a counterpoise that our arms

swing backwards and forwards with an inverse motion to our legs, the arm at one side going back at the same moment that the leg of the same side comes forward. An equilibrium is thus more easily maintained, and the centre point of gravity, which governs the whole, is brought back each time to the basis which it cannot abandon without ruin to the edifice.

You see that in order to run many precautions have to be adopted. Nature takes them for us when we are ignorant of them, and, quite unknown to us, our body arranges itself as the laws which rule it desire. But this does not dispense with our learning to know these laws. A mind that has any respect for itself would feel ashamed to know less than the mere instrument of its will.

There are many things I could still tell you, dear child, about the working of this "walking machine," (I cannot return to our old term without a feeling of pleasure,) the study of which has already occupied so much time, and cost so much trouble, at least, that is to say, to myself. I trust it has not been the same with you. All things considered, I think enough has been said. If I tried to make you too learned, I should only be laughed at for my pains. Not that this is anything very terrible, (we must not always be afraid of being laughed at,) but I might perhaps end by wearying you, and of that I am always afraid.

You now know from top to bottom the framework of the walls of the house you inhabit, to borrow the expression of an English author, a far more wonder-

ful house than any king's palace, since it walks, and the walls are living. It remains for us to study the more curious part, but unfortunately also the most difficult for the mind to take in—the power which makes it walk, the invisible breath which causes its walls to palpitate. We approach the great mystery of life. Most certainly I cannot explain it to you, but you may at least learn in what it consists, and what more can one know of a mystery?

Before leaving this world of bones and muscles, whose difficulties appear to me like child's play compared with that on which we are about to enter, I wish you to carry away with you one useful reflection.

You have observed the solicitude with which your body constantly watches over its equilibrium, how, if I may so express myself, it exercises its wits, how it invents, how it endeavours, how it expends science and will, to maintain itself erect upon its basis of support. Do not permit your soul to do less to preserve its uprightness. It also is called to rise towards heaven, and, like the body, it has its struggles to sustain, with the attractions of earth. Pride and earthly yearnings, the lusts and appetites of the flesh, constantly tempt it to stoop to things below; and it would soon lose sight of the higher regions of honour and devotion, which are its heaven, if it ceased to hold itself steadily on its basis of support. Now this basis allows no one to balance himself upon it. It is the conscience which we are forbidden to force, under penalty of rendering it useless. On this account you

must pay great attention, and call to your assistance all the helps you possess, in the shape of knowledge and will, to keep you straight on the inflexible line of conscience. On this account, be indulgent to the faults of others. When a poor man has fallen down on the pavement, every one tries to give him a hand, and if he has hurt himself, every one hastens to lift him up. Do not forget, my child, when you are grown up, that you must deal gently and helpfully with fallen souls, for there are none more deeply to be pitied, since the sorrow they work for themselves is the greatest that can be imagined.

And in the meantime, endeavour to fall down as seldom as possible, and if any one tumbles near you, whether brother, sister, or companion, assist him to rise, like a good little girl, without giving yourself any airs; otherwise take care of yourself, for, however firm you may imagine your equilibrium to be, the centre of gravity is always exposed to mischances where the heart is not in the right place.

LETTER III.

ELECTRICITY.

ELECTRICITY ! You will imagine, in reading this word, that we are losing sight of the subject which we ought next to study—viz., the nerves and brain. But I have not lost sight of it, I only wish to prepare your mind to comprehend as much as can be comprehended about them.

I recollect an idea which pleased me greatly, many years ago, when I undertook the duties of Professor of Natural Science to some young ladies. It occurred to me that man, being placed in the highest rank of creation, all its known laws would naturally centre in him, and he being thus, as it were, an epitome of the whole, the explanation of these laws, as exhibited in him, would make their action elsewhere sufficiently plain. Setting out with this idea in mind, (to which I have already alluded in the beginning of the history of the movements,) I wished to limit my entire course of natural science to the explanation of the human body, reserving to myself the right of becoming discursive on the way, when it might become necessary to make you understand the phenomena we might meet with. I have been compelled to relinquish this plan, because, shall I unblushingly own, I have found

the execution too difficult for myself, and, I may say, for my pupils also.

You must have already noticed, since we began our conversations on the life of man, that I have often required to introduce other topics than the human body, in order not to leave the most interesting points in its history in obscurity.

Could you have understood anything of the mechanism of the lungs, if I had not informed you what was meant by "atmospheric pressure?"* or of the results of respiration, without my little lesson on oxygen, and its union with the body? Did not our study of the subject of animal heat oblige us to make acquaintance with hydrogen and carbon? and did not the composition of the blood require us to touch on chemistry? This subject we should have thoroughly explored, had we been capable of doing so. And again, not long ago, in speaking of the movements, we were obliged to branch off into dynamics,† a word that would have frightened your mother on your account if I had let it slip. When we come to describe the eye, we must, whether we like it or no, speak to you of light, and optics,‡ as natural philosophers term it. When we arrive at the ear, we shall then have to study the laws of sound, or acoustics,§ as they are called. We shall, however, only touch on

* See "A Story of a Bit of Bread," p. 150.

† Dynamics in Greek means power. Dynamics is the study of force, or power with regard to motion effected by it.

‡ From the Greek word "opsis," signifying vision.

§ From the Greek word "acous," I hear.

these subjects, since that will be sufficient for you : we should go deeper into them if we intended to study them thoroughly.

You can now see that the study of the human body touches on everything, and that whoever completely masters it, knows all there is to know of physical laws. What I have just said may seem to you a little strong, but it is weak when compared with the expressions of Pascal, where he says, "He who thoroughly understands a grain of sand understands the universe." And Pascal was right ; whence I conclude that I need not feel alarmed at the boldness of my own expression.

But all this will not interest you. Let us now speak of electricity.

You know the yellow amber used by men as mouth-pieces for their pipes, and by the women of the East for their necklaces, which I fancy would be much admired in our own country, if they were only more expensive. When next you see a piece of this substance, so soft to the eye and touch, I recommend it to your notice, for with it originated the idea of the electric telegraph. Moreover, its own merits sufficiently recommend it to the attention of inquiring minds, for it is one of the antiquities of the globe. It is derived from the resin of old pines, which grew long before the era of man, in the forests of the North of Europe, and from time immemorial it has been fished for (for it is really a fishery) along the shores of the Baltic, the waves of which tear it from its bed, by breaking up the sand beneath which it lies buried.

The ancient Greeks, who were intrepid merchants, went to buy it from the savage tribes on the borders of the Vistula and Elbe, by sailing northwards from the Euxine Sea,* by the great rivers of Scythia. It is a great pity (we may observe in passing) that not a single record of these expeditions has been preserved, for undoubtedly they must have possessed some. The Greeks were far too fond of narration to lose so good an opportunity. In short, they were well acquainted with amber, and gave it the name of "electron."

Theophrastes, who lived three hundred years before the Christian era, tells that in his time they had recognised a singular property in amber, that of attracting light bodies when it is rubbed. Rub a piece of amber, and then place it near a bit of thread or a fragment of straw, they will at once fly towards it. This will give you an idea of the trifles which lead men to great discoveries, and how often the great laws of nature may, so to speak, lie within reach of man, without his thinking of extending his hand to seize them. He who had dared to announce to the worshippers of Jupiter Tonans† that the mystery of the thunderbolt lay hidden there, in this fragment of straw adhering to a morsel of amber, would most certainly have been taken for a madman in that age, and might perhaps have been invited to drink hemlock, in company with Socrates, the despiser of the gods. Unhappily,

* The Euxine Sea of the Greeks is now called the Black Sea, and their Scythia extended over all the steppes of the south of the Russia of the present day.

† Jupiter the Thunderer.

they did not think so much instruction could be concealed in a child's toy, and human science made no advance on this point for two thousand years.

At length, about the beginning of the seventeenth century, a man appeared who thought of examining this singular play of the amber and straw, so long considered as merely an insignificant caprice of nature, more accurately. It was an English physician, Dr William Gilbert, respectfully termed by a learned man of the last century, (whose book I have in my hand,) the "father of modern electricity," and whom we seem to lose sight of, now that his discovery is of world-wide renown. Such ingratitude is by no means uncommon. For my own part, I do not hesitate to rank the day on which the English physician rubbed his first bit of yellow amber amongst the great days of the history of man, although people take no note of it. He ended by discovering that this property belonged to other bodies besides the "electron" of the Greeks; to him belongs the imperishable glory of giving the first hint. It was soon perceived that we were in presence of an element, up to that time unknown, which was to be found everywhere, and to it the name of electricity was given, in memory or remembrance of the body which had manifested it in the first instance. Less than a hundred years after Gilbert, a new science was established, of which I shall give you a brief account.

Suspend a morsel of paper by a silk thread and then put near it a stick of sealing-wax which has been well rubbed. The paper will fly towards the

sealing-wax, adhere to it for a moment, then will again fly back, and if you pursue it with the sealing-wax, will continue obstinately to recede from it, just as if two friends had begun to embrace each other, but suddenly quarrelled in the midst of the embrace. The experiment is easily made, and it will amuse you if you try it.

Next take a long and narrow phial or small glass bottle, so that you can rub it more easily. Recommence the play, and you will have the same results.

If afterwards, taking the glass bottle in one hand and the sealing-wax in the other, you place one at each side of the bit of paper, you will produce another effect. The pendant paper will go from one to the other, escaping from the wax after touching it, to run towards the bottle, rushing from the bottle to return to the wax, and each time adhering for a moment to the new friend it is immediately going to desert.

In all this you see nothing but a little bit of amusement. The immediate successors of Gilbert might have thought like you. Let us do as they did, and go forward.

An explanation must be formed of these extraordinary movements. Here is what was first supposed.

Imagine two friends much accustomed to each other's society. They live peacefully side by side, happy to be together, but making no demonstration. Separate them, and they will only think of how they can meet again, and if they come in sight of one another, they will throw themselves with transport

into each other's arms. Well, in all bodies, there exists a double electricity, a couple of friends who say nothing when they are together, and whose presence we consequently forget.

When amber, sealing-wax, or any resinous substance is rubbed, one of these two electricities disappears, the other remains alone. The name of "resinous electricity" is given to the one that remains in the resin. When glass is rubbed, it is the resinous electricity which takes flight, and its companion remains faithful to the glass. This receives the name of "vitreous electricity," and bodies are said to be "electrified" when one or other of these two electricities is isolated.

The friend left alone, whether in the glass or resin, ardently longs for its lost companion. Now this companion is everywhere present in conjunction with the other, but the bonds which retain it cannot be broken without great effort. When the body is not too heavy, and when it is near enough to the electrified glass or resin, it is carried by the force of attraction, which its disconsolate friend constantly exercises in its vicinity, to recall the companion to itself which it misses, and it flies forward and rejoins it.

This is what the Greeks witnessed, and you understand now why the bits of straw flew towards the amber, and also why the little paper alternately adhered to your bottle and the piece of sealing-wax.

But this is not all; once adhering to the sealing-wax, which possessed only resinous electricity, the paper gives it all the vitreous electricity it contains, and,

small as it was, it has not sufficient for its requirements, what happens? It finds itself filled with resinous electricity, having lost all its vitreous electricity.

Have you never met with people who cultivate your society while they can get anything out of you, but when that is ended, show you the door? This is what the sealing-wax does to its little benefactor, when it has extracted from it all its precious vitreous electricity, without much change in its own condition. It repels it, and this is the more easily effected since the paper no longer desires to remain in its company. All bodies electrified in the same manner repel each other mutually, and we resemble them somewhat—when two persons cannot mutually aid each other, they do not care to live together.

If the paper be placed between the wax and the glass, both being electrified, what will happen? Robbed by the wax of its vitreous electricity, it will go to refurnish itself on the glass, which is fully provided. But in exchange for its present, the glass will remorselessly take possession of all the resinous electricity of the paper, and the poor little wretch will only have changed one state of misery for another; it will now find itself vitreously electrified. A fresh departure ensues, a fresh refurnishing from the wax, followed by a similar result, and thus ever backwards and forwards, until the paper, having effected an exchange, by conveying vitreous electricity to the wax and resinous electricity to the glass, until a perfect equilibrium is established between

the two, and the paper recovers its own equilibrium. Then all is right again, and things in their usual state. There is nothing more to see, the game is ended, unless we begin rubbing again, and so recommence the process.

You can imagine that the thing could be more quickly done, by suppressing the intermediate agent—viz., the paper, and merely suspending the glass bottle and the sealing-wax side by side. They would then go to each other, and make the exchange themselves by reason of a second law, which is the fellow of the first. All bodies electrified in an opposite sense mutually attract each other. This law we also understand. How often do we see persons of different characters sympathise with each other, each friend delighting to find in the other what is not to be found in himself?

If it depended on myself, dear child, I would give you no other theory of electricity. This is far the nicest, the most easy to understand, and the most pleasing to the imagination. But unfortunately there is another, and, what is still more unfortunate, it is to this other theory the names belong, which are in use at the present day, so I am obliged to explain it to you also.

Prepare, then, to take leave of our two friends, the resinous and the vitreous. They are now out of fashion, but, nevertheless, do not forget them. It was through them men first began to understand something of this great marvel, electricity, and through them also children are most easily taught what electricity really means.

LETTER IV.

ELECTRICITY—(*Continued.*)

THE naughty man who put our resinous and vitreous friends out of fashion was an American named Benjamin Franklin. The idea which he substituted is a very simple one, and as it does not make any material change in the manœuvres of our small bit of paper, a few words will suffice for me to explain it to you.

There are not two kind of electricities in bodies ; there is only one, but its quantity varies.

The stomach of the man who has had just the quantity of food he requires is contented and tranquil ; but an empty stomach, and one that is overcharged, not only suffer, but each gives indication of its painful sensations. In the same way bodies which have the necessary amount of electricity give no sign of life. Those which have too much, and those which are deficient, are both equally in distress, or, as it is termed, electrified—the first has too much, the second too little, and hence the two names, positive and negative, are given to one and the same electricity. These two words are easily understood. The one which is overcharged is positively out of order, because of what is there, the empty one is negatively

so, on account of what is not there. It is simply the negative and affirmative you find in your grammar.

When glass is rubbed, the electricity in it increases, and thus it passes into the positive state; when the wax is rubbed, the electricity it possesses disappears, and it passes into the negative state. The first, then, desires to throw off its surcharge, and the latter to make up its deficiency. If you bring them into contact, the mutual understanding is perfect; they run towards each other, this to receive, that to give. If the piece of paper is brought into play, it will fly alternately towards the rich side, to relieve it of its excess, towards the poor one, to offer to it all it possesses, and, becoming rich or poor itself by turns, it will be repelled by the party it has relieved, as soon as it can no longer render any service. Thus, as you see, whether there are two kinds of electricity, or only one, whether it is called vitreous or positive, resinous or negative, the effect produced will always be the same; bodies electrified in an opposite manner will always be mutually repellant. This theory of repletion and emptiness is by no means poetic, but if poetry loses, science gains, and this is of far greater importance. At the present day the terms invented by the American are the only ones in use.

I just now called this Benjamin Franklin "a naughty man;" I was angry with him for having robbed us of the two little friends that would have suited us so well; were he still living, he would not be angry with us for this; he was much too sensible a man for that. But, between ourselves, we have not spoken of him in

terms of sufficient respect, for he was a remarkable man, and I much regret my inability to give you a little sketch of his history before proceeding ; but take my advice, and read it for yourself the first time an opportunity occurs. In the meantime I must tell you that it is to him we are indebted for the discovery of the important part which electricity now plays in the world.

You would be unable to understand anything of this discovery, if I did not carry you a little further forward in the study we have already commenced.

First, seeing that electricity exists in all bodies, how does it happen that glass, resin, and a few other bodies are the only ones that can be electrified by friction, the effect of which should be the same everywhere ? Did you ever ask yourself this question ?

In the middle ages, communication between different countries was neither safe nor easy ; what one country produced, wheat, for instance, could only be consumed where it grew, and thus whole populations might be dying from hunger, while the granaries were overflowing with corn scarce three hundred miles off. Now-a-days, thanks to our railways, and the universal security which prevails, when the harvest fails in one place, corn immediately flows in from all the countries where it is abundant, and those deadly famines which used to carry off the poor by thousands have become literally impossible.

There are some bodies in the same condition that we were in during the middle ages, and on the surface of which electricity cannot circulate. If they have too

much in one point, so much the worse for them ; this superfluity remains where it is. And again, so much the worse for those parts which have not sufficient ; none comes to them from other quarters. These bodies are called non-conductors, they do not understand export and import, and this is the case with glass and resin.

There are other substances, especially metals, in which the transmission of electricity is accomplished with astounding rapidity ; it is said, at the rate of ninety or a hundred and twenty thousand miles in a second. These are the good conductors, and you may rub them as much as you like ; for as fast as they become electrified on one point, whether positively or negatively, the equilibrium is immediately re-established throughout the entire body. Thanks to this rapid transmission, in comparison of which that of a railway train is like nothing ! Moreover, it is right you should know that your own body is a pretty good conductor, and by means of your hand, which holds a piece of metal, the communication being established between it and the ground, (the great common reservoir of electricity, according to the authorised expression,) it becomes as difficult to impoverish or to enrich it, as it would be difficult, by pumping, to empty a well that was in communication with the sea, or to cause the same well to overflow by pouring water into it.

If, however, either glass or resin were placed between the ground and the metal that has been rubbed, the case would be different. The metal

would be insulated from the great common reservoir by these non-conductors, which do not allow electricity to circulate on their surface. This is termed their insulating power; and then the metal may be electrified. If you were to make the wheels of a train run upon glass rails somewhat raised from the ground, the wheels would be electrified by the friction, and by their means the train would, in its turn, become electrified with all it contained. Can you guess what must happen the moment communication with the earth is established, were it even by means of a passenger putting his foot to the ground while holding on to the carriage-door? The whole would explode, and I will prove upon what grounds.

When your bit of paper adhered to the sealing-wax or glass, it was only able, on account of its size, to take from the one or yield up to the other a very small portion of electricity. Had it been put in communication with the inexhaustible reservoir of the globe, by means of a metallic wire, it could not even then have given or taken much more electricity than before; because, owing to want of circulation on the surface of these bodies, the equilibrium could only be established at the point touched by the paper. On this account you neither saw nor heard what passed, for the re-establishment of electrical equilibrium is always accompanied by sparks and a crackling noise, proportioned, it is true, to the quantity of electricity set in motion, but this most certainly took place. Perhaps some microscopic animal, lost in the minute recesses of the paper, as we should be in a mountain

gorge, was struck down by the effect produced, but it was too weak to be perceived by you.

Suppose a large metallic surface insulated from the ground, strongly electrified, (this is done by means of an electric machine, which I have not time just now to stop and explain to you,) and then to have some body which is a good conductor brought into contact with it; the equilibrium would instantaneously re-establish itself over the whole surface, by means of its prodigious facility of transmission. A torrent of electricity—if I may be allowed the expression—would rush from one body to the other, and its passage would be revealed by a bright spark, and a sharp noise like the crackling of wood. If the body which was the good conductor happened to be your own, you would experience a shock by no means the most agreeable, I can assure you; a sensation in all respects so peculiar that you must feel it yourself in order to realise it.

Enlarge the surface, the spark, the noise, and the shock increase with it, and if it attains certain proportions it becomes a flash of lightning, a peal of thunder, instant death for whoever may be bold enough to try the experiment. An electric machine the size of a railway train would kill a man as instantaneously as the lightning itself, and it would kill as many hundreds as happened to be in it at the moment of the discharge, which is the name given to the sudden re-establishment of equilibrium between two electrified bodies.

We now come to the discovery made by the great

American ; but before entering upon it, one detail more requires to be noticed.

I resume my supposition of a train electrifying itself on glass rails, with the perspective of certain death to the passengers at the first moment of contact with the ground. This will never happen, but there is no harm in imagining it. It is thus that fairy tales were invented, which grave men will do away with when there shall no longer be any children.

What is to be done to save these unfortunate travellers ? If we touch them they are lost.

There is no difficulty in the matter. The train stopping of its own accord, I should cause it to be surrounded by a battalion of soldiers, with orders to cross bayonets at a foot from the carriages, and after five minutes pause the soldiers may with confidence give a hand to the travellers and help them to alight ; the danger is over.

You do not understand how this can be ! and it is in fact as marvellous as any fairy tale. This wonder arises from a singular law of electricity, the explanation of which would take up too much time ; but I can give you an idea of it in a few words.

Electricity is in a manner chained to the surface of bodies when they are flat or round. It can escape far more readily when they terminate in a point ; this is what is called the power of points.

My imaginary train, having rubbed on the glass, which becomes positively electrified, would itself become negatively so ; for you must recollect, that two bodies rubbed together electrify each other always

in an inverse sense, one giving, the other receiving; from whence it results, we may remark in passing, that the same body is capable of taking indifferently either of these two states of electricity, according to the nature of the companion against which it is rubbed. The train would then most certainly have lost its electricity, and the danger to be feared from contact with an exterior body would arise from the immense torrent of electricity suddenly precipitating itself over so vast a surface to establish the equilibrium. Each bayonet directed towards it would have exactly the effect of so many tubes pouring streams of water with an incalculable rapidity into an empty basin; the basin would soon be filled. The same with the train, and the travellers, restored with it to their usual condition, could resume communication with the great common reservoir, the earth, without any danger.

Now I shall give a little account of Benjamin Franklin.

He was not exactly a learned man, for he was originally a printer, working for his daily bread, but liking study very much, and he wrote certain books for the improvement of his contemporaries, which will never go out of date, because they inculcate the secret of all true manliness. A book that happened to be sent from England, falling into Franklin's hands, taught him what I have just now been endeavouring to transmit to you;* and the idea occurred

* We must except the power of points discovered by himself.

to him, that since the discharge of an electric machine resembled, as it were, terrestrial electricity of a certain force, celestial electricity or the lightning of heaven, with its noise and its brilliancy, might after all be nothing more or less than an immense electrical discharge.

And he found out that he was right.

Franklin had for the space of three years announced, that by placing metallic wires on end, at a sufficient height insulated from the ground, and each terminating in a point, one could see them electrified on the approach of a thunder cloud, and he was waiting until a steeple, then in course of erection in Philadelphia, should be completed, that he might make the experiment. Tired of waiting, however, he at last constructed a kite with two sticks and a handkerchief, arming it with a metallic point, and one stormy day he went out into the fields to fly it. A large black cloud having passed over the kite, Franklin produced electric sparks by touching a key with his finger, having first fastened the key to the end of the kite string;* this was indubitable proof of the presence of electricity in the cloud.

This took place in June 1752,—and now, mark well the danger of delay. By waiting so long for the steeple, the illustrious American was not the first to realise the idea which he was the first to conceive.

* The key was retained by a silken cord which intercepted the communication with the ground. Silk, as you perhaps know, is one of those conductors called insulators, or non-conductors.

A month previous, on May 10th, at half-past two in the afternoon, the first electric spark drawn from the clouds, as one may say, was seen by a carpenter at Marly—the Marly of Louis XIV.—which will one day be talked of for this, let me tell you, much more than for its having been the occasional abode of the great king, for whom the world at large will care but little. (Marly-le-Roi is near St Germain, and belonged to Madame de Maintenon, for whom it was built by Louis XIV.)

I must give you the history of this spark, which is more worthy of record than many a battle.

Buffon, the celebrated naturalist, had undertaken to introduce the ideas of the Philadelphian printer into France, as he already began to astonish the scientific men of Europe, who were somewhat mortified to see themselves left in the back-ground, by one who hitherto held no rank among philosophers. “As Buffon was occupied with more important affairs,” says one of his contemporaries, * “he abandoned this duty to one of his friends named Dalibard.” This Dalibard was an intelligent man, and had so strong a liking for the new doctrine that, impatient to know whether the inventor was right in his surmises, he could not wait till Franklin had tried his experiment. “It never thunders in Philadelphia,” was already the byeword

* This phrase is taken from the first of the letters on electricity. (1752,) by the Abbé Nollet, one of the famous natural philosophers of the last century, who amusingly jokes the new comer as to his pretension of being able to invoke electricity by sticking up points (metallic) on the highest parts of buildings.

in Paris, amongst those who were teased with Franklin's delays. I quote the expression to show you how little was known of America at that period.

Dalibard caused a pointed iron rod one hundred feet high to be placed on end, well insulated from the ground, on a property he possessed at Marly. As no storm occurred he returned to Paris, leaving the iron rod in charge of a carpenter, who had orders not to lose sight of it, in case the weather changed. The storm came at last, the iron rod emitted sparks, and thus it happened that, owing to the fortuitous arrangement of Franklin, Buffon, and Dalibard, this carpenter was the first man to see, with his own eyes, the fire of heaven coming by command, and exposing itself for the gratification of human curiosity.

Those long pointed iron rods that are seen rising from the roofs of large buildings, are the invention of Benjamin Franklin. They act the very part that our bayonets did a little ago, and silently discharge from the clouds the electricity, which might destroy the edifice by passing too near it. It is the iron rod erected at Marly, but with a most important alteration. Instead of being carefully insulated from the soil, the lower extremities of lightning conductors are put in communication with it, and a thousand methods are invented to render this communication as complete as possible, otherwise, so far from being any protection, the lightning conductor would become very dangerous, for the electricity of the clouds accumulating there, and finding no issue, would immediately discharge itself on the building, and thus

we might bring down upon us a dangerous visitor, which, but for the conductor, would probably have kept at a distance.

When you see metallic cords reaching from the rods to the ground along buildings which are surmounted with lightning conductors, you will now know what is their use, and remember you must never go near them during a storm. The electric fluid, silent and invisible, is very probably there, and as the proverb says, "Let sleeping dogs lie."

Now, what do you say? Have we not made some progress from Gilbert's yellow amber, and the chip of straw adhering to it? and have we not attained to something more serious? Well! you have still more wonderful things to hear about. We shall by means of a frog's leg, arrive at a series of revelations which will surpass all we have yet seen.

LETTER V.

ELECTRICITY—(*Continued.*)

IT was in 1786, thirty-four years after the spark had been observed, as has been described by the Marly carpenter, that a physician of Bologna, Professor of Anatomy, set about preparing frogs (to use the consecrated term) with a view to scientific research, that is to say, after having killed them he flayed them, in order to ascertain their organisation more accurately. As he prepared them, he hung them one by one upon his balcony, by means of small copper hooks passed through their loins at the very spot whence the large nerve, known by the name of the lumbar nerve, issues, and which is situated in the same locality in man also, for in the general plan of the nervous system we are not differently constructed from the frog. A breeze arising, caused a movement amongst the frogs, and each time that one of them touched the iron bars of the balcony with its pendant feet, it suddenly doubled up with a convulsive movement, as if the poor little dead body had begun to jump.

How frequently human glory is the simple result of chance! If this Professor of Anatomy had been standing at this moment with his back turned to the balcony, he would assuredly long ago have sunk into

the same oblivion, into which so many other professors of his day have fallen, who doubtless were as worthy of remembrance. But happily he saw the frogs jump, wished to know the cause of the phenomenon, and became immortal ! This man was called Galvani. When you hear the words galvanoplastic, galvanised iron, galvanic brushes, &c. &c., you will at once know them to be derived from the name of the experimenter on frogs.

Galvani at once understood the nature of the convulsion which appeared to resuscitate the little dead feet. He said to himself that the shock could only be the effect of an electric discharge.

But whence proceeded the electricity thus discharged ?

Galvani being a physician, at once attributed it to the nerve and muscles which had been put in communication by means of a metallic circle. He declared that an animal electricity existed, of which the nerves were the conductors, self-producing in living bodies, and existing in them for some time after death.* He was right, but his discovery was only partial.

This opportune gust of wind sufficed to render two men immortal. Volta, Professor of Physics at Pavia, had the intelligence requisite to work out the remaining part, and so to complete Galvani's discovery. Being a natural philosopher, he laid aside the idea of nerves and muscles, and turned his attention to metals. Declaring in his turn, that the cause of the dis-

* After a certain lapse of time, a dead frog becomes insensible to the double contact of iron and copper.

charge resulted from the contact of the two metals, namely, the copper hooks and the iron balcony, the one of which having attracted all the electricity from the other, had become positively electrified, the other, negatively. A celebrated controversy arose between the two professors, who both came off triumphant, (a solitary instance, I believe, in the annals of science,) and whilst Galvani successfully established his share of the discovery in obtaining shocks by placing the nerves and the muscles of the frogs in direct contact without the intervention of any metal, Volta established his theory, no less successfully, in the invention of the famous "Voltaic or electrical pile" that still bears his name.

Making his experiment the reverse of that of Galvani, Volta replaced the half-dead frog's legs by something inanimate, such as a bit of wet cloth, and from one experiment to another, he, at last, arrived at the conclusion, that the two metals most suitable to electrify one another in an inverse manner, by contact, were copper and zinc. He also found that the effect produced became more considerable, if a series of pieces of metal (copper and zinc) were always coupled two by two in the same order. This was the origin of his pile, formed with a certain number of couples, (copper and zinc) piled one upon another, making a kind of column terminating above in a piece of copper, below in a piece of zinc. No animal electricity could by any possibility be formed here, nevertheless the two pieces of metal placed at the extremities of the pile were electrified—that of the copper negatively,

that of the zinc positively. If two metallic wires were attached, one to each end of the pile, and the other extremities of the wires brought into contact with each other, an electrical discharge was produced, or rather, I should say, a continuous succession of discharges. The equilibrium constantly destroying itself as fast as it was established, scarcely had the electricity reached the negative extremity, ere it returned to the end, positively electrified, from which the surplus always renewing itself was as constantly thrown off! You can imagine the water of a cistern running into a barrel without a bottom, and through which the water falls back again into the reservoir. It is quite clear that the barrel would never become full, nor the reservoir empty. And this is the case with the two pieces of copper and zinc placed at the extremities of the pile. If ever there was a scientific name happily chosen, it is this of electric current, given by Volta to this inexhaustible stream of electricity, which flows from the one piece of metal to the other.

This is a very different thing from the spark of the electric machine, even when that is magnified to the proportions of the thunderbolt.

I remember a game we used to play at school, called "The Stag." It began with a large herd of stags, pursued by one dog. If I recollect right I was delighted to be this dog. At the onset all chance seemed against him, but as soon as he had caught a stag, it immediately became a dog, and had to assist in capturing another stag, which, in its turn, joined

the pursuit, and thus by degrees, the pack gradually increasing in number, succeeded in capturing the last stag. This, in some measure, resembles the war commenced by man at his creation against Nature. Alone at the beginning, and as if lost amongst a thousand inimical powers, the combat seemed a very unequal one, but the first that he overcame immediately became his auxiliary, and it is by, in a manner, forcing each new captive to fight by his side, that he has at last succeeded in plucking so many feathers from the wing of Nature, if I may be allowed thus to express myself.

Now, in a warfare of this nature, the importance of the capture ought to be calculated in proportion to the amount of service the captive can render, and the new form under which electricity revealed itself this time was a great boon to man. It is no easy matter to make the electric spark do our bidding, but an electric current! can we control it? Think what we can make a stream of water do!

Scarcely was the pile discovered than it showed us what use it might be turned to. I have already told you that, in nine lbs. of water, one lb. of hydrogen and eight of oxygen are found. The very first experiment of the pile taught us this. Until that moment, no one had ever thought of seeking for anything but water in water. Water was, as you are well aware, one of the four elements* recognised by the ancients

* Element is synonymous with simple body, a word now used to express a body which as yet has not been decomposed into several others. At present we can number sixty simple

as earth, air, fire, and water, and these four were considered as the universal basis of all bodies. An Englishman who, for the first time, was studying the effects of the new apparatus designed by Volta, was struck by a smell of hydrogen, which could not be accounted for,* and by dint of observation, he at last convinced himself, that the water contained in the wet layers was decomposed by the passage of the electric current into two gases, of which the one, oxygen, went to the positive extremity of the pile, and the other, hydrogen, was disengaged at the negative extremity. It was an easy matter for philosophers to collect with exactitude, to measure, and to weigh the two gases thus produced, and they had soon a clear proof of the fact they maintained. By directing an electric spark through the two gases enclosed in the same vase, they effected an explosion accompanied by sparks. This was the reunion of the two disunited gases, and only some tiny drops of water were found in their place; what the electric current had divided, the electric spark re-united.

The discovery of the true nature of water was made in the year 1800, and the discoverer's name was Nicholson. I wish you would accustom yourself to remember the names of these conquerors and the

bodies, but it is a list that is exposed to constant change from the discovery of new indecomposable bodies, or from the decomposition of old ones. Some persons are of opinion that there ought only to be two simple bodies. Perhaps there may after all be only one.

* Hydrogen has a peculiar odour, sufficiently distinct not to deceive a chemist's nose.

dates of their conquests. What are those odious little battles between men compared with the great and fruitful battles of man against Nature? And tell me, if you please, which deserves the place of honour in the memory of my young friends?

These were sad times for the famous quatuor of elements, so long the undisputed fathers of all bodies. Only a few years before, the illustrious Frenchman Lavoisier had at one blow divided the air into two gases, oxygen and azote, and scored out fire from the list of simple bodies by proving, scales in hand, that it was only an illumination produced by the union of gases.* Then here comes an Englishman to deprive water of its rank as an element; and seven years later another Englishman named Davy, (another name I wish you to remember,) gave the last blow to the sole survivor of the four, already in a very shaky condition, by discovering, thanks to the pile, metals in the earth.

At that time the name earths, in the plural, was given to potassa, soda, alumina, silica, magnesia—in short, to all those substances which, mixed together, form almost the entire composition of stones in general; and consequently the soil of our fields, which, though you may not be aware of it, is nothing else than pulverised stone. Nicholson's discovery concerning water led the way to similar discoveries with regard to many other bodies, which all permitted of

* Lavoisier's theory, as it is generally understood, is, that combustion consists in or results from a combination of bodies, with the oxygen floating in the surrounding air. — TRANSLATOR'S NOTE.

their bonds of affinity being broken up by the electric current; and what is singular, it was always the oxygen, or the portion in which this gas was most abundant, which appeared at the positive extremity—the other part invariably passed to the negative. In the year 1807, Davy, who had arranged a very strong pile, submitted potassa, soda, and their companions to the action of a very powerful current, and produced the result anticipated. The earths were destroyed, the oxygen appeared at its post, and potassium, sodium, magnesium, aluminium, &c., &c., were successively discernible at the opposite end, and were henceforth classed in the order of the old metals—iron, copper, gold, silver, &c.,—under the name of earthy metals.

All these metals terminating in um, sound very scientific to our ears. There is one of them, however, aluminium, that you must be acquainted with; for it has had the good taste to place itself at the service of young ladies, in the form of trinkets, since a noted French chemist, Henri Sainte-Claire Deville, has found out how to obtain in ingots what the pile only produced in particles far too small for use. There is another which also appears destined to enjoy a brilliant future; this is magnesium, which is beginning to be used on special occasions for lighting, and a single wire of which, when burning, gives forth a light surpassing that of any lamp. If potassium were cheaper, its wonderful power of spinning round upon water, and darting forth actual fireworks, would long since have brought it into notice as an object of curiosity. I grant there is nothing very important in all

this, but it is only the beginning, and the Davy's metals have not yet fulfilled their destiny. Aluminium is already making a very respectable apprenticeship as an available metal in the industrial world ; and if this were the only one, it would be sufficient to place the English philosopher in the rank of those who have extended the field of human knowledge. The French philosopher also deserves his share of praise ; and we must not forget the great Italian who invented the pile. There is this advantage in opening up a new furrow in science, that all who have contributed to its development are entitled to our gratitude.

Unfortunately, we have not sufficient time to pass in review all the conquests due to the pile. Still, I cannot bid adieu to Davy without speaking to you of the electric light, this sun kindles at our bidding, whenever we require it, by means of the pile.

It was Davy who produced the apparatus used at the present day to obtain those prodigious effects of light which enable workmen to labour in the dock-yards by night as easily as they can in broad daylight. The electric current produces these effects, by traversing small pieces of charcoal placed one after the other at the extremity of the two wires of a strong pile. If Gilbert, whilst rubbing his bits of amber, had been told that, by means of this simple art, one of his countrymen would, two centuries later, have invented a new light for the use of mankind, fancy how great his astonishment would have been ! Nor would it have been less cause for wonder had he been told that, thanks to him, a day would come when silver spoons



would be more common than pewter ones were in his day. You must understand that I am here alluding to galvanoplastics, of which I wish to speak to you more at length, inasmuch as it is far more nearly connected with the subject now occupying our attention than you can possibly guess.

In that celebrated garden of Greek roots, of which we spoke in the chapter on Ruminants, (a ruminator is a man who muses,) we read this line which, had he seen it, would have extracted a grimace from Boileau,

“Plassô, forme, enduit, fait semblant.”

Such as it is, it suits us, for it teaches you that “galvanoplastic” means coated by Galvani. It ought to have been “voltaplastic” to be accurate, but that is of no consequence.

You have just now seen that where the demolition of a body is effected by the current of the pile, the oxygen retreats to the side that is positively electrified, or carries off to that point its intimate friends, who remain hooked on to it in the struggle. The remainder runs to the negative side.

This being settled, recall to your mind those beautiful blue crystal pyramids, of which you must more than once have admired while passing the druggists' shops. The mass, who have remained faithful to the name employed in the middle ages, call this “blue vitriol”—the scientific name is sulphate of copper. These blue crystals are full of copper; but try if you can extract it with your fingers! it is held there in bonds of affinity infinitely more complicated than those

by which hydrogen and oxygen become water, and perhaps you will not be sorry (to speak in lawyer-like style) to know the condition of the contracting parties.

From the first union of copper with oxygen, a new body is formed, known as oxide of copper, which alone appears like a black powder. This oxide in its turn unites with sulphuric acid, which again is only a composition of sulphur and a large proportion of oxygen, and all these unions combined produce the blue crystal. There are a great many unions in this affair, are there not? but I am persuaded that you will be able to recognise them all. You disentangled more intricate family webs than this the other day when you accomplished the numbering of the relationship with your cousin.

The current of the pile will soon unravel them, and what is more, partly untie them, if you will make it traverse a basin of water in which you shall have melted one of these blue crystals full of copper. It is a voyage which you can compel it to take by putting one part of the basin in communication with the positive, and the other with the negative wire; it immediately rushes from one wire to the other across the bluish water, which is a good conductor, and sows discord among the component parts all along its passage. The oxygen which was united to the copper abandons it all on a sudden, and runs to the positive wire in concert with the sulphuric acid, upon which the copper, deprived of its oxygen, produces the same effect as a girl without a dowry does upon a miser. The copper thus forsaken, "liberated," as

chemists say, makes for the negative wire, and on arriving there, behaves as amiably as we could desire, now that we know how to make it subservient to our use.

If it encounters a metallic object there, or one simply washed over with a layer of metal, no matter how thin, it immediately makes friends with the comrade presented to it, and deposits itself all over the surface of the object in impalpable particles, penetrating the most remote corners, so that after a certain length of time all this surface is covered with a uniform layer of copper, a thousand times better applied than could have been done by the hammer of the best tinsmith the world can boast of.

Bodies resulting from these double unions such as that of the blue "vitriol," or sulphate of copper, are called salts. If you dissolve salts of gold or of silver, or any other metal you wish, in the basin of water, the operation will be exactly the same, but instead of a layer of copper, you will have a layer of gold or silver, as the case may be, which will adhere to the object attached to the negative wire. Hence all this new cheap silver plate, which rejoices the hearts of the humblest individuals.

When you eat your soup, if the useless luxury has been abolished in your house of using solid silver spoons and forks, you can say to yourself, that you are acquainted with the history of your spoon. It has passed through an electric bath of a salt of silver, out of which it has come plated. This coating, the coating of Galvani, is of incomparably purer silver

than is that of royal spoons, when, indeed, kings condescend to make use of silver. Only I must warn you that it is exceedingly slight. Do not take it into your head to follow the example of a very zealous cook that I once knew, who scoured some electro-plated covers with ashes with all her might. What is noble on the surface only, is soon rendered ignoble by rough usage. On this account deal gently with your spoons; and that you may have nothing to fear from the rubs of the world, let your little heart be silver to the very core.

LETTER VI.

ELECTRICITY—(*Continued.*)

THE inconvenience, or if you prefer it, the advantage of study, my dear child, is this, that it always leads you farther than you thought of going. In order to prepare you to understand the action of the nerves, and the part they perform in your body, I have been obliged to speak to you upon a variety of subjects, each one more curious than another ; and now, whether disposed or not, I am under the necessity of explaining the electric telegraph. An invention of the Almighty which dates from the first moment an animal began to move.

This electricity, which has for some time occupied our attention, is a very mysterious power. I do not know any better comparison than that of an actor performing a play, which is so arranged that by varying his dress and expression of countenance, he is enabled to personate each character in succession. This power is to be met with everywhere, always the same in principle, but manifesting itself under different aspects, according to circumstances. We have it first quietly accumulating on the electrical machine, and instantly disappearing at the smallest contact. Again we saw it carried away in the form

of an endless current in the pile ; and I much regret that I had not time then to enter into its whole history. You would have been amazed at the thousand forms under which it shows itself.* Now we come to a new form of electricity, so different from the others, that, for a long time people were deceived about it, and believed themselves in the presence of a totally distinct power ; but there is no longer any doubt on the subject—I refer to what is called Magnetism.

Magnetism comes from the Greek word “magnis,” (*Μαγνης*) which signifies a magnet. You are aware that the magnet attracts steel. To be ignorant of a discovery made more than two thousand four hundred years ago would be a great disgrace. Thales, one of the fathers of Greek philosophy, taught us that the loadstone possessed a soul capable of attracting iron, and I should like his explanation well enough if we could agree about the meaning of the word “soul.” The natural loadstone such as was known to the Greeks, and the artificial magnets of the present day, attract

* The piles in use at the present time bear no resemblance to that of Volta, and in their construction and the explanation of them, his first idea of the virtue of metals brought in contact with each other, has been completely abandoned. It has been recognised that all chemical actions, all changes in the conditions of bodies, and even a simple difference of temperature between one end of a metallic pile and the other, produced electric currents. The term “pile” has nevertheless been indistinctly applied to all the different apparatus invented since the time of Volta, for producing these currents, and with some justice, for from his pile originated all the more recent discoveries.

iron, as a piece of amber that has been briskly rubbed attracts bits of straw. Here is the first resemblance between the power inherent in them, and that observed in the old "Electron,"—but we are only at the beginning of our subject.

Ask your mother to lend you one of the needles she is in the habit of using. The probability is, it has become magnetised by the manipulation it has been subjected to by your mamma's fingers, while passing it rapidly and frequently through her work. You may also present one of the points of a pair of scissors in active use to the needle, and you need not be surprised to see the needle adhere to the point. In this case, rub the needle freely against the two points of the half-opened scissors ; magnetism being there, it will be communicated by the rubbing, from the needle to the scissors, just as good and bad habits circulate amongst little people who live together. But if this experiment do not succeed, (for these little feminine implements are not without their caprices, and it is not every lady who is gifted with the power of magnetising with her fingers,) you have still another left. Ask your papa to buy you a magnet ; there are plenty to be had in every toy-shop at about a shilling each, and I can assure you it is as amusing a toy as any you can select. They are generally of the form of a horse-shoe elongated, the two extremities of which incline towards each other. Hold your needle by the middle, and rest the two ends upon the magnet, giving it a little see-saw movement ; a moment will suffice to magnetise it.

In short, hold in your hand a magnetised needle any way you like. Before trying your experiment, satisfy yourself as to the direction in which the north lies from the point at which you take your stand. This is exceedingly simple. If you turn your face to the sun at mid-day, the south will be immediately in front of you, and the north consequently at your back.

This important point once settled, take a cork and cut a delicate round slice off it, and place it in the middle of a plate full of water. This will form a kind of little boat capable of carrying your needle ; place the latter on the cork in any direction you choose, you may rely upon one end pointing towards the north, the other consequently towards the south ; turn the cork and needles as you like, they will always by mutual consent return to their post. The northern extremity turning from the south with horror, and that of the south fleeing from the north with all its might.

This, dear child, is the compass ; and I advise you to look with great respect upon this needle which turns about in the plate of water. Man is indebted to instruments of a similar kind to guide him on his way on the open sea, when he sees nothing around him but a boundless expanse of waves exactly resembling each other ; and but for the unfailing instinct of these little needles, we should in all probability still be ignorant of the existence of the American continent. At any rate, our bravest mariners would tremble at the idea of venturing upon a voyage across

the Atlantic, and so one half of our globe would be lost to us.

But this has nothing to do with our subject. Let us go back to our shilling magnet, for I conclude you possess one ; it will best answer our present purpose.

Look at it well. You will observe the letter N marked on one of its extremities. This end will always turn to the north, if you hold the loadstone suspended by a string, and notice its movements. It is that end of the needle which rubs against it that you will notice points towards the south. Present it now to the other end of the needle, that which, like itself, is directed towards the north, and is called its north pole,* it will fly from it ; reverse it, and present the south pole to the needle, it will rush towards it.

Do you not recognise in all this those fundamental laws of electricity to which I recently called your attention ?

Two bodies rubbed against each other become electrified in a contrary sense.

Bodies similarly electrified repel each other.

Bodies differently electrified attract one another.

It is clear that we are dealing with facts of the same nature, and there is every reason to suppose the power producing them to be the same. But there is something beyond this.

Navigators for a long time observed, with despair,

* These terms "north and south poles" have been given to the two extremities of the magnetic needle, to assimilate them with the two poles of the earth, which may be considered as a large magnet.

that in stormy weather, when the compass was most necessary to them, it sometimes indicated a route the reverse of that intended to be followed ; turning at random, as if it had lost its head. Do not smile at my expression ; it differs but slightly from that used by seamen, who in these cases speak of their valued compass as if it were a living creature, saying it is bewitched, or, in other words, gone mad.

Storms being ascertained by Benjamin Franklin to be nothing more than electrical phenomena, and this peculiarity in the movement of the needle having been so often observed, led to the belief that there was an evident connexion between magnetism and electricity. This supposition was corroborated towards the close of the last century by natural philosophers, who produced on the compass all the effects of a storm, nay more,* by means of the electric machine.

* Note for grown-up persons, taken from Cavallo's "Treatise on Electricity," 1785 :—"A violent degree of electric power is not only capable of destroying the virtue of a magnetised needle or changing its poles, but can even communicate magnetic attraction to a body not possessed of it. If a fine sewing needle be placed in the direction of the discharge from a glass tray of at least eight or ten feet square, the needle will in some instances become magnetised, and that while floating on water, and will turn towards the north. It must also be remarked that if, at the time of the discharge, the direction of the needle be east and west, the point that is struck will mark the north. If, on the contrary, the direction of the needle be north and south, the extremity looking north will continue to indicate it after the shock, no matter from which side it comes, and in this latter case the needle will be more powerfully magnetised than in the former. Lastly, should the needle be placed perpendicularly to the horizon, and the shock passed by one

Immediately upon the discovery of the pile, it seems to me that scientific men ought promptly to have tried the effect of its currents upon the compass,—an effect much more easily ascertained, considering its constancy and regularity, than in the rapid and capricious discharge from the electrifying machine. It was not, however, until the year 1819 that a Danish professor called Ørsted felt himself in a position to announce to the world that the compass lost control over itself when in the vicinity of a wire crossed by the current from the pile. After the experiments described by Cavallo, if you have had courage to read the extract I made from them, the discovery (between ourselves) was not a very extraordinary one. This did not, however, prevent its making a great sensation; for Ørsted (a really scientific man) at the same time that he made the discovery found the means of utilising it. Thanks to him, the illustrious Arago was enabled, the following year, to establish the fact on which an entire telegraph system rests, namely, that a bit of soft iron* became instantaneously magnetised,

or other of its extremities, the lower one will always point to the north."

* In submitting iron to a certain process, it is rendered much harder and very brittle—it is then called steel, and ordinary iron takes the name of malleable iron, as opposed to steel. Iron wire, which is readily bent, is made of malleable iron. Needles, which pierce our work so easily, and snap asunder when we try to bend them, are made of steel. Steel and malleable iron have not the same magnetic properties; the former can only be slowly magnetised, taking certain precautions, and then it remains magnetised for ever—thus all load-stones are manufactured from steel. The second, namely,

so soon as the voltaic current (I do not stop to explain the word now) crossed a wire rolled round it, and that it ceased to be so, simultaneously with the cessation of the current across the wire.

This fact established, nothing was easier than to set up electric telegraphs. I have told you with what startling rapidity electricity rushes from one end to the other of bodies which are good conductors. Let a metallic wire be led out a hundred miles, (a thousand if you like,) and at the end of its journey let it be rolled round a bit of malleable iron. At the same moment if from the spot on which you are standing you send an electric current along your wire, putting it into communication with a pile of which you hold the one end in your hand, the bit of malleable iron at the remote extremity will suddenly become a magnet; this will be quite perceptible to any person wishing to see the experiment, as it will attract to it needles which may happen to be presented to it. At the very moment when by a slight blow of the hand you suppress the current by interrupting the communication between the wire and the pile, the artificial magnet will all at once lose its borrowed virtue, and cease to possess any power of attraction. This is the principle of the electric telegraph; and, as you see, it is very

malleable iron, receives magnetic virtue immediately on its simply coming in contact with a magnet, and retains no trace of it after the contact is suppressed. It is just like children who learn their lessons very quickly and forget them as readily. There are also memories like steel, which require longer time to be acted upon, but in the end are none the worse for that.

simple. The rest is only a mechanical affair, and I leave to some one else the task of explaining to you the various kinds which up to the present time have been invented.

Now, dear child, we can pass on to the explanation of what is called the nervous system. I have made you wait a long time, but it is because we shall find electricity connected with it. This universal power, which seems to preside everywhere, presides also, it is more than probable, over the mysterious acts of life in our bodies; and it was requisite you should know something of it, before speaking of the nerves which may be considered as its agents. Only, it is neither the electricity of the electrifying machine, nor that of the pile, nor that of the loadstone either; it is living electricity, if I may so speak, having no resemblance to any other kind in its manifestations, but which is not less the same power producing other results because exercised under different conditions.

The few remarks we have made to-day are quite sufficient to give you an idea of the possible transformations of one and the same power. You have, I presume, no longer any doubt regarding the intimate relationship existing between magnetism and electricity; and yet I have not said all, for I might have shown you how electric currents may be produced by magnets, in the same way as we make magnets with electric currents. A magnet is therefore, in reality, a permanent battery; and scientific men have so perfectly understood this, that they have given the name of poles to the two extremities of the pile—the posi-

tive and the negative. But what a difference ! This battery is under your control. You can touch the two poles at the same moment, and put them in contact with a variety of bodies which would produce marvellous results if acted on by an ordinary pile. Nothing stirs, nothing reveals the presence of the marvellous virtue sleeping imprisoned within it. Iron alone has the privilege of awaking the beautiful sleeper ; it alone can set it working ; it alone can harbour it. What is the reason of all this ? We know nothing about it.

What is the peculiar property of animal electricity, since I must give it its proper name ? We know nothing of it either. I thought I would tell you this beforehand, lest you should come with exaggerated hopes to the study we are just entering on.

LETTER VII.

THE NERVES AND SPINAL MARROW.

I REMEMBER seeing in the manager's office, of one of the first-class hotels on the German border of the Rhine, a large frame, the interior of which was furnished with a variety of small labels, one or other of which, every now and then, sprung up with a sharp, quick sound; they were raised by an invisible wire, and exhibited a number—the number of some particular room, as you may suppose. The manager, thereupon, stretched his hand towards a row of numbered handles placed in a line in front of him, and pulled one of these, when a waiter immediately ran to attend the summons, no matter in what remote part of the house he was wanted.

In all this you have a representation—though but a rough one, it is true—of what goes on in your brain. From all parts of the body mysterious threads issue, for the purpose of carrying all their demands to it. The manager pulls the handle, and the waiters are at once on the move.

You must not, however, suppose that this is in all respects a parallel case. We are quite aware from what points these signal wires issue, but no person has as yet been able to discover their precise termi-

nation, nor can they determine accurately in what spot the handles used to transmit the orders are placed. In fact, the manager himself has never been visible, though assuredly he exists, inasmuch as there is something to be managed; but who he is, and the manner in which his duties are performed in his office, is a problem still to be solved.

The manager's office, and its double play of wires, is, my dear child, to some extent, similar to our nervous system. We have now pretty well examined almost all our bodily machinery, and we cannot terminate our lesson better than by considering that portion which may be called its very soul. I speak now as an engineer would do, who sees a soul wherever there is a power, and means no harm in so speaking, though, it is true, he does not deal with intelligent powers; but we are not yet in a position to speak about intellect.

I do not recollect whether I ever told you what is meant by a system, at any rate the explanation will not be inappropriate here.

In philosophy, a system is an assemblage of ideas in harmony with each other, uniting in concert to establish a doctrine. In physiology, it is a series of organs similar in structure, all accomplishing the same function, or, if you prefer the term, all occupied with the same work. Thus the assemblage of bones supporting the body constitutes the osseous system; the assemblage of muscles giving it motion is the muscular system, and so on.

Now a vast number of duties are required to be performed by this nervous system, of which I find my-

self forced to speak to you, much to my regret, I can tell you ; for the more I reflect, the more I read and re-read my masters, the more I hesitate as to what I am to say to you about it.

First, then, as we shall presently see, it is an electrifying apparatus, and in this capacity it presides over the contractions of the muscles, which, to my idea, are nothing more than electric phenomena of a peculiar nature.

Next, it is an interpreter, informing us of what takes place within and without us, telling us this in a very simple way, by the pleasure or the pain which attends each of its revelations.

Lastly, it is, what shall I call it ? an indispensable condition without which we can neither think nor will—it is to us the organ of thought and will.

In all this we have just now only one thing to consider, undeniably the easiest, namely, the part which the nervous system plays in connexion with our movements. This will complete our history of the walking machine, which has for so long a time occupied our attention. Another subject will immediately follow, which, if I were simply a naturalist, I would call “The history of the feeling and thinking machine ;” but it is not a very attractive title, and would be as repugnant to you as to me ; besides, it would not be correct, for concealed beneath the visible machine lies the invisible ; so let us call it “The history of sensation and thought.”

Let us now rapidly glance at the “ensemble” of this wonderful apparatus, which plays such an import-

ant part in our economy, and leave the details to follow in proportion as they become necessary.

Imagine a number of threads, the fibres of which being untwisted from below become entangled in all directions, and so intertwine themselves as to form small strings at first, then small cords communicating from all sides with a kind of centre cord where they are bundled together. This is the simplest idea I can give you of the nerves and of the spinal marrow where they all meet.

These scattered nerve fibres, which when united form nervous cords, are extremely minute. The keenest eye is quite unable to discern them; however, thanks to the microscope, we know pretty well how they are formed.

Have you ever amused yourself by noticing to what an extent a string of treacle hanging from a piece of bread may be stretched? Just imagine one of these strings elongated until it becomes invisible to the naked eye, and encased in a fibrous transparent sheath. This will give you a very tolerable idea of the appearance of nerve fibre in an elementary state as seen through the microscope. Gratiolet, in his beautiful book on the nervous system, compares the interior of the fibre to a glass thread, which bears some resemblance to our thread of treacle, (as I presume he refers to melted glass.)

It is this minute, imperceptible, transparent thread which is the important element of the nervous fibre—the agent of life, I should say; and each fibre is under the direction of that part of the body whence it pro-

ceeds, which it puts in communication with the centre,—now to carry messages to it, now to bring back orders.

These fibres all run parallel to each other along the nervous cords, where they are enclosed in a common sheath, and there remain, each as distinct and separate from its neighbour, as the different threads of a skein are from each other. They thus reach the spinal marrow, and continue their course to the base of the brain, at which point you can no longer follow them—they become lost in the inextricable labyrinth of fibres intersecting one another in every direction in this mysterious region. Thirty-one pairs of nerves emerge, right and left, from the spinal marrow through small holes or openings at either side, the whole length of the vertebral column, at the points where the vertebræ unite. They are like so many little doors, by which the agents of life scattered through the body, reach the universal meeting place in compact battalions; but at the moment of entry, those agents divide in each nerve into two bands, each of which branches off into a different direction. The one glides into the spinal marrow, at the edge adjoining the base of the vertebral column, the other by the edge in proximity to the “dorsal apophyses,” if you have not forgotten these old friends. I would call your attention, “en passant,” to this division made by the nerves as they approach the marrow. You will see by and by that something very curious is hidden beneath all this.

These two portions of the marrow—that in front and that behind, (or the anterior and posterior por-

tions)—are separated from each other by a deep fissure which runs down the two sides. Another furrow, deeper still, divides it in the middle throughout its entire length into two equal parts ; so that in reality we possess two marrows—one to the right, and the other to the left. If you have been able to keep in your mind what I told you in my long explanations of the median line, this arrangement will not surprise you. You are aware that our body is composed of two halves exactly equal, at least in all that concerns the walking machine ; it is therefore fair that each half should possess its particular marrow.

Each of these two marrows is, in its turn, composed of two substances. (Everything, then, is in couples.) The one is of a gray colour, forming the nucleus ; the other is white, serving as an envelope to the gray. Their consistency is about the same, resembling pulp. Just imagine two custards of different colours, the one enclosed within the other.

Probably all this affords you but little interest, my dear child ; but have patience. You may consider this a kind of geographical lesson, (the historical one will follow in due order,) but it was necessary beforehand to introduce you to the theatre of action, so as to be able to make you understand what follows. Historians adopt this plan when they come to great battles, and the nervous system is our great field of battle ; it is there where the meeting takes place between mind and matter, to express to you, in familiar language, an idea that escapes us when we wish to lay hold of it.

Now it seems that this meeting takes place in these two substances, the white and the gray, which we shall presently find spreading out at their ease in the brain. I may as well tell you this beforehand, it will increase your interest in them.

Lastly, to end this description, which I am curtailing as much as possible, there is a triple membrane surrounding this precious and delicate assemblage upon which our life depends, and which, were it less carefully packed up, would be injured by the smallest shock. The term "packed up," seems rather trivial, but I cannot find one more fitting.

These membranes are somewhat oddly named ; but never mind, I will give them as they are.

That forming the immediate investment of the spinal cord is called the "pia mater ;" you need not appeal to me for an explanation of the expression, I have never yet met with one. This pia mater, to speak correctly, is only a prolongation of the fibrous sheath, which acts as a common envelope to the nervous fibres, which extends along the marrow, when they penetrate to it. It holds its contents very tightly together, so much so, that, in the event of the smallest rupture to the envelope, a protuberance is visible from the outside, and this support gives it a certain consistency, and in case of a shock, keeps all in its place.

The dura mater, a name of the same class as the preceding, forms above the immediate envelope of the marrow a second fibrous tube, much more voluminous

than the marrow, which would oscillate in it, in a most disagreeable manner for us, without an admirable arrangement of Nature, who has converted this dangerous void into an additional security.

For this purpose, the inner surface of the *dura mater* is lined by one of those serous* membranes, of which I have already had occasion to speak, when treating of the synovia in the joints, which incessantly distil a fluid drawn from the serum of the blood. This liquid fills up the intervening space between the two envelopes; and when you have to trust anything very fragile on a long journey, I think you can conceive no safer or more simple mode of packing it, especially if you adopt the precaution taken in this instance; for on all sides, and all along the canal where the marrow swims, (as it were,) a resisting ligament stretches from one edge to the other, which controls the marrow, and retains it exactly in the centre of its liquid protector.

For greater security, the *dura mater* does not fit exactly to the sides of the osseous canal of the vertebral column; if it did, the various shocks to which we are liable, would be too suddenly transmitted to the cord—it is round, and the canal is triangular. The interval between them, caused by this difference in form, is filled up by a sort of stuffing, composed of fine soft tissue, which adheres to the bone on one side,

* This membrane, of an exceedingly fine texture, is called in Greek "*arachnoide*," meaning spider's web.

and to the membrane on the other ; and this, you will readily believe, goes far more towards breaking a shock, than any amount of hay can do in a hamper of goods.

Nothing short of all this is required, my little friend, to enable you to use your skipping rope as you do. The poor little pulp that you carry all along your back would not make much resistance there had it been left at perfect liberty in the vertebral canal, like a chocolate cream in its crust.

One word more about the marrow, and we shall have done with it.

It does not descend to the lowest point of the vertebral canal, at least not in the same manner as I have described it. Reckoning from the second lumbar vertebra, below the spot where it receives the nerves of the legs, it sends off prolongations, the appearance of which has suggested the somewhat disrespectful name of "horsetail." In the upper part of the loins, where the nerves of the legs centre, a perceptible enlargement occurs, it then decreases, swelling out again at the lower part of the neck, where it receives the nerves. Lastly, it again diminishes in size, as it approaches the occipital opening, through which it passes into the cranium ; but this passage once effected, the enlargement increases so much, that it is no longer recognisable ; it then loses its former name, and is henceforth called the brain.

Such changes often take place in upstarts, who, when they become important personages, assume a new name. On this occasion, we have, to speak the

truth, to do with a very great personage, so superior in his new rank to what he formerly was, that one may conscientiously adopt the change.

We are now going to examine it with the attention it merits.

LETTER VIII.

THE BRAIN.

HERE we are in the manager's office. It is a somewhat dark place, I admit, but we shall see well enough for what we have got to do just now ; we have only to make an inventory of the fixtures. I will not say as much for us when we try to explore its intricacies.

You probably think that the best way to ascertain what lies beneath the skull will be to remove the lid carefully and look within. If you adopt this plan you will be nicely taken in—what you would find is simply a covering to what lies beneath. You would only discover a grayish cap divided in the centre and furrowed by large zigzag folds in all directions, which might even be mistaken for a portion of the intestines rolled up. This is not the place, then, from which to commence your inspection.

When we wish to examine the interior of a house we do not climb on the roof, we enter by the door ; that is what we must do now.

Suppose we glide in with the marrow through the occipital opening, we shall then be very well placed for commencing our observations.

Here we are, then, immediately above this irregular mass of protuberances, of points, and bony knobs

forming the base of the skull ; and from a description of all of which I have hitherto recoiled, when studying this rugged part of the skeleton. As the brain is moulded by the skull, or, to be more exact, the skull by the brain, you must already conclude that we shall have to encounter all kinds of irregularities.

Hardly has the marrow made its way through the entrance, when it begins to expand. It continues increasing so as to form a kind of rounded pyramid ; this is, in fact, the name given to each of the two halves of this part of the marrow, for it still continues to be marrow, although it has penetrated within the skull. In this region it preserves its general type so distinctly, that a mistake is impossible ; thus it is here called elongated marrow, or "*medulla oblongata*," by anatomists.

It there receives one upon another, within a very small compass, seven pairs of nerves, which proceed from the tongue, the mouth, the ear, and the face. The service is far more active in this region than it is along the vertebral column ; it is quite natural to meet with an increased number of the manager's advertising wires here.

I told you in my last letter that the nervous fibres, coming from all parts of the body, continued to traverse the entire length of the marrow towards the brain. Arrived at the top of our pyramid, they there perform a curious evolution. Those coming from the right side of the body pass to the left, while those coming from the left take the right side. You will see later on the result of this crossing of the fibres,

which the investigating scalpel of the anatomist has discovered far in the depths of the pyramid where it slyly takes place.

This sleight-of-hand trick accomplished, the great transformation commences.

The upper part of the marrow expanding to a very considerable extent, bursts forth to right and left, and becomes the cerebellum.

Put your hand upon the projection made by the back of the skull above the neck—that is the seat of the cerebellum, or small brain. It is really a kind of small brain quite distinct from the large one, beneath which it disappears when we look at the cerebral mass from above, and which has its own particular form as well, no doubt, as its own special function.

It has a furrowed or puckered surface, resembling that of the real brain, but the folds here are quite differently disposed. They have been compared to the leaves of a book. I own I have examined them very carefully, and can in no way trace any such resemblance thereto. Fold a dark-gray shawl very small, and gather up the folds so as to make a rounded buffer of it with a hollow in the centre, and you will then have something that will give you a far better idea of the appearance of the cerebellum than the leaves of a book, however crumpled they may be.

I advised you to choose a gray shawl, because the cerebellum is composed of this gray substance constituting the nucleus of the spinal marrow, but it is traversed in the interior by threads of a white substance, so arranged that when the organ is cut from

above downwards through the centre, a distinct regular outline of a leaf with all its fibres is discernible. From this design anatomists in a poetic moment gave it the name of "*arbor vitæ*."

Must I say it, my dear child? Your cerebellum is very small, much smaller by comparison than mine, which ought to be about one eighth of the total mass of substance lodged in my skull. I say about, because there is no fixed rule for it, and you can readily understand the impossibility of obtaining the accurate weight of any one portion of a living person's body. It is an organ that requires time to mature, just as the bones do. It waits to begin its ordinary development until the time when we look for down upon youths' cheeks, and expect young ladies to become reasonable.

The cerebellum is divided into two equal parts. This being the invariable rule from the top to the bottom of the median line, I should not waste my time in again alluding to the fact, had I not some reason for so doing. These two halves are united underneath, by a large bundle of white substance which rests against the base of the skull, concealing what remains of the medulla oblongata, over which it passes, like the arch of a little bridge thrown across a stream.

The marrow as if taken prisoner, enclosed within a ring between the cerebellum which overhangs it and its uniting bundle, disappears at this point. For this reason, the bundle projecting beyond the cerebellum has been called the annular protuberance; but

it has also another name, and one you will more readily remember, viz., the "pons Varolii."

There are favoured hours in science as well as in all other things. Happy he who succeeds in making useful discoveries. This Varolius, who has stamped his name under all our skulls, immortalised himself at a very small cost, with this bundle of the cerebellum. The discovery was by no means a difficult one. In my last letter to you I spoke about geography. Varolius flourished in the sixteenth century, the period of great geographical discoveries in the human body as well as upon the globe. He lived at the time when anatomy was only in its infancy and its discoveries at their dawn, and thus had the good fortune to be one of the first who delineated a map of the brain, upon which he inscribed his own name, as invariably happens in similar cases. A map as valuable as any other; and when the progress of universal knowledge shall have placed every one in a position to see their way within the labyrinth of the brain, I do not know that I would exchange the honour of discovering the "pons Varolii" for the strait of its contemporary Magellan. Scientific men in the present day have no such good fortune to expect. The geography of the brain is complete or very nearly so, and discoveries there are as unlikely as in the Mediterranean Sea. It is true that in the time of Varolius, anatomical experiments were sometimes as dangerous, as the expeditions of those intrepid navigators who made the tour of the world in mere shells of ships. Anatomical investigations might have brought their authors to the

stake. It is said that the illustrious Vesalius, who placed the scalpel in the hands of Varolius, was obliged, while giving his first lessons, to conceal himself as if he had been a malefactor. The guardians of ignorance, opponents of progress in those days, raised the hue and cry of profanation of God's image ; and some of them may charge me with profanation for having tried,—but we have gossiped enough on this point ; let us now return to the marrow.

It reappears beyond the bridge of Varolius, in the form of two little thick cords, which unite and form a mass, the irregularities on the surface of which furnished a fine field for the play of the imagination of early investigators. They saw in them all kinds of resemblances, which I need not allude to here, particularly as up to the present day, we have been unable to discover what is the exact part these hollows and elevations perform in the human machine, the outlandish names of which would teach you nothing.

The whole terminates in four small eminences, which are designated optic lobes—the term sufficiently explains their use. They preside over the sight ; and it is here that the principal branches of the nerve of the eye are united to the central organ—the nerve, I mean, through the medium of which we see ; for in addition to this, the eye has other nerves to which it owes its exquisite sensibility and its variety of movements.

The region of the optic lobes is, we may say, the upper extremity of the marrow which stops here. We, however, have not quite finished with it yet.

Do you remember what I once said to you regarding

the bone of the nose, that rudimentary vertebra which I represented to you as "the last effort of nature in its completion of the vertebral column," (see Letter VII., on the head and chest.) Well, the idea I wished to give you in that instance, finds a sort of confirmation here. There is also a last effort at construction in the marrow when it reaches its extreme limit. Two horns branch out from its extremity, of which they seem like a prolongation, and guess what they are? They are neither more nor less than the olfactory nerves,* which, terminating at the upper part of the nose, preside over the sense of smell.

Before ending in this rudimentary nasal vertebra, the vertebral column rises in an arch, thus forming the skull. The same with the marrow; before producing the olfactory nerves with their bulbs, it gives birth to the marvellous guest for which the skull has been constructed.

I have not given you the names of these two thick cords which spring from beneath the pons Varolii, a bridge of Varolius,—they are called the peduncles of the brain. I conclude you have learned enough of botany to understand the meaning of the word "peduncle." It is what is commonly called the stalk, that by which the fruit is attached to the tree; but never peduncle bore fruit equal to that which grows here on the marrow. Whilst its lower part continues to thread its way distinctly along the base of the skull, the peduncle spreads itself upwards, and projecting its fibres in every direction, loses itself in the expanded mass of the brain proper.

* Olfactory, from the Latin word, "olfacere," to smell.

LETTER IX.

THE BRAIN—(*Continued.*)

It is a pity that for this once we must confine ourselves to a description of the brain ! There are many subjects more amusing than this ; nevertheless it may interest you to learn something about the formation of an organ, which is without doubt the noblest, if not the most essential of the whole body—that one in which resides, do not take it amiss, your little self ; for were it to cease working, all that would remain of you would be a mere machine, unconscious of everything, even of your own existence. Your body may be considered as your house, but your brain is your chamber, your own private corner. You will not complain, I am sure, of the hurried glance we are going to take of it.

The brain being placed upon the median line, it naturally follows that, like the cerebellum, the marrow, and other portions of the body, it also is divided into two equal parts. Only in this instance, the line of partition is more strongly marked than elsewhere. The “cerebral hemispheres”—for such is the name given to these two halves—are separated, the one from the other, by a deep furrow which descends almost half way to the base of the skull. It is only at the

base where they unite on a layer of white substance called the "corpus callosum," or callous body, a name that I should feel puzzled about if called upon for an explanation. I fully understand—and most probably you do also—what is meant when one speaks of a callous hand; but as for this callous body, which is nothing more than a thin, delicate slice of brain, I own that I know not for what reason it has been so named.

I spoke to you about the three vertebræ which are to be found in the skull. This division has its parallel in the brain, which is transversely divided into three lobes, as they are called; the anterior lobe, which is formed under the frontal bone; the posterior, under the occipital; and the medium, which corresponds to the parietal bone.

To be honest with you, dear child, very minute inspection is necessary to recognise, amid the numerous furrows visible on the surface of the brain, the respective limits of these three lobes—above all, that of the two last named; it being, between ourselves, a somewhat conventional limit. I strongly suspect that anatomists have taken the same liberty in the construction of their chart, as diplomatists sometimes do with theirs; with the best will in the world I have the greatest difficulty imaginable to see, in the line which they have invented, anything which might be called a natural boundary or frontier. As to the line of demarcation on the frontal lobe, that is quite another affair. Nature has marked it by a fissure or furrow much deeper than the others; it bears the

name of the "Fissure of Sylvius." You must also bear this name in mind, for Sylvius, like Varolius, was one of those happy and fortunate individuals of the sixteenth century, who founded modern anatomy; but the former has this superiority over the latter, (Varolius,) inasmuch as he was not the disciple but the master of Vesalius.

I have already informed you that the whole surface of the brain has the appearance of a grayish mass—the interior is white. Here we again encounter the two substances which I pointed out to you in the marrow—the gray and the white; only in the present instance their positions are changed. We now find that the white substance which in the marrow covered the gray, is here covered by the gray. A thin layer of this gray substance extends over the entire surface of the three lobes, and may be compared to a species of bark, from which circumstance its somewhat singular name of "cortical" is derived. And now I must tell you, dear child, that this cortical substance has the honour of being considered as the seat of intelligence, and this to an extent bordering on possible. After that, judge of people by their names.

The white substance which fills the interior of these two hemispheres is not a compact mass. You must have observed what large holes you sometimes find in your breakfast roll—a most unwelcome discovery to a very hungry child. Well! a similar vacuum exists in each of these two hemispheres, and one might truthfully exclaim, What wonderful economy Nature has employed in her arrangement of the brain! Most

assuredly it is all wisely ordered for our good, else why should she have placed a passage of communication between the exterior surface of the hemisphere and its interior cavity, upon the walls of which the highly-favoured cortical substance is continued. The intelligent bark—you understand what I mean by the expression—is thus allowed fuller scope for its development. From this circumstance you will also perceive how unsuitable the term “empty-headed” is, in the way in which we frequently hear it employed, to convey anything but a compliment. All of us, without distinction, have empty spaces in our heads ; and were the brain a compact mass, it is to be presumed we should gain nothing by it.

These cavities of the two hemispheres, like those of the heart, are named “ventricles.” They are also called “lateral ventricles,” from their being one on either side. Exactly at the base of the brain, underneath the callous body, is a third cavity, known as the middle ventricle ; and lastly, the cerebellum has its own ventricle, communicating with the middle one by means of a kind of passage which, extending over the prolongation of the marrow, crosses the “pons Varolii.” And here the names of our two great anatomists are brought into contact. This passage of communication is known as the Aqueduct of Sylvius.

I could find you others were I to lead you over the whole brain ; investigators have not been wanting in this locality. I must own I feel some scruples for having introduced you so far into such a labyrinth, in which people will perhaps tell me you have no busi-

ness, inasmuch as no person has yet been able to discover the particular function each part of the brain discharges. However, I hope you will not blame me. Imagine yourself visiting some ancient temple, belonging to a creed no longer existing—with what curiosity and interest you would pry into its crypts and galleries, although ignorant of their former use. And are you not equally interested in this little living temple, into which the Spirit of the Almighty descends as each good thought ascends? Can you not survey its details with a curious eye, even though the meaning may often be as a sealed letter to you?

I have almost finished; there is only a tiny chapel to introduce you to, which might easily be designated the sanctuary. I hold to your making its acquaintance—its name is the “pineal gland.”

Immediately by the side of the callous body, and upon the same line, a little above the entrance to the aqueduct of Sylvius, there is a kind of little gray tubercle, quite isolated from the surrounding mass, and which appears as if it had been thrown there as an enigma to be solved. Greek physicians, and Galen at their head, misled by its peculiar appearance, imagined this pineal gland to be the seat of the soul. According to their theory, the soul resided there, and guided the body much in the same way as a coachman manages his horses from his seat on the box. Two small white bands proceeding in the direction of the optic lobes, appeared to them fully to corroborate this theory, and were named the reins of the pineal gland. I should never have alluded to this fantastic idea, which

like many others of its kind would now have been forgotten, had not a modern philosopher of note taken it into his head to revive the supposition, and append his own name to it. This was no other than "Descartes," and when you are grown up, take my advice, and read his work called "*Discours sur la Methode*," in which our ancestors studied the art of reasoning. Thanks to Descartes, the pineal gland has had its palmy days, though unhappily they are passed away, and I truly think the soul would have found it but a poor lodging. Small stones, which medical men designate as calculi,* are often found in this gland. Bichat once found the whole gland transformed into one concrete mass, which by continuing to increase in size attained unusual dimensions. You must agree that in this instance, the soul of him who possessed this pineal gland would have been ill at ease.

The three envelopes of the spinal marrow are found at their post surrounding the brain—the pia mater lies immediately over the organ ; the dura mater is placed next to the osseous walls without being attached to them ; the spider web of the arachnoid is between the two. You can easily understand that the marrow in its transformed state, and in a new home, could hardly be expected to have the same coverings as it possessed when in the vertebral canal. When a gentlewoman becomes a duchess, she requires new associates and an improved toilette.

* From the Latin "*calculus*," a stone. From this the universal acceptance of the word "*calculation*" is derived. Roman children were always taught to count with pebbles.

With each pulsation of the heart, a considerable stream of blood is precipitated towards the brain almost in a straight line ; this part of the body receives a greater quantity of blood at one time than any other ; it is, moreover, the most sensitive, and the most readily deranged. A sudden rush of blood proceeding towards it from the great arteries would place it in imminent danger : Nature has provided against this disaster.

You have a little garden of your own, and you know as well as I do the havoc a watering-pot makes amongst a plot of seeds, if you neglect the precaution of putting on the rose, which, by its multitude of perforations, converts the stream into a gentle shower. A somewhat similar precaution has been adopted here. Before penetrating the brain, the arteries employed to convey the blood are subdivided into an infinity of small canals, which, running along, interlace themselves on its surface, and thus, as it were, they shower out the blood, drop by drop. A multitude of small venous canals arranged in the same manner on their part pump out drop by drop, through thousands of thread-like veins as fine as hair, the blood, after it has served its purpose. Thus the circulation of the blood in the brain is effected by an endless variety of arrangements, the result of which is to regulate, in exact proportion, the departure as well as the arrival of the vital fluid. If the brain is the great instrument of life, the blood is its virtuoso ; a virtuoso whose caprices would be fraught with danger—if too fiery he would break the strings, if

too indolent he would allow the harmony to be disturbed.

Now, if you search on the surface of the brain for the pia mater, that dense covering which held the marrow in the centre of the canal, it seems to have disappeared. You only perceive, in its place, the network, of which I have just spoken to you, of small arteries and veins, scarcely held together by an imperceptible tissue which can hardly be called a membrane. It is, however, the self-same covering ; and in order to satisfy yourself on this head, turn to the entrance of the occipital opening, when you will see it has glided with its precious charge within the skull, and is for one moment recognisable in its passage over the elongated marrow ; but it soon grows thinner, and at last, somehow or other, becomes annihilated by numerous invasions of small blood-vessels, before which it disappears. It is like a tender mother who sees her child in imminent danger, and confides him to the hand outstretched to rescue him.

Setting out from this point, the duty of immediate protectress hitherto exercised by the pia mater, passes on to the dura mater, which in the skull attains an extraordinary solidity and thickness. Here there is no vacuum between the dura mater and the other parts. It is true that the space is much greater, but it is entirely filled up by the cerebral mass, which slightly touches the dura mater, applied closely as it is to the walls of the skull, so that it forms a kind of periosteum to them. It only leaves them, in order to bury itself in the groove running between the two

hemispheres; its powerful intervention being necessary to prevent any contusion resulting from the repeated oscillations of the head, and to support the occipital lobe, above the cerebellum which it overhangs. You will find no difficulty in recollecting the names given to the two prolongations of the dura mater; they speak to the imagination. The first bears the name of "sickle," from its lengthening out in the same sense as the curve of the brain. It pretty nearly resembles the blade of a sickle. The second has been called the "tent" of the cerebellum, from being stretched over it like the canvas of a tent. There is also a third prolongation, which performs the same service for the two halves of the cerebellum that the sickle does to the two hemispheres of the brain, and for this reason it is named the "sickle" of the cerebellum; but this latter is of very trifling importance compared with the other two.

The dura mater forms so solid a covering, and adheres so firmly to the organ it is destined to protect, that the skull may be broken by repeated strokes from a hammer, without injury to what lies underneath. I ought to mention that I here allude to a lifeless skull, which has passed into the anatomist's hands, and the hammer is therefore wielded by a skilful operator. But this is quite sufficient to prove to you how closely and carefully the cerebellum is packed up in this dura mater, and what a small space is left to the liquid secreted by the arachnoid, to be effused with impurity.

On this account, inflammations of this little spider

web, insignificant as it is in appearance, so soon terminate fatally. Tightly enclosed between the dura mater and the pia mater, scarcely does it begin to secrete a little more abundantly than usual, than pressure is experienced on the brain, the action of which is immediately interfered with. The whole machine is thrown into disorder, and sometimes after the lapse of a few hours life becomes extinct, to the no small grief and astonishment of the surviving friends. I hardly know, my dear child, how I have had the courage to enter upon such a subject with you ; it awakens in me recollections which send a shudder through my whole frame. Say nothing of this to your mother.

LETTER X.

ANIMAL ELECTRICITY.

LET us go back for a moment, dear child, to the "History of a Bit of Bread," which I took such pleasure in relating to you when you were much younger than you are now, and when we looked upon study as a mere diversion. We have now become more serious, and I know very well it is less amusing; but you learn more, which is the essential point; and this will always be the case as you advance in years. Your play-hours will be less numerous, but if you are good, believe me, you will be no loser by the exchange. The realities of life, when we come fully to understand their vast importance, are far far superior to the amusements of childhood.

I hope you have not forgotten the "magic steward"* I told you about in our earlier interviews, who distributes to the workmen throughout the house we occupy, (our body,) whatever materials they require, and whose inexhaustible pockets, continually replenished by the stomach, contain whatever is necessary to each individual organ. I also told you how in proportion as the constructions are effected, the materials for which are furnished by the blood, they disappear

* See History of a Bit of Bread, p. 34.

of their own accord, the old bricks making room for the new ones, and returning to the torrent which brought them. Later on I explained the secret of animal heat, always kept up within us to the same temperature, by reason of the incessant combustion of our own substance, and I related some of the feats of oxygen, hydrogen, carbon and azote, or nitrogen—"that wonderful quadrille of the aliments* of nutrition," which may be transformed at will. Now albumen, then fibrine, again casein, according as the dancers are grouped for the performance of different figures.

Remain perfectly still for one moment, give your whole attention to yourself, and listen to the life going on within you. Do you not perceive a kind of general crackling which becomes stronger the more your thought is fixed upon it? This crackling continues through life, but we are so accustomed to it that we take no notice of it; nor would there be any object in our concerning ourselves about it, we have no power whatever over it. Nay, on the contrary, if I may so express myself, it exercises a power over us,—a supreme power; for it is no less than our physical life, the essential basis of all the others, speaking of what we are able to understand. In its depths are found intermingled, pell-mell, all those phenomena of construction, demolition, combustion, transformation of the elements of our substance from one to another, and all this, to give it its true name, is only one continued course of chemical action.

I made use of the term chemical action, in my note

* See History of a Bit of Bread, p. 263.

with reference to the pile. I was in a great hurry that day, and knew its turn would come, so I did not explain the word in its proper course. Moreover, "chemical action" is the very term I should have used when speaking to you of the union of bodies ; therefore the thing itself is already known to you, if the word be not.

There is a secret power inherent in every atom of the diverse substances that we encounter. Scientific men speak of it as "affinity," (a Latin word signifying relationship, connexion,) in virtue of which they contract unions amongst themselves which are sometimes lasting, sometimes transient, according to their particular character, and also with some regard to the occasion allowed them of showing a fickleness of disposition ; in other words, according as the inducement is more or less urgent to break off old alliances and form new ones. This going and coming of the atoms, clinging together, separating, forming friendships elsewhere again to be broken, is what is called "chemical action," because the name "chemistry" has been given to the science that treats of these unions and separations, to turn them to our profit when a body, of which we hold the isolated elements, requires to be formed, or to rescue one element that only concerns us from amongst a multitude of others of which we have no need.

I spoke to you of all this at pretty considerable length, when I told you of the important services rendered us by the pile, and you must already have formed some idea of the important part electricity

plays in all these arrangements. You have seen what an all-powerful agent it is, in building them up and in destroying them ; but this only gives you one side of the connexion existing between chemical action and electricity. If the combinations of atoms are formed and destroyed on the passage of the electric currents, the atoms, in their turn, each time they change their combinations, produce electric currents. Thus it is that we are enabled to form the most powerful piles, by enclosing certain substances which act upon one another in an apparatus suitably arranged.

When these substances come in contact, their atoms mutually invite to movement, and they run away hither and thither from their present dwelling, to form fresh alliances amongst themselves, or, in other words, to constitute a new body. This is the source of the electricity of the pile. Its currents maintain their energy as long as the dance is kept up ; let it begin to flag, and at once their power decreases. They disappear directly the primitive bodies, destroyed and brought to nought by the flight of their atoms, cease to furnish to the new combination the aliment necessary to its continuation. Suppose you found a pile which possessed the power to renew its own provisions of active substances as rapidly as they were destroyed, and also to disencumber itself of their useless produce, the consequence would be, its operations would be carried on for an indefinite period, or rather, I should say, as long as the work of renewing and discharging should continue. If you

have the curiosity to see a pile of this description anywhere, look at yourself, dear child ; your own body is one.

You need not appear so much astonished. It is no cause for wonder that electric currents are produced in the pretty little pile that you form, seeing that this pile is incessantly (and in every part at the same moment) the theatre of a myriad of chemical actions, one of which would suffice to produce a current, though it might be a very weak one. It would be cause for astonishment if the laws presiding over the change of atoms, throughout the whole universe, were found purposely suspended in your body, whilst all others, those of motion for example, exact the same undeviating respect from it that they are accustomed to do from the very stones. Your little body, then, is a pile because it is a chemical laboratory—because it is, as I once before told you, a stove,* and because it contains everything that we require to put into our piles when we wish to make them work.

Do not think disparagingly of yourself, if I appear to place you on a level with a scientific apparatus. He who formed the human pile is much more powerful than Volta, Bunsen, or Daniell—more powerful than all the illustrious pile-makers put together, and nothing that is imperfect can issue from His hands.

* The fire that we make with our combustibles, being nothing more than a chemical action of an extraordinary energy, he who unthinkingly crams his winter stove, sets incalculable torrents of electricity in motion. If scientific men should one day take it into their heads to treat of the subject, they would very soon convince us of this.

In my next letter I will tell you wherein lies the overwhelming superiority of the Almighty's work over ours. You have had quite enough to think about for to-day; fatiguing lectures should be brief.

If I have been unable to resist the great desire I had to explain some things which may be beyond your years, it is because they shed a wondrous light on what I formerly taught you, without being able fully to carry it out, from your not knowing anything of electricity. They reveal to you the true reason of this perpetual renewal of our substance, which lives only in virtue of its continuous destruction. Now, you understand how the oxygen conveyed in the blood stirs up the organs it comes to burn, by inundating them with electricity, and I no longer require to teach you that we owe not only animal heat, but even life, to this internal combustion. As I proceed to explain motion to you, you will soon see what a close bond unites our life of nutrition with that of relation, the aliment changing into power as well as into substance; and that if the members are the servants of the stomach, the stomach is also servant to its members,—not only because it nourishes them, but also because it helps them to walk.

Will you not candidly own that all this information is worth a little fatigue? And if your poor little head is wishing for a rest, thank me, but do not scold me.

LETTER XI.

VOLUNTARY MOVEMENTS.

I STOPPED just in time with our last letter. That there is within us a production of electric currents, may be boldly affirmed from the simple fact that the contrary is impossible, unless, indeed, all the laws of the universe were reversed; therefore I felt I was right in speaking to you with confidence. I should, however, have been obliged to lower my tone, had I then touched on the question which is now to occupy us—viz., what is the action of these electric currents, what end do they serve, and in what manner are they directed? It is not precisely suitable for one of your age, my dear child, to hear these mysteries discussed, and I do not know how to set about presenting you with an enigma, the solution of which has puzzled stronger heads than yours. My courage will be like that of certain soldiers on the field of battle, who march forward simply because their retreat is impossible.

Have you ever asked yourself what is meant by the “will?” No. I am sure you have not. It is one of those things children never do ask, because they do not trouble themselves about it. The “will” is when we “will” a thing, you will most probably

reply. I have many a time received this answer during the years that I have taught a ladies' class, and it is as good as one of a more pretentious kind. Certain it is we have within us a something of which we are perfectly conscious, by means of which we command our members to execute movements that are agreeable to us. To "will" does not suffice, however, in order to the execution of the movement; it would be far too easy if that were all: with the best will in the world, when our strength is exhausted we can do no more. "Exhausted strength," what does that imply? There is, then, a power, which receives its orders from the will, and executes those orders whilst strength permits. If this power be not the electricity produced in us, by the perpetual interchange of atoms, I do not know where to look for it, and I shall soon have a grand proof to produce in its favour, in showing you the electricity from without incontestably exercising over our muscles the action which I conclude is exercised by that from within.

Now, here is the mystery!

Let your mother give you an order—you, as an obedient child, at once do just what she bids you, it never occurs to any one to express the least astonishment. There is no great difficulty in establishing connexion between your mother and yourself. You and she form, as it were, but one soul, and it is almost as if she had given the order to some part of herself.

When your father calls his dog—(forgive the com-

parison, I will show you presently that it was necessary;)—well then, when your father calls his dog, and the intelligent animal runs up to him, leaving everything to obey its master, this obedience creates no surprise in the mind of any one present. Great as the distance may be between the dog and ourselves, we are well aware, that it is not insuperable, and that the dog is an old servant we are accustomed to. Nevertheless, the difference is great. If you were to order “Turk” to wash himself in the morning, and to soap his paws without helping him, I think you would find it a difficult matter to make yourself understood. You are not sufficiently of the same species to carry on a conversation.

Now, try in your turn to attract to you, without showing them any bread, the little gold fish which are in the globe in the dining-room. I say try, for there is just a possibility of your hoping for success. Fish are too far removed from us in the scale of animal life for the most rudimentary conversation between us to be understood; but they have eyes with which they can see us, appetites that we can satisfy; a species of understanding is, to a certain point, possible between them and us, and there is nothing exactly ridiculous in the idea of giving them an order.

But what would you say of a gentleman who should undertake to exact obedience from an oyster, to make it open or close its shell when ordered to do so. Such an individual would render himself liable to be sent to a lunatic asylum, to carry out his experiments there. Between the oysters and ourselves there can be no

mutual understanding,—any one must be devoid of reasoning who could for one moment suppose that there is.

Do not be impatient—you will see my meaning directly. If we are obliged to renounce the possibility of being obeyed by the oyster, how much more difficult must it be to obtain obedience from the shell. It is self-evident that inanimate objects cannot be subject to our orders. Did the idea ever come into your head as to the possibility of your controlling the rain that falls, the wind that blows, the heat that issues from a stove, or the electricity that runs along the wires of the pile? Well, it is exactly this last miracle that is performed by you, each time you raise your arm. You “will” something, and the electric currents obey. Over what bridge is the passage of your will transmitted to them? Ask the Great Architect who has constructed it?

Very probably you are anxious to know what becomes of these docile currents, which ever appear ready to put the members in motion upon the first signal of the will, whilst the body is in a state of repose, and you ask me, Do they sleep when the members do? or are they shut up in barracks like so many soldiers in time of peace, waiting for the moment of action?

Certainly not ; do not imagine such a thing, Nature has no warehouses stored with unemployed forces ; she knows too well how to produce them the very moment she requires them.

You already know—it is learned soon enough—that

when nations are not agreed amongst themselves, they have recourse to war in order to ascertain who is in the right, for this reason we have armies which are naturally more numerous during war than in a time of peace ; this is what is called being on a war footing. A nation that knows how to conduct itself prudently keeps only the amount of armed force necessary to maintain order during the time of peace. Each man attends to his own business, without troubling himself about the government ; indeed, so far as he is concerned, it might easily not be in existence. Instead of the national wealth being squandered, it accumulates, and proves an invaluable resource in days of strife. If war is declared, government immediately issues a call to arms, and armies appear to come out of the earth as if by enchantment.

Nature has adopted exactly the same arrangement in us.

During the moments of rest, the pile of which we have been speaking is self-acting, utterly regardless of the will, and only produces the exact amount of power that is requisite to keep up the work going on in the organs,—a work which would suddenly come to an end, if these electric currents did not traverse them. It is here that the provision of substances accumulates, destined to be consumed, in supplying us with force, when an extra demand of it shall be made.

Movement is perpetual warfare ; our arms war with all that we pull, all that we push, all that we lift, all that we strike ; our legs war with every obstacle that

lies in our path ; the entire body wars with this ever-present enemy which we call gravitation, and which stretches us on the ground, the moment we cease to struggle with its influence. I daresay you never thought of all this, my dear child ; but you should say to yourself as you raise your spoon, you know where, that you and it are at war. You oblige it to ascend, and it would like to descend.

It is at such times as these that the government wakes up. As soon as its counsels have determined to open hostilities, the will issues its despatches, and in the twinkling of an eye the muscles are all ready for the combat, the blood suddenly rushes to the call, movement of the atoms is accelerated ; the supplementary currents all at once spring up, and under their action the muscular fibre, just now motionless and extended, shortens, and contracts, carrying with it in its movement, the parts of the framework to which it is attached.

I have yet to tell you how these electric currents determine muscular contraction,—how, at least, we are best enabled to represent their action. I shall reserve this explanation for our next meeting.

Before separating, I do not wish to allow so good an opportunity to escape without explaining to you what sleep is, which is our great “time of peace.”

Movement has its charms for us, and so has war for some nations, it appears. Still, when it is prolonged beyond certain limits, and has caused the country too large an expenditure of energy and men, (for these are its component atoms,) in vain government issues

its despatches, the exhausted subjects lie down and beg for sleep.

This is your daily history when you have given the reins to your electric current, and when your stock of destructible substances is exhausted. Your drowsy subjects turn a deaf ear to the call to arms made by the will. However valiant a warrior you may be, you must then beat a retreat before this overwhelming force, and you will soon find defeat await you on your pillow. We should not curse war as we do were it always to end thus.

LETTER XII.

VOLUNTARY MOVEMENTS—(*Continued.*)

A FRIEND of mine was talking to me one day of a motor power which he had been fortunate enough to discover. If you do not happen to know the meaning of the term "motor power," let me tell you that the expression is applied to every kind of machine capable of producing movement.

Here in a few words is the discovery made by my friend ; and after the little lesson I recently gave you on the subject of magnetism, I think you should be quite able to understand all I am going to tell you.

Picture to yourself a double rosary composed of small pieces of soft iron placed at a short distance from one another yet united by flexible fastenings. A spiral copper wire is rolled round each of the rosaries, which can, at will, be immediately placed in communication with a pile in a state of activity. A very simple contrivance establishes a communication between the two wires, so that each rosary, in its turn, is embraced in the electric current.

You are aware that under these circumstances soft iron becomes magnetised. The little magnets, which are thus suddenly produced in the rosary, subjected

to the current, having their poles necessarily in the same direction, seeing that they are in a line, it follows that each north pole faces a south one, (the extremities always excepted,) and by reason of the law I before explained to you—viz., that “bodies electrified in an opposite manner will always attract each other”—all these magnets make a sudden rush at one another. Again, imagine ten such magnets all placed in a line, an inch being left between each; directly their poles are united by reciprocal attraction, so as to form one unbroken line, your rosary will be exactly ten inches short of its original length, a very considerable difference, you will say.

Now if you arrange the two rosaries so that they can act in an inverse manner upon a rod of wood or iron, each chaplet will attract the rod in its turn—the magnetism in the pieces of iron being conveyed with the electric current from one to the other, and a see-saw movement of the rod is established similar to that of the piston of a steam-engine at work. Hook the bar on to anything you choose, whether lever, bar, or crank, and it will work just as a piston does.

“Oh!” exclaimed I, as my friend concluded his explanation, “it’s the human arm you have been inventing there!”

I do not pretend to say that my exclamation was perfectly correct. This is not exactly the arm of a man, but I am greatly mistaken if the movements of the human arm do not take place after this manner.

And here, dear child, I think it advisable to repeat a remark I made to you when speaking of “muscular

fibre." I told you in an earlier letter that "these threads (or fibres) look like a kind of rosary, the beads of which placed at certain distances from one another alternately shorten or lengthen the fibre according as they approach each other, or return to their original position."

One thing was wanting in my lesson at that time; it was the explanation of the alternate movements of the muscular fibre. This I could not give you then. Now, without pretending to enter fully on the subject, I can at least give you an idea of the manner in which they are produced.

Whatever be its origin, it seems to me evident that when we will a movement, an electric current rushes from the brain along the nerves to the muscle intended to execute it, and there determines a flow of blood, together with the necessary chemical action. The beads of the "muscular rosary" must then become so many small magnets, each having its pole in the same direction, and attracting each other with a power proportioned to the energy of the magnetism transmitted, the muscle remaining contracted so long as this influence continues. It is thus on account of the peculiar electric condition of the biceps and the muscles of the shoulder that the fore arm bends on the arm, and the arm on the body. If we wish to bring the arm forward the cerebral current immediately changes its direction, transporting itself to the antagonistic muscles; these in their turn contract, bearing away the bone in an inverse sense,—the rosaries of the opposite side suddenly losing their

magnetic influence, allow their beads full liberty as soon as they are abandoned by the current.

All this appears very scientific, does it not? and yet I have dispensed with all the mysterious parts in this game of electricity, which, for very good reasons, I have by no means fully explained. Whatever use you may be enabled to make of this partial explanation, it is sufficient to give you some notion of the wonderful way in which our muscles contract; and if you one day chance to see your mother's needle and scissors magnetised by repeated contact with her fingers, you will understand how it all happens.

Whilst we are speaking about fingers, I wish to call your attention to something that you may probably never have noticed.

Open your hand and stretch out your fingers, then try to close the middle one, keeping the others fully extended. If you succeed, you are cleverer than I am. Although my whole will is concentrated upon my middle finger, I cannot master it. Every time I attempt to close it, all its companions move along with it, waiting for no order—nay, it is worse than this, for they move contrary to my order. The fault must surely be mine, for I have seen people obeyed under similar circumstances, and the middle finger close upon the palm of the hand, whilst all the others remained extended. It must be that the electric currents communicated to my hand by the instigation of my will are like so many disobedient servants following a routine, and being in the habit of moving in unison, refuse to act singly, whenever I am disposed

to call on them to do so. Pierre Gratiolet, in the remarkable book which he has left us on "*La Physiologie et les Mouvements d'Expression*," gives the name of "sympathetic" to those movements which we are called upon to make simultaneously with other movements, and which the will does not always accomplish without severe discipline. He especially notices a child's first efforts in learning to play on the piano—the great difficulty it experiences in acquiring a perfectly independent movement with its two hands—the trouble and tedious practice necessary before it can play a scale so steadily, that the little finger of the left hand exactly coincides with the thumb of the right, and the first finger of the one hand with the third of the other.

This leads me to speak of the liberties in vogue in this little kingdom of arms and legs, over which you preside, although you are perhaps less absolutely its queen than you would naturally suppose. Besides this voluntary movement, which is entirely subordinate to your will, there is also a mechanical one, which the machine executes without any intervention on your part, just as a well-trained animal may be taught what is expected of it, and to attend to its duties, without being constantly guided to them by its master. In the act of walking, for instance, when you are absorbed—I will not say in your thoughts (though that will come in good time,) but in one of those interesting conversations you carry on with your little friends, how frequently you dispense with this voluntary movement, and substitute the

mechanical one! Your will is all the time occupied with something else, yet your legs continue to carry you along of their own accord, without a false step. Be honest now, and own that you would be sorely puzzled if the whole management of walking was left to your own guidance. You control your steps much in the same way as three-fourths of our kings command war—they give the signal for it, but it is carried on without their assistance.

These habits, which our agents adopt, and then, after a time, carry on without any help from us, are not the least of the mysteries found in our organisation. I can bear testimony to a very tiresome trick my hands are guilty of, and which I have been unable to cure them of hitherto. Every evening, before I undress for bed, I am accustomed to wind up my watch, which is all very right and proper if you want to know what o'clock it is when you rise on the following morning. Now when I have occasion to change my clothes during the day, no sooner do I unhook my watch-chain from the buttonhole of my waistcoat, than my hands, taking advantage of my thoughts being occupied with something else, stealthily set to work, and before I know what I am doing, the watch is wound up. Who is the agent in this instance? Am I the agent? Did my hands perform the deed? Certainly I could not have done it, for I was not thinking of it.

Now observe, that the watch is not wound up by one single movement, by one emancipated muscle which slyly contracts itself; there is a whole series

of complicated movements, which I need not enumerate. You have but to call to mind the working of your fingers as you wind up that pretty little watch of which you feel so proud. But, compared with what I have yet to tell you, all this is very insignificant.

How long and how patiently your mother devoted herself to teaching you to speak! You can neither recollect nor realise the labour it cost her! You will one day know it, if you have a little child of your own whom you will teach to say, "Mamma." If you take notice then, you will see that in order to pronounce each of the syllables, of which words are composed, the tongue and lips must assume a variety of positions successively. The lips open, then close, are pressed together, advance, whilst the tongue strikes against the palate at one moment, leans against the upper teeth at another, or gently places its tip just within the lips. Added to all this, each muscle of the chest, throat, jaws, cheeks, and even of the nose, has its peculiar work which is constantly changing. In order to pronounce the simple word "confiture," which seems to come quite naturally from your lips, you have no idea of the number of little muscles that are at work at the same moment, and the various manœuvres they have to execute. Thus you see the first words little children utter are composed of one syllable twice repeated, as "Papa," "Dada." It is so difficult for them to enunciate at first; that all they can do after having succeeded in pronouncing a syllable, is to recommence, the fatigue of passing on to something fresh, would be too much for them.

Tell me, if you can, what is become of all the effort each word cost you as you learned to stammer it out? How is it that now you can prattle away for hours together without a pause, just as if the words were so much running water? It is simply because the education of this set of servants is completed, and they cease to cause you any anxiety. No matter at what speed the little tongue runs on, each word finds the muscles at their post, and the rapidity of thought to conceive a sentence is frequently surpassed by that with which it is pronounced.

In all this, may we not ask, as we make use of our tongues, To whom then belongs the honour of speech? I answer: To our intelligence; because, although the mechanism of words is claimed by the muscles, we must in the first instance furnish the ideas they express, which is evidently a higher power. But I have something more extraordinary to tell you of yet.

I know a very old lady who, when a little girl, was taught a prayer which she repeated, as too many children are in the habit of doing, without once thinking of the meaning of the words. Let me observe, in passing, that to offer mere lip homage to our Maker, in which the heart takes no share, is but mockery. You may as well imitate the Tartars who stick their prayers upon a roller and turn it with all their might, exhorting it to intercede for them. God, who looks into the heart, sees and knows who really desires to honour Him, and He knows how far this old lady acts up to what she has been taught; it is the intention He considers. Strange as it appears, though she

has quite forgotten the prayer taught her in her childhood, (for words to be retained in the memory must have some hold upon the mind,) yet when the desire suddenly seizes her, this old lady will go through the prayer by rote. Perhaps you have sometimes heard of travellers, who, losing their way at night, and despairing of recovering the beaten track, will throw the rein upon the horse's neck and trust to its guidance. This is precisely what my old lady friend appears to do, she shuts her eyes so that nothing may outwardly interrupt the performance of her duty, and fearlessly yields the rein to the muscles which preside over speech. These muscles have performed their work so repeatedly that they are easily set in motion, and the prayer which its mistress has mentally forgotten, the lips are made to utter mechanically, but I must admit that the prayer is blurted out, and if she is interrupted, all is lost. Who after that would quarrel with muscles which perform such a wonderful feat of memory?

Assuredly, if these are also voluntary movements, inasmuch as the will gives an impulse to the speaking machine, you must own they have reason to boast of their independence, and I leave it to philosophers to point out the director of this assemblage of muscular contractions which rapidly and blindly succeed each other in the same invariable order.

The question is far beyond us, and I prefer making this occasion profitable by exhorting you, whenever you commit anything to memory, to store the words well in your head, and not on your lips, as certain young ladies of my acquaintance do, who read their

lessons over as loud as they can that their muscles may be well exercised for the recital. How will you make any progress by teaching words to your muscles? What are they to do with them?

LETTER XIII.

THE CEREBELLUM

I ADVISED you at the close of my last letter not to teach your muscles any words. It is not exactly the muscles which learn, although to speak the truth, it amounts to the same thing, they seem to learn. In order to acquaint ourselves with what goes on in their province, we shall require to take a little tour through the capital, or in other words, to pay a visit to the head, since the word "capital" is, as you probably know, derived from the Latin "caput," signifying a head.

I have already informed you, that this invisible director—who imparts impulse to the muscles, and holds in his hand all the telegraphic wires by which the orders of your will are transmitted, resides in the brain. You are this director. To call him by his proper name, he is your own little self, and he is incapable of performing any act without your knowledge.

Now there is also a sub-director in close proximity to this director, through whose hands each wire must pass before it reaches its destination; he is the real regulator of each manœuvre the muscles perform, and this is no longer you—he works in the dark without letting you into the secret of his acts and gestures. What he is, no one knows; his whereabouts only is

known ; for he resides in the cerebellum and its dependencies, or, to be accurate, in the pons Varolii and around the Aqueduct of Sylvius. (I hope you have not lost sight of the little chart we made of the brain.) Order and the progress of movement are regulated in this department ; we have a most beautiful proof of this, or a horrible proof, you may feel inclined to call it, when you know the facts, and you are at liberty to call it so if you please.

The species of study which I intend to bring before your notice first suggested itself (at least on a large scale) to the mind of a French physiologist called "Magendie." It is a barbarous study seemingly, for it has caused thousands of animals to be cruelly put to death ; but where science is concerned, savants look upon any leaning to the side of humanity as only puerile. Are they justified in this ? It is not for me to decide. Every one has his own conscience—let it be his guide.

I borrow the subjoined facts from Milne Edwards's "*Cours de Zoologie*."

If, after opening an animal's skull, you cut a small portion from off the base of the brain, situated in the vicinity of the cerebellum, and which is known as the "*corpus striatum*" or striated body, (though for what reason I cannot say,) the animal suddenly darts forward as if carried away by an irresistible power, and it runs on and on until some obstacle presents itself in its path, or it stops through sheer exhaustion, but backwards it cannot go, for it is deprived of all retrograde movement.

Again, if a section be made simultaneously, on each side of the cerebellum, or pons Varolii, the result will be exactly the reverse—in this instance the animal makes an equally sudden rush, but the motion is retrograde, and according as the animal is a quadruped, a fish, or a bird, it will walk, swim, or fly backwards, having lost all power to move forwards.

Lastly, if an incision be made in one side only of the cerebellum, or pons Varolii, you will witness a no less singular result—the wounded creature will revolve upon itself : if the incision has been made at the right side, the movement will be from right to left ; if on the left side then the movement will be reversed ; and so rapid has it been in some instances, that more than sixty revolutions in a minute have been remarked.

From all this it may warrantably be concluded that a despatch office exists below the apartments of the “will,” whence orders are issued to every part of the body, and that it resembles an ordinary government, inasmuch as, to enforce obedience, the offices must be intact. Nay, the case is even more serious ; one false despatch issued by the subaltern sets all in motion, but precisely in an opposite manner to what is intended.

We are now in possession of a key to these movements, which are executed either without the will being consulted on the subject, or in direct opposition to it. We shall also find some analogy to this in government arrangements, in what is called office routine.

There are certain old affairs long forgotten by the

head of the department, the papers connected with which are in the repositories of the subaltern, and which he, on a simple order being received, terminates mechanically without the aid of his director. This is the story of the old lady and the prayer she learned in childhood to repeat by rote. You see how little there is to boast of, if, when you learn a lesson, you bury it in the subaltern's repository, never letting it reach the Master's eye.

This is not all. Nobody is more obstinate than an office clerk. What he has long been in the habit of doing, he *will* do, and not even king or emperor would succeed in making him depart from his routine without immense difficulty. The orders may be given, yet the clerk still mechanically pursues his accustomed course. The clerk of the cerebellum is every whit as obstinate as his compeers. You wish to move one finger only, or to make one particular finger move in concert with another—this is not his general habit. He lets you issue your commands, but he forwards his despatches in the direction familiar to him. And thus it is, my little friend, that he sets you at defiance without your perceiving it, and even sometimes when you do perceive it.

An industrious and determined master will nevertheless overcome these routine difficulties, but only by repeated efforts on his part. Even you must acknowledge how fast your once undisciplined fingers are getting under your control—they now find their way on to the right notes on the piano, without noticing who their companions may be. You are not obliged

to be so constantly on the alert. Routine exists here, but it is a good form of routine instead of a bad one. In this lies the grand secret of good government.

It is nevertheless necessary, however determined we may be, that the offices be in good condition, if we wish to be obeyed; for otherwise, with the best *will* in the world to go forward, we might walk backwards, or even turn round and round, which would be still more disagreeable.

You, no doubt, consider yourself exempt from all these disagreeable mishaps, satisfied as you are that no investigator of science will ever take it into his head to make incisions in your cerebellum, that he may ascertain the effect they would produce. Who can say, but that amongst some of the people to whom you relate what I have just been saying, you may not encounter some, who, for the sake of the secrets they will divulge, will look upon these experiments as quite justifiable. If so, undeceive yourself, my dear child, and let us caution lovers of science against too hastily coming to the conclusion that the end justifies the means. Nature deals pretty severely with some of us at different times, and has, of her own accord, unveiled to us fully as much of her workings as we have ever learned by the intervention of vivisection.*

Now and then we have it in our power to report very extraordinary instances of irregular movement, resulting from some injury to the cerebellum. Amongst other examples mentioned in my books, I find that of

* "Vivisector" is the name which those who experimentalise on living animals give themselves.

a poor lady who was more seriously affected than any of the animals experimented on by the scalpel. Her limbs, owing to the equilibrium between the extensors and flexors being disturbed, bent, without any possible resistance on her part, so that she used to fall down in a heap, and in this position she might be seen turning round and round utterly powerless to stop herself. Flattening or shrinking of the cerebellum was discovered after death.

Now, I have told you quite enough about this impertinent organ, which we may well imagine is placed where it is, to stem the pride of little people who think themselves masters over their own bodies. Let me give you a word of caution, not to be astonished at the striking similarities between our interior government and those of human societies, resemblances which have just occurred to me while endeavouring to make you understand the part which the cerebellum performs in our economy. A society is like a man on a large scale, it tends by a natural inclination to organise itself on the same plan as the human organisation. I must have told you this already, but I will make it plainer than ever to you in my next letter.

LETTER XIV.

THE NERVOUS CENTRE.

WE are now come to the delicate part of our explanation of movement. Whether cerebellum or cerebrum, it is assuredly from the entire cerebral mass that the electric currents determining muscular contractions radiate; but where are they produced?

This is a question well worthy of investigation, for here the will has no control. Chemical agency is as requisite to create an electric current in the human pile as in any other, and it would be impossible to produce one by a simple act of the will.

"Encephalon" is the common name assigned to the entire nervous mass lodged in the skull; it is, beyond a doubt, that it is in this mass in which it is natural to suppose the largest amount of electricity is produced, the greatest quantity of blood is found circulating, and the brain in particular is specially adapted by nature for this arrangement. All this I told you when speaking of the pia mater. Besides, the soft and delicate nature of its substance must give free scope to the movement of molecules, which to all appearance takes place more rapidly here than elsewhere.

It would seem natural, at first sight, to expect that

the *will* would here meet with its required agent ready made to its hand. Now, absurd and presumptuous as some persons may think me, I venture to assert that this is by no means the case.

The cerebral electricity never travels to any great distance for the purpose of compelling the muscles to contract—it may rather be likened to some stately dame who has much higher functions to perform, and who executes them without moving from the spot. I feel it busily at work in my head at this very moment, while taxing my ingenuity to give you a clear idea of what I do not too fully understand myself. Of this working I am convinced, because I am alive to the fatigue now present in my head, and also because of the superabundant flow of blood to that point, (similar to what takes place in the muscles when they are in exercise;) so great is it, that in spite of a lighted stove at my side I am suffering from cold feet.

To work one's brain, is an expression which presents itself to the mind of the most unenlightened, so vivid and universal is the physical sensation resulting from the incomprehensible act of thought. If I have not occasionally been afraid to make your brain work, my dear little friend, it is simply because intellectual education is most important at your age, and also because exercise strengthens all the organs equally, the brains which reflect, (Stop a bit, where does reflection take place?) as well as the arm that is required to saw the wood. If the amount of electricity expended by muscular movement were produced in the

encephalon, then fatigue would be experienced in that point, just in the same degree as the expenditure of electricity, resulting from intellectual labour, is felt there. Now, when you have been walking all day, and the entire body succumbs, one single part of it remains insensible to fatigue ; it is the head, or rather what is within it, the encephalon, for the muscles which retain it in its place are subject to the laws of other muscles ; and in this instance, therefore, they participate in the general fatigue.

We must search elsewhere, then. Suppose we return to our comparison of a government.

Have you ever heard any one speak of what are termed "Crown Lands?" in other words, property, the entire proceeds of which are appropriated to the personal necessities of the sovereign. I should be disposed to look upon the encephalon as being our Crown Lands. The personal revenue of him who governs is always, as you know, far greater than that of other people, hence the frequent disputes as to who shall govern.

Besides all this store of wealth, a tax is levied throughout the country which goes to government, to be returned, under its direction, to those parts of the country which require common aid. Do not let us forget that a constant warfare is going on on this subject of movement where we are ; it is a state of war we are speaking of in which the members of a society ought to aid each other in fighting the common enemy. Those, of course, who are immediately engaged in the struggle will be called upon to suffer the

greatest personal loss. Government receives with one hand what it gives away with the other, and by this method cannot be ruined.

Such is the idea I form of these bountiful supplies of electricity distributed by the encephalon amongst the muscles which are called to the combat. I will not undertake to explain them to you as I did the currents of the voltaic pile. We are in the presence of too complicated an apparatus, the working of which is concealed from our investigation, and the electricity developed there has a character peculiar to itself, differing as widely from its namesakes in the inanimate world as the action of the magnet does from that of the electrical machine. But the results are there. It seems to me quite impossible that things should take place otherwise.

Whatever proceeding Nature employs here, there must of necessity be a continual circulation of electricity carried on between the provinces and the capital, and *vice versa*. During sleep, when the body is completely at rest, and when there can no longer be any question of muscular contraction, the electric tax paid to the nervous centre has its natural destination ; it returns in a quiet and uniform current, determining, everywhere on its passage, the chemical actions which have produced it, as does the current of the pile, and in this manner life maintains itself in our bodies until the substances capable of producing electricity fail, or the circulation in the apparatus becomes interrupted, whether by the occurrence of an accident or through exhaustion.

This interior service necessarily continues throughout life, inasmuch as it is life itself, and we may compare it to what we call "public service." Postal communication for example, which is always going on, and because essential to social life, must be maintained alike in time of peace or of war. In time of peace the taxes are light, there is not so much to provide for then, and this is, as I have told you, the time to economise. With the renewal of hostilities or of movement comes the war-tax, demanding those extraordinary contributions which wear the body out in a very brief space of time, and forcibly compel it to take refuge in the economy of sleep. When war is going on in any country, those provinces that are its theatre are naturally more speedily exhausted than any others; and so it is with our muscles, they can only endure local expenditure of contraction for a certain length of time. But the general expenditure is not the less felt everywhere; and if you compel any single member to work too energetically, lassitude will, after a time, pervade the whole body, because the other muscles have been overtaxed on its account. If you pay attention to them, the involuntary contractions which then agitate them are quite sufficient to warn you that danger is impending. Thus it was that Russia finished by exhausting herself, in directing all her forces to the Crimea when Sebastopol was taken.

From all this, we may conclude that movement must be suppressed in any member when its communication with the nervous centre ceases, or when the centre becomes inactive. Every observation

which has been made is in accordance with this conclusion.

Let us proceed to establish the first point.

The spinal marrow is the grand means of communication between the capital and the provinces; it has given vivisectors (they say) great opportunities to demonstrate scientifically, as they call it, a fact which the military hospitals, without speaking of others, teach us only too well. They sliced off small pieces from the spinal marrows of mammiferous* animals, commencing with the lower part, and always found that the movement was proportionably weaker in those muscles supplied by nerves issuing from below the section so made, and which had consequently been cut off from all communication with the centre of impulsion. The experiment was easily made. It never fails when a head falls beneath the axe of the executioner. The entire body becomes inert by one blow, because the executioner has commenced at the upper part of the spinal marrow.

But it is not requisite to slice the marrow above any member in order to destroy movement there, for the same result may be obtained by cutting the nerves which preside over the contractions of the muscles in the vicinity of the marrow.

This requires a few words by way of explanation.

You probably recollect the two little holes pierced at the interlacing of each vertebra—the one to the front, the other to the back of the column, and when

* You will see farther on why I select mammiferous animals only.

the nerves, after separating into two perfectly distinct cords, effect an entrance into the vertebral canal. I called your attention at the time to this division of the nervous fibres on their approach to the marrow. The moment is now come, as I told you it would, for me to teach you what there is beneath it.

When speaking of the circulation of the blood, we noticed that it travels through a double system of canals,—the veins bringing it from the extremities to the heart, the arteries carrying it from the heart to the extremities. The encephalon is a species of electric heart, (if I may so express it;) it is the point of arrival and departure to a double system of fibres,—the one set conveying information, and probably the tribute of the life of the body to it; the other taking back its orders, and the amount of strength necessary to execute them. To carry out our comparison, they are to our government what the civil and military agents are to others.

These two classes of agents, after mixing together during their passage through the nerves, suddenly diverge when they reach the high road of the capital. Just imagine a regiment of soldiers walking pell-mell amongst a crowd of civilians. As they approach the town, the drum beats, and in the twinkling of an eye, the soldiers are in line, each man at his place—the troops on one side of the road, the crowd on the other. This is exactly the way in which our nervous fibres act. The military cord, or that of movement, penetrates the vertebral canal by the front entrance—the civil cord, or that at the head of the “inquiry de-

partment," enters by the back door, after which they continue their separate paths towards the encephalon, gathering up, on either side, as they journey along, the bands of comrades ejected from each entrance before which they pass ; and this is the way the two large cords are formed at either side of the spinal marrow, as I pointed out to you before, to the right and left of the median line. Each receives one kind of nervous branch only, the anterior cord, or that to the front, the fibres of movement ; the posterior cord, or that to the back, the fibres of sensibility,—consequently they share the general office of transmitting despatches throughout the body. Do you recollect the little dog biting your leg, and the kick you gave it for doing so ? Well ! pass your hand over your vertebral column ; it was by means of the band of marrow next your hand that the sensation of the bite reached you, and it was through the internal or anterior band that the order was transmitted to your foot.

I have tried in vain, dear child, and am sorely indignant, but I cannot avoid speaking to you of certain revelations made by the scalpel, which, while enriching science, have dishonoured it, as is ever the case with ill-gotten wealth. They abound here with a superfluity that is truly revolting, and which would, I am convinced, have been considerably lessened if those to whom we owe them knew that on their return home every evening a little girl would be waiting to embrace them, and oblige them to give an account of how they had passed the day. As I have ventured

to speak to you upon these, naturally very interesting subjects, it is only fair that a few examples should now follow.

A Scotchman, Sir Charles Bell, the man who, of all others, has perhaps shed the greatest light on the functions of the nervous system, and who, according to the opinion of a competent authority, M. Longet,* has in this department made the greatest discovery of modern times, recoiled from inflicting torture on the living animal for the purpose of wrenching from nature the hidden mysteries of life. The scientific glory which this man of rare genius and accurate observation acquired is untarnished by ferocity ; and I must further say, to the honour of England, that whenever her physiologists desire to pursue their cruel investigations, implied in vivisection, they go to France for the purpose, not daring to attempt them in their own country. Charles Bell operated upon rabbits immediately after they were killed, and profited as much as possible by the small remnant of vitality existing in their still palpitating organs. We have scarcely any right to reproach him for so doing, as we do not scruple to kill these little animals for our own eating. Unhappily, though his demonstrations are very practical, they would involve explanations that would lead us too far into the subject. His successors, who were less scrupulous, have made experiments which require no explanation ; and as it will sufficiently answer our purpose, I will relate one only of them which was performed by a German named Müller, in

* Longet, *Anatomie Comparée du Système Nerveux*.

the year 1831, twenty years after Charles Bell's discovery had been made public.

He took a frog, an inferior animal that possesses great tenacity of life, (a mammifer would have died too soon under the operation to have allowed him sufficient time to observe it at his ease;) and near to the spinal marrow he cut a part only of the three nerves communicating with each of the hind feet; he cut the anterior branches at the left side, and the posterior at the right; this rendered the left foot incapable of motion, whilst it retained the sense of feeling. Means were not wanting to ascertain the certainty of this fact,—the right foot became perfectly insensible and incapable of motion. Assuredly this experiment was sufficiently satisfactory, and did not require a second trial.

Sensibility and movement disappear at once in a member when we cut the nerves below the point where the two classes of fibres separate, the whole nervous supply being thus simultaneously arrested. The government is perfectly ignorant of whatever may occur afterwards, and can no longer enforce obedience. It has been isolated at one blow from its clerks and soldiers.

Lastly, we can, if we please, separate without touching the nerves, either the first or the second class of fibres, simply by making an incision in the spinal marrow above the limb, either in the posterior or the anterior portion of the cord. Here, however, the separation of the fibres is less certain, and, by dint of repeated experiments, it has finally been ascertained

that contradictory results sometimes follow. It would appear that soldiers and civilians fraternise on the confines of the two bands, and here and there, on the journey, each side contains some deserters, and this capricious exchange somewhat baffles research. But what can be the use of so determinedly pursuing a few vagabond fibres existing within these poor creatures, the presence of which on forbidden ground cannot possibly alter the grand law discovered at so little cost. What can justify needless cruelty, when we have not exactly a right to absolution whilst practising it for a desirable object.

But enough on this subject. At the commencement, my intention was, not to speak to you on these matters, but my wish to find fault has superseded my resolution. It is before the tribunal of women and children that questions of this nature must be decided. Men are apt to accept all kinds of good excuses which would not satisfy you.

Let us next see what happens when the action of the nervous centre stops.

LETTER XV.

THE NERVOUS CENTRE—(*Continued.*)

HAVE you not sometimes suffered from those unpleasant dreams in which you distractedly flee from an indefatigable enemy, and try by a thousand ineffectual efforts to drag your legs along, when all the time they refuse to stir? If you can call to mind the wretched state of feeling into which this apathy of your members plunged you, by so reluctantly attending to your urgent entreaties, you will be able to form some idea of that terrible malady known as paralysis.

“Paraluo,” in Greek, signifies I “untie,” and paralysis unties those mysterious bonds within us, which unite the electric current to the will.

This imaginary paralysis of our dreams is accounted for by the general drowsiness of the encephalon, the base of which continues in a lethargic state, after the imagination awakened in the upper part of the brain first, has aroused the companion at its side, namely the *will*. The government disarmed and incomplete, (if I may so express it,) but partially aroused from its torpor, vainly struggles to exercise its authority, and hence the positive sensation of refusal to obey, which is so well known to us under the form of

nightmare. Imagine a monarch presenting himself to his people, and attempting to issue his orders in his night costume, unattended by police or soldiers! Such is the sleeper, and such the paralytic.

The will, when strong or over-excited, sometimes succeeds in enforcing obedience under any circumstances, and by its strength will shake off either sleep or paralysis. You can readily understand that the power of the will is not equal in all; it may differ in strength as do kings, but there is no absolute rule for this. It is difficult to picture Louis XIV. exercising any influence over the people, without the red heels to his shoes and his wig; it was quite different with regard to him whom the soldiers called "The Little Corporal," and who was not less imposing (but rather the reverse) in his gray riding coat than under his imperial mantle adorned with golden bees.

It is related of Semiramis, the great queen of Babylon, that as she was one day engaged at her toilette, somebody suddenly told her that the city had revolted. She rushed furiously from the hands of her female attendants, and half-dressed and with her hair in disorder, she restored tranquillity with no other accompaniment of royalty save the energy of her speech and the flash of her eyes.

There are several instances on record in which a sudden fright, or outburst of excitement, has caused the will, of its own accord, to resume the reins it had before allowed to escape it; and paralytics have been known to recover the use of their limbs in a moment. This happened to the lame man whose history is so

well-known, who, lying upon his couch when a fire broke out near him, was so terrified by the sight of the flames, that with one spring he jumped up and ran off.

With regard to sleep, I once had a friend who had power over his dreams when they became too painful, and who by an impulse of his will could emerge from the paralysis of nightmare. Singularly enough, this faculty, which is not without its value, was a recent acquisition, observed when his character became formed. He had no influence over his sleeping phantasmagoria until he had learned to control the actions of his life.

You also, my dear young friend, must have assisted at this struggle between the will and paralysis more than once, and I should be very much astonished if you are ignorant of what it is.

In the morning, when it is time to rise, has an idle fit never taken possession of you? Try it to-morrow, just to see, and take special notice of what occurs. All is awake in the brain, where the faculties are at work as if in full vigour, more even than at other times, because then all the powers of life are employed in their behalf. The will is also at its post, but it is undecided and listless; it feels as if it were hovering beneath the top of the skull, and it is not the desire to get up which is wanting. Unfortunately, there is a weight at the nape of the neck which fixes the head to the pillow—this is the base of the encephalon, the cerebellum, and its appendages, the torpor of which is not yet shaken off; the clerk has not yet opened the office. At last a great shock from the will forces the door open, the business of despatching orders immedi-

ately commences, the body which was lying paralysed now holds up its head, and life begins anew. All depends upon this opportune shock. For this reason it is a very easy matter to rise when there is some pleasure in prospect towards which the will bends. An excursion into the country, for instance, or the pleasure of being useful to your mother, ought to be sufficient stimulus were you always reasonable and dutiful; but as little people are not invariably so, I am going to give you a receipt, by following which, you will more readily overcome this sleepy clerk. Raise your head first, (a very little will suffice,)—the effort required is not great; by this means the office is shaken, and the clerk at once compelled to bestir himself.

I thought, my dear young friend, that by placing before your eyes an example so familiar to you as that of sleep, I should render the phenomena which accompany (in point of sight of movement) the interruption of the action of the nervous centre more readily intelligible to your comprehension. And now we must enter a little more into details.

The suppression of nervous energy seen in paralytics may be considered as a partial and permanent sleep, most frequently following on “cerebral congestions.” This is the term* applied to those sudden rushes of blood which inundate the encephalon, for which we cannot always give a reason, and which deranges its action when they do not immediately arrest its work

* They are also called “apoplectic strokes,” and “apoplexy,” two words with the same meaning, the second signifying in Greek a blow or stroke.

and produce death, or at least disorganisation of its tissues.

A strange phenomenon is sometimes observable in these circumstances.

I hope you recollect the median line dividing our body into two similar halves, which are joined together at the middle, like the two halves of a walnut shell. Sometimes after the disturbing flow of blood has subsided, it happens that only one of these halves is rendered torpid by the shock it has received from the blood, and the muscles on the one side are still alive, while those on the other side are dead, so to speak. Perhaps you may some day meet an unfortunate individual painfully dragging along the dead half of his body by the help of the living one. If you see that his face is all drawn to one side, you have the reason fully explained here. The muscles of the face are marshalled in pairs throughout the length of the median line, towards which they all centre, as so many combatants equal in power, producing equilibrium. The equilibrium is suddenly disturbed, if one of any of the pairs of the wrestlers occupying either the right or left side is struck by death; its surviving antagonist drags the powerless muscle over to its side.

It is by a similar disturbance of the equilibrium that the median line is so horribly displaced in children who make grimaces, who amuse themselves by distorting their features, lest they should grow up too good-looking! but the *will* is the culprit in these cases. It renders the contest an unequal one by send-

ing a reinforcement of electricity to one of the two bands; and they who make faces would be rightly served, if, by dint of being contracted for no cause, the muscles of the privileged band* were to acquire the habit of it. You know that the muscles very readily acquire habits which they afterwards retain, in spite of our efforts to cure them. Let me advise you to tell this story to your little cousin, who, if he continue, for sheer amusement, to disturb this precious equilibrium, so wisely established by Nature on the two sides of the median line, may one day find himself with the face of a paralytic.

Having settled this point, we will now return to those misfortunes which occur in spite of ourselves.

You may probably already have forgotten it, but there is a detail I pointed out to you when speaking of the species of rounded pyramid which the marrow forms after its entrance into the brain. Having reached the summit of the pyramid, if you remember, the nervous fibres that are collected there from all parts of the body decussate or cross each other at this point. Those coming from the right side of the body pass over to the left, and those from the left pass to the right. You will see by and by, I then said to you, what is the consequence of this interlacement or decussation of the fibres, which the indiscreet knife of the anatomist has revealed in the thickness of the pyramid where it takes place slyly. It is now the moment to explain this consequence. When

* It is almost always to the side which they first distort that the faces of children turn who indulge in grimaces.

paralysis manifests itself to the right of the median line, its seat is sure to be in the left half of the encephalon. If it betray itself in the left side, then the right half of the encephalon is the disordered part.

This is not all. I told you in my last letter that we have two systems of nerves—one for movement, the other for feeling; and that we can, at will, render a member powerless or insensible according as we cut the motor or the sensitive cords. Well, sometimes it is one, and sometimes the other of these two systems, which ceases to act after an apoplectic stroke followed by paralysis, according as the springs have been damaged in the cerebellum or the cerebrum; at least we have the right to suppose it.

The offices whence sensibility issues are, in fact, to be found in the cerebrum; those connected with movement are found in the cerebellum; this we shall see further on; but nothing is so obscure as the after-effects of these violent disturbances which disorder the workings of so delicate an apparatus; and doctors even are often sadly perplexed to indicate the exact point where the damage has been inflicted. The changes which it leaves behind it are rarely visible, and its results are most capricious. Not only does it choose between the two halves of the body and the two systems of nerves, but even there it takes and leaves, sometimes destroying the movement or the feeling only in certain places, while at other times it destroys them both only partially. The members in these cases retain a portion of their power, which may still be made use of by the will, but at what a sacri-

fice! This is neither more nor less than the paralysis of nightmare producing in reality during the waking state the imaginary effect of which we dream in the hours of sleep. The action of the nervous centre is not suppressed in this instance, it is only fettered and lowered. Who can tell us what kind of obstacles it encounters? Even in apparently extreme cases, when a limb, both powerless and insensible, seems entirely withdrawn from the action of the nervous centre, we cannot doubt but that some sense of feeling still remains. It is easy to note the moment when the decisive arrest of the electric circulation takes place, for then gangrene sets in.

The word I have just uttered is a very terrible one, my dear child. I spoke to you a short time ago of the dead half and the living half. I then went a little too far. A muscle is not dead simply because it has lost its contractile power; and the proof that it is still living is that the fundamental sign of life, the continued renewal of its substance, still goes on in it. The chemical laboratory remains in activity; therefore the electric currents traverse it as hitherto, though less energetically, it is true. You can satisfy yourself on this point by taking hold of the hand of any person suffering from severe paralysis. A death-like coldness is already perceptible, although the arterial blood penetrates it as well as all other parts of the body, but the elements of combustion that it carries with it, and with which it meets there, cease to receive sufficient encouragement from the electric agent to maintain in it the ninety-eight degrees Fahrenheit, of which we

have already spoken. This hidden source of life—the chemical life—is lowered a notch. You might imagine you had come in contact with a reptile. I speak of a living one. Divide the last links that attach the cold hand to the centre from whence it receives its remnant of life, separate it from the arm, and decomposition will speedily ensue. When absolute paralysis shall silently sever these last links, there will be no occasion to cut off the limb—decomposition will take place in the hand, whether it be an appendage of the arm or no, and this is what is known by the expression “gangrene,” which is death, positive death, seizing upon part of a being still in life.

We will not pursue this subject any further; besides, we have finished the history of this nervous centre which holds the members so completely under its authority. Can you guess what thought came into my mind whilst I was showing you a hand reduced to the inferior life of a reptile? It was this, that the members of a reptile are better distributed than ours; at least, they are more independent; their life is not left so completely under the absolute action of a centre, as for them not to be able to dispense with it. If you were to cut into the spinal marrow of a lizard in such a way as to intercept all communication between the head and the hind feet, the latter would still be able to move, and would be convulsed if you were to pinch them. In the reptile, life goes on in the provinces, though the latter be separated from the capital. If we descend lower still in the animal scale, we shall come into collision with organisms where the

capital is so unnecessary that there is none. This is one of the most distinctive laws of animal organisation, that in proportion to its perfection, life tends to centralise itself more and more. You fully understand that I am just now speaking of the life of relation; and the human body, the masterpiece of the animal kingdom, is the one of all others in which, without contradiction, this centralisation is the most complete. Not long ago I said: "Society is like a man on a large scale; it tends, by a natural inclination, to organise itself on the same plan as the human organisation." I greatly regret these questions do not belong to our present subject, because in discussing them I should have had an opportunity of throwing light on a great quarrel, of which, one day or other, you will hear something. I shall only say a word about it here.

We belong to a country, my dear child, which, as regards others, is to a certain extent what the human body is among other organisms, and which, into the bargain, suffers from these circumstances. The capital being gorged or surcharged paralyses the provinces, and this is a disease we should endeavour to remedy; but this does not prove that it is necessary to take away from it its title to social superiority by decentralising its life. When the head is too full of blood, we put mustard poultices to the feet. Why not act in a similar manner on the provinces? Let them be exhorted to react upon the capital in the same way as moxas are applied to a benumbed limb, to restore the electric circulation there, by making it rouse the brain.

This is perfectly right, it is combating the evil by remaining within the limits of the law of social life ; but to advise a return to their former isolation would be as absurd as to counsel our members to retrograde towards stages, over which nature has passed, in order to arrive at the point we have reached. People may say what they like, the lizard is a Girondin.

Ask some one else to explain to you what a Girondin is ; I avoid doing so for fear of being scolded. But how, I ask you, is it possible to dispense with politics when speaking to a queen of her government ?

LETTER XVI.

THE INVOLUNTARY MOVEMENTS.

WHAT would you say, my dear child, if, whilst you are moving about in your mother's room, answering her gentle voice and tender look, as naturally as you breathe, one of those beggar women, whom you sometimes see in the streets, were all on a sudden to place herself between your parent and yourself, and seizing you roughly by the hand compel you to obey her vulgar commands?

I fancy I see you trembling from head to foot, vainly calling upon your mother to come to your assistance, as dismayed by the termagant, you struggle in hopeless despair under the tyrannical restraint that tortures you. Well, then, a similar scene takes place within our bodies when the rude, coarse electricity of the pile, making an inroad in our members, violently repulses the friendly currents which are sent there by the will.

There are piles constructed expressly for this purpose. You take hold of a copper handle in each of your hands, and the current that rushes from one pole to the other passes through your body, it having suddenly been converted into a passage of communication between the two poles. The result of all this very

clearly discloses the mysterious cause of muscular contraction. No matter how much you endeavour to prevent them, the hands instantly clench the copper handles as if some irresistible power issued from them; and they are certainly endowed with a power, and one that we are all well acquainted with, inasmuch as it is that of electricity.

In this instance, the muscles are placed between two sources of electricity of different kinds, between two very different masters, each of which governs according to his own fashion. If we may be allowed to consider the brain as a sort of *animal* pile, whence proceed along the nerves currents of organic origin, civilised currents, if I may so express it, disciplined, guided in their course, whether by intelligence or instinct. The pile, in its turn, may be compared in its action on the muscles to (excuse the expression) a kind of *mineral* brain projecting in a straight line, currents of inorganic origin, which on their journey through our muscles conduct themselves like a band of unrestrained savages dashing straight ahead across a country. In the one case, as in the other, the muscular contraction is always caused by electricity, but what a difference in the procedure of the pile and that of the brain! The former invades the muscles all at once, causing them to contract instantaneously, in a riotous, painful manner as it passes along, and the antagonists of each pair of muscles pull, at the same time, in despair upon the bone, which does not know who to obey. Instead of the regular transmission to and fro, effected with so much calmness and gentle-

ness, when the brain issues her successive commands, the pile, like a stranger in the castle, by her blind and contradictory orders, produces nothing but universal confusion.

What have you to say of all this, my little friend ? Did you expect, when I was giving you the history of Volta's frog, that we should end by finding the same thing repeated in ourselves. However, there is no use in our denying it. Electricity exercises the same action over us, whether it is produced from within or without ; and I have a proof of this, which struck me very forcibly the first time I became aware of it.

You know that we possess two sorts of nerves, those which carry information from the body to the brain, and create what is called sensation, the others which transmit the orders of the brain to all parts of the body, and preside over movement, that is to say, muscular contraction. Orders, then, and information, contractions and sensations, proceed from two different points in the regular working of life ; orders pass from the centre to the extremities, information proceeds from the extremities to the centre. Now when the current of the pile invades a nerve, it immediately produces either a contraction or a sensation, according as it moves in the direction from the centre to the extremities, or from the extremities to the centre. Therefore I was not wrong in telling you just now, that under these circumstances the pile acts as a sort of brain to the muscle. The nervous filaments there do not mistake the agent ; they act as electric conductors with it, exactly as they do with the brain, each in its

own peculiar way. I will venture to add, that sensations and contractions are produced pell-mell, and at the same moment, provided the foreign current be energetic, no matter what may be its direction. It is a blind brute force, not understanding the word of command, but trampling it under foot the moment it has the power to do so.

We have in the history of nations, the counterpart of this foreign power coming and brutally assuming the place of the constituted and recognised government. This is called invasion, and I hope, dear child, it may please God that you shall know it by name only. But invasion changes its name when it is the sovereign of a country himself who calls in a stranger to reduce his subjects to order, when he cannot succeed in doing so. It then becomes intervention; and if we still wish to continue the comparison between the interior of our own little household and that of large governments, we shall recognise intervention there also.

You have not, I think, had time to forget what I said to you regarding paralysis, that revolt of the nervous system, currents of which cease to be subject to the will, or only obey it in an idle manner, like wearied or discontented subjects who treat with indifference whatever orders may be given to them. The will, betrayed by its ordinary servants, can then compel the muscles to contract in spite of themselves, by submitting them to the currents of the pile,—ever-willing servants, blind slaves who never dispute, resembling the Swiss of the King of Naples who were so useful to him, that

he could dispense with the fidelity of the Neapolitans. It is possible in this way to re-establish the electric circulation of paralysed limbs, and apparently to imbue them with life for an instant. It is true that the life is but a foreign one momentarily borrowed from the external brain of which I have just spoken to you, and which, it is natural to expect, is condemned to disappear immediately communication is interrupted between the limb and the pile. But notice what a mysterious thing real life is, the life that has its centre in the true brain. The contact of foreign life is sometimes able to arouse it. The interior currents are themselves called into play, as if they were disposed to do their best on seeing the service of the muscles usurped by their younger brothers from without, and the impulse thus given persists long after the action of the pile has ceased. It may by repeated attempts even continue indefinitely. This is one of the means resorted to for the restoration of those afflicted with paralysis; and if you remember how those paralytics were cured and enabled to walk by a sudden effort of the will, you must, to a certain extent, be able to account for the wonderful effect the pile is sometimes capable of producing. Shock responds to shock; it may be compared to the winding up of enfeebled springs, though how it is accomplished in either case we are unable to say.

It would not, however, do to trust to this always. Intervention is dangerous in its nature, and the artificial life which is asked from it, occasionally breaks the springs instead of winding them up. We have

heard of more than one example of partial paralysis being rendered complete by the intervention of the pile. We have also heard of princes whose last remnant of popularity has been destroyed by their appealing for the intervention of the stranger.

The most extraordinary effect that can by any possibility be made upon the animal machine by currents from a foreign source, is one that can never be of any service. It is precisely that observed by Volta on his dead frogs ; it is the movement produced after death. Experiments have been made on bodies of which the executioner had just severed the head from the trunk. Death having overtaken these individuals whilst in the enjoyment of perfect health, they could be subjected to the currents of the pile while still possessing the necessary conditions to enable it (the pile) to play the part of the nervous centre which had just been destroyed. What spectacle can be more hideous than that of galvanised corpses playing at life, as it were, half raising themselves, twisting about, beating the air with their limbs, shaken for the last time by false convulsions, and then falling motionless the instant that the source of artificial life is withdrawn from them. One may well call this the triumph of intervention ; truly man has never approached nearer to Nature in his endeavours to extract the secret of life from her bosom ; but the triumph has been a most fruitless one, and teaches us, better than anything else, how utterly powerless we are to enter the lists with the law which regulates all things.

I headed this letter "The Involuntary Movements."

Here are some undoubtedly with which the will has nothing to do, and it would be somewhat difficult to set aside their claim to the epithet "involuntary." I know of others the dependence of which is less authentic; and as we never know what may be in store for us, I intend to enlighten you a little on the subject.

It is more than probable that you have heard people speak of hysterics, or nervous attacks. It is well known that the malady is peculiar to ladies, they having almost the entire monopoly of nervous disorders. Spiteful persons sometimes go so far as to say that they constitute a great portion of their arsenal, but we are not going to discuss the truth of these remarks. The fact is, that some physiological reason lies concealed beneath all this, and female nerves are in reality more difficult to keep in condition than are those of men.

This requires a word of explanation.

Nerves are something more than mere conductors in the human pile; they are generators of electricity themselves, and in that capacity they perform an action peculiar to them. We are compelled to acknowledge this to be the case in animals possessing nerves and no brain, which may be compared to those barbarians of ancient Germany, when every man made war after his own fashion, and only depended upon his sword. The army of nerves within is subjected to the laws of a very severe discipline, and quietly obeys the orders of a chief who may be said to hold the whole of them in his grasp. But no army is so well

disciplined as not to be liable to revolt when overmarched. Admirable as the arrangements are in the French army, it is not very long since it afforded us an example of this. It is true, it occurred amongst the Zouaves, the most nervous of its soldiers.

In moments of excitement, when vital activity is in excess, and electricity accumulates in the nerves, they are apt to work without orders, especially if from one cause or another there is general weakness, and consequently exhaustion of the brain. Then nervous attacks burst forth, agitating the members by involuntary movements, with so great an expenditure of power, that weak, delicate women have been known, whilst in this state, to struggle with vigorous men, afterwards undergoing the inevitable punishment of having squandered their strength, and remaining for a long time in a state of extreme prostration. Now, it seems quite clear from all this, that the larger the nervous cords are as compared with the brain, the easier it is for them to acquire the ascendancy over their chief; and this is just the case with women, who have, in general, in proportion to their size, larger nerves and smaller brains than men.

Do not, my dear child, conclude from all I have said, that in your future position of a grown-up lady, you are necessarily destined to suffer from nervous attacks on every occasion. No woman of any determination ever suffered from one of these attacks when she was really called upon to attend to any important business. I mentioned Semiramis to you when speaking of paralysis. Perhaps it would have been wiser

to have reserved the story until now, for this is a case of armed rebellion, more alarming, I admit, yet easier to put down than the simple refusal of the nerves to do their work, in a case of paralysis. These conditions may be said to represent a government contending with two obstacles; on the one hand, the rebels have raised barricades, on the other they obstinately refuse to pay the taxes.

A queen who has a will of her own is always certain in similar cases to keep her nerves in check, however large they may be, and on this account the rebellious movements of an attack of nerves are, properly speaking, only involuntary in a secondary point of view. Once allowed to take part in the insurrection, the nerves mock at the will, which, had it chosen, in the first instance, to act vigorously, would have obtained the ascendancy; and so it is that man's free agency always renders him responsible for his actions.

We must not, however, pursue the subject too far. It was quite right that you should be taught something about these little mutineers, which are not so easy to control when they have once been allowed to have their own way. But whilst endeavouring to caution you against the error of letting them lead you captive, I would not have you to be unnecessarily severe upon those whom you may be called upon to witness suffering from these attacks. In each one of us there is an entire system of nerves independent of the action of the will—that of the nerves of the internal republic—it has its own nerves;) and when

nervous affections proceed from this system, it would most assuredly be very cruel to judge harshly of those suffering from these attacks. I have had no occasion up to the present time to speak to you of these proud republicans ; they are quite distinct from the walking machine. Now that its history is completed, I must fill up a gap I was constrained to make in the preceding part. As we accompanied our "Bit of Bread" in its various travels, we followed the example of tourists, travelling through Switzerland from canton to canton, delighting in the glaciers and the lakes without ever troubling themselves respecting the government of the country. It is true that the government does not occupy a very large space ; neither does the government of the stomach, the heart, and the lungs occupy much space in us. For this reason I felt sure I might be allowed to skip over them without any considerable inconvenience. You must not, however, imagine the study is one to be despised ; and, believe me, I should not have felt justified in passing over it silently if I had been able to enlarge upon it with you. Yet how was it possible to do so with a little child who had never learned anything about electricity.

LETTER XVII.

THE GREAT SYMPATHETIC NERVE.

THESE minor governments in the world of nutrition which we have passed by unnoticed, have frequently been as little regarded by others, who either never observed them at all, or considered them as quite unworthy of remark. I must in justice say they make very little appearance.

Buried in the hidden recesses of the body, between the vertebral column and the great organs of nutrition, there is a double row of small knots of nervous substance, bound together by a series of nerves, running from one to the other in succession, from the neck to the base of the column. The whole appears like a sort of continuous cord with knots at certain distances, and for a long time this cord was looked upon as a dependency of the cerebral system with which it communicates by means of a certain number of nervous filaments. It had its assigned place amongst the great army of nerves, where it was known as "the great sympathetic nerve;" so well chosen a name, that I prefer to retain it; and by and by, when we come to speak of the passions, you will see my reason for doing so.

The illustrious Bichat assigned its proper place

to this great sympathetic nerve, and in this fact lies his best title to scientific glory. He was the first resolutely to proclaim in public what others had hitherto only ventured timidly to whisper, namely, that this pretended nerve, so far from being a subject, is the rival of the brain—its colleague, if you understand the term better. It is now acknowledged to be a mass of nervous centres, each of which possesses an independent life—a collection of little brains, if I may make use of the rather rash expression ventured on by some of the precursors of Bichat. It is, as the Swiss would say, the great council of this federative republic, which counterpoises the cerebral royalty within us. The nervous prolongations which unite these “ganglia,” (this is the name given to these little brains,) are only messengers employed to keep up a constant communication amongst them, as also the filaments proceeding from the vital centre by means of which a communication is established between the two great systems. As a messenger is only called upon to execute his commissions, he takes no part in the administration of affairs, therefore their respective independence remains intact.

Would you not feel somewhat curious to examine the presidents of our little republics rather more closely, my dear young friend? This is to be our last anatomical lesson, and you need not fear my making it too long a one. Do you not wish first of all to ask me of what shape are these ganglia? We are here in the land of liberty, where we shall not meet with that uniform symmetry, peculiar to regions

under a monarchical government. Round, oblong, triangular, sometimes very voluminous, at others shrunk to almost nothing, they vary in shape and appearance, in the most capricious manner, from one end of the cord to the other; in one individual they are different from what we find in another, and those of the same pair most generally differ between themselves. Even their place and their number are subject to a thousand variations; sometimes they are to be found in places where usually there are none, at others they are vainly looked for in parts where it is customary to meet with them. In this instance, Nature seems fully to avail herself of the liberty allowed her. And who can say but that the immense varieties of humour and temperament we meet with, may, in some degree, depend upon these caprices in the distribution of the nervous centres of the life of nutrition? You will be able to understand this better when we come to examine into their influence upon the actions of the moral life, as I propose doing at some future time.

The substance of the ganglia bears no resemblance to that of the spinal marrow and brain. It is a species of gelatinous pulp of a reddish gray colour, lodged within an extraordinary fine cellular network, from whence bundles of white fibres issue, the extremities of which disappear in the pulp of the cells. The fibres of the ganglionic nerve do not form tight cords like those of other nerves; the skein is loose, and every here and there its scattered threads are intertwined with those of the adjoining ganglia, to form what are called

a "plexus."* As I have selected a skein to illustrate my meaning, I will ask you to picture one to yourself that has become entangled in the winding, and some impatient little hand by dint of pulling at the threads in every direction, has drawn the whole into a ball. This will give you a tolerably clear idea of these "plexus," which are easily distinguished from the ganglia, because they are composed of twisted fibres only, in which no trace of pulp is visible.

Now let us take a hasty glance at the principal details in the ganglionic world. It is too hidden a country for its topography to prove very interesting to you.

We do not find all the ganglia on the line of the great sympathetic nerve. From those contiguous to the last pair of ribs, (each generally has its own) bundles of fibres issue, the definitive expansion of which produces an inextricable confusion of intermingled nervous branches and small ganglia which are sometimes separate, at others mixed up together in a manner baffling all description. All this assemblage of multiplied interweavings and stray ganglia form beneath the diaphragm and the liver, between the stomach and the vertebral column, a vast network, on which anatomists have bestowed the poetic name of "solar plexus," because, they say, it is a representation of the sun with its rays. We shall touch on the "solar plexus" again at some future time. The shock which the stomach sustains, a sensation so familiar to those who have suffered from great or sudden emotions, is

* Plexus in Latin signifies an interlacing.

due to this plexus ; and the ancients who placed the second seat of the soul there, (its lower palace, if you like to call it so,) were not far wrong in doing thus. That part of us over which we have no control, is scarcely distinct from what is called the soul ; I mean the superior element of our nature.

The "solar plexus" envelops with its ramifications the aorta and the vessels which it sends to the diaphragm, the liver, and the digestive tube ; it seems arranged on the same plan as the arterial network, and the same may be said of all the nervous prolongations of the ganglia. It is in threading along the arteries, following the same path, that they almost always penetrate into the organs over which the ganglionic system rules. This invariable arrangement of the nervous apparatus peculiar to the life of nutrition, in my opinion sufficiently indicates wherein lies the secret of its power over its royal neighbour ; it controls the blood which exercises immense authority over the brain.

Next to the "solar plexus," the most important is the one placed close to the heart, at the exit of the aorta, and the elements of which are provided by the ganglia in the region of the neck ; it is called the "cardiac plexus."* It was impossible for me to avoid mentioning this name ; it would never do to pass silently over so great a personage as the one employed to govern the heart.

* "Cardiac plexus," from the Greek word "cardia," signifying a heart.

Speaking of government, I ought to tell you that his majesty the brain is represented in these popular assemblages of plexus, where the cerebral filaments are mixed up intimately with those of the ganglia ; it is by their means that whatever intelligence has seen elsewhere is revealed here, a necessary revelation indispensable to their intervention in the affairs of the life above. The royal messengers in their turn do not fail to create trouble there. They even sometimes seize upon the direction of affairs, as happened formerly in the case of the Polish diets, so jealous regarding the management of their country. Thus it is that certain men (so rare, it is true, that they are brought forward as examples in physiological books) have possessed the marvellous faculty of stopping at will, and according to their fancy, the beatings of this pre-eminent republican, the heart. A person possessing this power is in no way to be honoured for having such a faculty, seeing that this phenomenon, so directly at variance with the recognised laws of Nature, can only be explained on the supposition of a defective conformation of body. Nature, who is so capricious in her disposal of the ganglia, no doubt neglected to give sufficient development to their contingent in the "cardiac plexus" of these individuals, and the cerebral fibres thought it a fine opportunity of showing their power, otherwise adieu to the royal will ; it would vainly try to impose upon us if all were at their post, and the proudest wills we have ever read of in history have never, so far as I know, prevailed over a cardiac plexus that was in proper order. When republics suc-

cumb, it can only be attributed to some error in the constitution.

Here I finish the history of our movements. It would have been incomplete if I had left out this chapter on internal movements, which, like the others, are performed by means of muscular contractions, determined by a nervous centre. Those muscles which work for the benefit of nutrition, are not exactly like those which the brain sets in motion ; but I do not think it necessary to proceed further with our anatomical examination into this ganglionic world, which, you must agree with me, it was quite right you should know something of. We do not pretend to be “blue stockings ;” it is quite enough that we have mastered (as an appendix to the history of the walking machine) the general description of those free powers which, in secret and in silence, keep all the parts of the eating machine in motion. This subject is so little known, that you may turn what you have learned to great advantage amongst your friends.

One word more before I take my leave.

I spoke to you the other day of centralisation. I am not quite sure whether I was right in doing so. At all events it is done ; and having begun the comparison between the social body and the human one, I am obliged to carry it out.

If it is true that each human being possesses within him a model worthy of being consulted by all those seeking for the best laws of social organisation—do not alarm yourself, I will put it before you in another form :—If our body is a little society in such harmony

as to serve as a standard for larger ones, we have here an explanation of that double instinct which leads nations to seek strength in centralisation, and freedom in decentralisation.

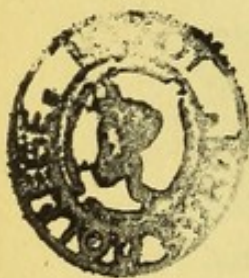
The domain of the brain: I know perfectly well where to look for it in governmental regions. The apparatus of relation is our Minister for Foreign Affairs, and the department of the muscles bears so strong an analogy to that of war, that military comparisons have continually presented themselves to my mind whilst we have been engaged in this study. It is evident a guiding will is necessary. Nations could not do better than imitate Nature, who has placed all the powers of the body under one guidance, whose action is felt in every part when a struggle has to be maintained against the stranger. I do not require to recapitulate the conditions under which this supreme chief exercises its power, which becomes inert immediately the heart ceases to co-operate with it.

But other laws govern the interior life. The nutritive apparatus of a country, its commerce, its industry, the incessant labour of its citizens, by which public wealth is kept up, and let us also add the throbs of a national heart—all this the ganglionic system full plainly shows us requires to be left to itself. It would be a fine affair if the brain had to watch over the service of the stomach, or if, at its convenience, it regulated the movements of the Master who disposes of its life. Besides, how could it accomplish all this, and what would become of the poor body, if the least drowsiness attacked the universal centre? Happy is

it for us, and do not let us be slow to own it, that Nature has armed herself against these encroachments of power, and only made them possible by some false step on her part. I have already told you that when government interferes with what does not concern it, it is the fault of the ganglia. Remember the history of the cardiac plexus.

With this, my dear child, we shall take leave of each other. We have now reviewed almost every part of the human machine, and I have little left to show you. That which remains to be seen is not the least curious part, being the outposts, so to speak, of our sentinels, that which, of all else within us, is the most artistically fashioned, the most exquisitely elaborated. Upon this will follow, perhaps, the most interesting of all,—I mean the invisible, that which is unseen. Adieu, then, my dear child, until the time when I shall have the pleasure of bringing before you the “History of the Senses and of Thought.”

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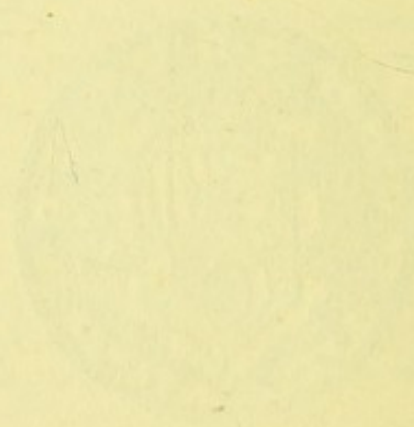
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