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Electricity: An Underlying Entity in Matter and Life, A Sustaining Principle in Modern Civilization

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Electricity is really just organized lightning.

– George Carlin

Basis of Modern Civilization: *Modern civilization rests on our understanding and use of electricity.*

Human culture rests on certain fundamental features which are manifested variously in different locations and at different times. These include our capacities for language and symbolism, our ability to count and compute, our creative inclinations for music and art, our yearning for something beyond material satisfactions, and our urge to interpret and comprehend the world of experience.

On the other hand, the underlying material factors sustaining civilization have been the science and technology of the place and time. For millennia these utilized raw materials like stone and wood, devices like pulleys and inclined planes, substances like coal and candle, and so on. In the first decades of the 19th century the eminent thinker and historian Thomas Carlyle wrote¹ that “the three great elements of modern civilization are gunpowder, printing, and the Protestant religion.” By modern civilization he must have meant the dominance of Europe at the time. Today Carlyle’s statement does not seem to make much sense. This shows how much the world can change in a very short time.

If we reflect for a moment on the factors enabling the functioning of human civilization in its current phase, a great many things may come to mind: trains and telephones, planes and computers, factories and television, and countless such inventions.

The principle that propels it all is electricity. Take away electricity from the modern world even for a few short hours, and all will come to a silent standstill. When power plants fail, people scurry to get their batteries and flashlights, and only if these too fail do they resort to candle or kerosene. Even these can only serve as light in darkness. But there are a hundred other needs that

¹ In his work, *The State of German Literature* which was first published in 1827.



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keep civilization such as we practice it going. Few elements in it are independent of electricity. At every step and in every gadget, this invisible principle comes into play.

Electricity as harnessed power has entered millions of dwellings all over the world. Even if there are homes in remote regions where no current flows to heat the ovens or light the rooms, there is not one modern nation whose capital and government can afford to work without electricity.

Electricity serves us in countless ways, and it is a frightening thought that we have become irrevocably dependent on it. Electricity is no longer a luxury, it has become a dire necessity.

Lightning: *The lightning is a visible manifestation of electricity.*

Human beings have seen manifestations of electricity in the physical world since time immemorial, but they did not recognize them as such. The most dramatic of these is lightning which was once imagined as a flashy expression of divine wrath, followed by a reprimanding noise (thunder). In the Vedic vision Indra was the god of thunder and lightning. In the Brahmanas it is said that “lightning is Brahman”, (*vidyud hi eva brahma*), which suggests a vision of lightning as a cosmic effulgence. The ancient Greeks thought lightning was a weapon of their god Zeus, while Athena invented the thunderbolt. In Norse mythology it was Thor (the god after whom Thursday is named) who used the thunderbolt to attack their enemies. One can go on and on. Overall, there was a legitimate fear of lightning and thunder, as expressed in the lines of Joaquin Miller in the poem, *The Ship in the Desert*:

*I saw the lightning's gleaming rod
Reach forth and write upon the sky
The awful autograph of God.*

Without the benefit of courses in physics, this was as good an explanation as any for something that can at times become quite catastrophic. The reason for recalling these is to remind ourselves that modern science has been jolting out *darshanas* (worldviews) in significant ways.

It was not until the middle of the eighteenth century that lightning came to be associated with electricity. Many have heard of Benjamin Franklin (1706–1790) and his kite experiment. In 1752, with the assistance of his son William, he is said to have tied a kite to one end of a silk string and an iron key to the other. There are many accounts of this experiment. Here is one in a recent biography²: “Franklin flew a silk kite (with a hemp line holding a metal key near the

² H W Brands, *The First American: The Life and Times of Benjamin Franklin*, Anchor Books, New York, 2002.



end) underneath a cloud during a thunderstorm. Franklin connected the device to a piece of silk to insulate himself. After flying the kite for sometime, he noticed the fibers on the hemp line standing up as though charged. He touched the key with his knuckle and felt a charge from the accumulated electricity in the air, not from a lightning strike.” This was how the electrical nature of lightning was discovered. Franklin sent his findings formally to the Royal Society of London with a proposal to construct lightning conductors³. Fascinating as the story is, the details of its historical status have been questioned by at least one historian⁴.

It must be noted that Franklin was not the first to do the experiment establishing the electrical nature of lightning. In 1750 he published his idea of doing an experiment on this by somehow reaching into a thunder-storm cloud. Thomas-Francois D’Alibard in France did a lightning conductor experiment based on Franklin’s idea⁵. Franklin’s kite experiments were reported. When a certain Professor George William Richman tried this in St. Petersburg in 1753, he was electrocuted⁶.

We are justified in cringing with fear when the gigantic flashes fill the sky. These are electrical discharges of enormous power. A single flash may contain enough electricity to light up a million electric lamps. Dedicated meteorologists keep track of how many lightning flashes dazzle when and where in the earth’s atmosphere. Elaborate detection systems detect practically every single lightning that strikes the earth in some regions. It has been estimated that about a hundred lightning discharges of various magnitudes are occurring every second in the atmosphere. It all adds up to enormous amounts of energy.

Electricity in the Physical World: *Electricity is as ubiquitous as light.*

It is not simply human civilization that is dependent on electricity. The entire universe is likewise dependent on it, for electricity is at the very basis of all matter which is the primary substance in the physical world. At its core, matter, in molecules and atoms, contains electric charges, and it is sustained by electrical forces. The glue that keeps the constituents of atoms and molecules is electricity. Many common properties of matter arise from ultimate electrical principles. The forces of tension in strings and friction between bodies, all arise from inherent electrical actions. Much of the electricity in matter is not directly discernable because, from a

³ *The Philosophical Transactions of the Royal Society of London*, Volume xvii.10.

⁴ Tom Tucker, *Bolt of Fate, Benjamin Franklin And His Electric Kite Hoax*, Perseus Books, New York, 2003.

⁵ May 10, 1752: ‘First Experiment to Draw Electricity from Lightning’, in *This Month in Physics History*, *APS News*, Vol.9, No.5, May 2000.

⁶ Gerald Molloy, *Lightning; Lightning conductors; Thunderstorms*, The Humboldt Publishing Co, New York, 1890.



global perspective the overall electrical effects cancel out. That is why for ages this important root of perceived reality had remained unnoticed for the most part.

What about the light that is spilt all across the length and breadth of this universe, and all its sister electromagnetic waves? The very name betrays the role of electricity in them. The subtlest components in the entire universe arise from the heart-beat of electricity (electrical fields) in vacuous space. Strange and mind-bogglingly rapid processes are involved in those omnipresent electromagnetic waves which interconnect the distant corners of the cosmos.

What is Electricity? *Electricity is a unique property, associated with every bit of matter.*

What exactly is electricity? How do we know it exists? What is its nature, what is its origin? These are among the questions physicists have been investigating only during the past few centuries, never before. These investigations have amassed an impressive corpus of information about the world in which we live.

As to how we know electricity exists, this is the reasoning: Many observed features of perceived reality cannot be understood or interpreted unless we suppose that there exist in the physical world certain ultimate entities with certain characteristic properties. For example, bits of paper rubbed on a wool surface tend to cling to our bodies and to other materials. If we assume the existence of a property called electricity, we are able to explain and synthesize, calculate and predict, an enormous range of phenomena in the physical world.

It is common scientific knowledge today that underneath the world of experience and undergirding its functioning are these not-directly perceptible entities. We refer to them as electric charges. These electrical entities are tenuous and subtle, and like much of beauty and ugliness, they can never be found except in association with matter. In other words, we have found electric charges only in conjunction with material bodies. At the deepest level they are attributes of the foundational bricks of the material universe. There can be no gross matter without electricity, and there cannot be electricity without the material bits we call protons, electrons, and the like. Pure electricity without association with mass does not seem to exist.

We have come to understand a good deal about the properties of electricity, thanks primarily to painstaking research, serious discussions, taking wrong routes sometimes and retracting, debating and mutually criticizing, etc. This is what constitutes universal scientific knowledge. This kind of knowledge is beyond the reach of pure speculation, meditation, philosophical debates, cultural patriotism, and the like. It is by the pursuit of serious science that our knowledge of electricity, as in other areas, has grown considerably, and has enabled us to use it to transform human civilization. The technologies arising from our understanding of



electricity have made life easier and more comfortable for billions of people, immensely facilitated locomotion and transportation, and resulted in dramatic revolutions in communication, and medical technology.

Does all this mean we know what electricity really is? Not really. All we can say is that electricity is a fundamental principle in the physical world which generates a force quite distinct from gravitation. That force arises from sources we call *electric charges*. In other words, just as tangible mass is the source of the gravitational force, intangible electricity is the source of electrical forces. Mathematically sophisticated theories have been trying to picture electricity as some kind of an obscure twist in a space-time-transcending dimension of the universe.

Kinds of Electricity: *There are two kinds of electricity.*

That bodies display interesting properties of attraction when rubbed with wool or glass had been known for a long time. A substance in which this property was first detected and studied was amber. So it was that when in the 16th century William Gilbert (1544–1603) wrote a treatise on magnetism he introduced the word *electricus* (meaning *like amber*) into the English language⁷. He stated in his book that the electrical principle had nothing to do with the magnets he was studying.

It was not until the 18th century that we became aware of the existence of two kinds of electricity. Charles Du Fay (1690–1739) was one of the first to recognize this. He reported his finding to the Royal Society of London, stating⁸ that “there are two distinct electricities, very different from which other; one of which I call *vitreous electricity*, and the other *resinous electricity*...” Less than fifteen years later Benjamin Franklin dubbed them positive and negative, and the Franklian nomenclature won the day.

The dual nature of electricity was one of the major discoveries of the eighteenth century when the air of science was rampant with electrical researches, both serious and playful. According to one story, for example, a Leipzig professor named Georg Mathias Bose secretly charged a damsel with static electricity, insulated as she was by the shoes she was wearing. Dinner guests were asked to kiss her politely, but when they did this they were literally shocked⁹. Perhaps the story has been embellished, but it typifies the kind of popular presentation of this interesting

⁷ Gilbert's classic *De Magnete* is a book on magnets. It was written in Latin but an English translation of it is now available, published by Dover Books.

⁸ Quoted in Henry Smith Williams, *History of Science*, Vol.II, p.159, Kessinger Publishing re-print.

⁹ For details on developments in electricity during this period, see John Heilbron, *Electricity in the 17th & 18th Centuries: A Study in Early Modern Physics*, University of California Press, Berkeley, CA, 1979.



phenomenon which scientists were investigating in right earnest.

Since the most ancient times reflective thinkers have noticed duality in many contexts. In the moral world we have the dualities of good and evil, just and unjust, kind and cruel, and so on. On the physical plane there is up and down, right and left, light and darkness, etc. This remarkable feature is found in the world of electricity too: positive and negative charges.

Coulomb's Law: *Like charges repel, unlike charges attract.*

As noted in a previous essay, the universe would be a static drab if nothing happened in it. It would be like a group of people sitting still in a room, each single and silent, with not a glance or word exchanged. To be otherwise, for things to happen in the world, there must be interactions: forces between the entities in the world. We have seen that gravitation is one such interaction. Thanks to it, planets move in orbits around stars, and we are kept safe and secure on our planet.

Electrical charges are fundamental in the physical world because they interact: They exert forces on one another. Or else, just the heaps and heaps of electric charges strewn all over the world would be a wasteful contribution to inactive inertness. The charges interact, not at random and arbitrarily, but in accordance with precise laws.

The basic law of interaction between charges is known as *Coulomb's law*, because Charles Augustin de Coulomb (173 –1806) uncovered it with quantitative precision. Du Fay had already noted that charges of the same kind repel one another, while charges of different kinds attract. Thus, positive charges attract negative charges and repel other positive charges; and the same for negative charges too. Joseph Priestley (1733–1804) had stated the law also. But Coulomb verified the quantitative aspects experimentally. To use Coulomb's own words in translation¹⁰: "It follows therefore from these three tests, that the repulsive force that the two balls electrified with the same kind of electricity exert on each other follows the inverse proportion of the square of the distance." The farther two charges are from each other, the less is the corresponding force between them¹¹.

The intensity of the force depends on the quantity of charges and the distance of separation. Electric charges came into being with these implicit instructions, as it were, not unlike genetic codes, governing their behavior for all time to come. Recall that with gravitation, attraction was

¹⁰ This was in what was titled as the *First Memoire on Electricity and Magnetism*, (*Histoire de l'Académie Royale des Sciences*), p.575, 1785b. http://en.wikipedia.org/Charles-Augustin_de_Coulomb

¹¹ Expressed as a formula, the force F of attraction or repulsion between two charges q_1 and q_2 separated by a distance d is given by $F = k(q_1q_2)/d^2$. Here k is a constant.



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the only mode. But here, because we have two kinds of charges, there is both attraction and repulsion. This has opened up many other possibilities.

Coulomb's law is among the basic rules from which follow many of the wonders of the physical world: formation of atoms and molecules, which means the variety of elements and compounds that we see around us. It is remarkable how so much can result from such simple basic principles.

Natural Unit of Charge: *Electric charges appear as multiples of a fundamental unbreakable natural unit.*

A fundamental requirement of science is the measurability of aspects of the physical world. We therefore need to establish a scale for measuring electric charge. The scientific community, to honor the name of the discoverer of the basic law of electricity, calls the unit of electric charge a *coulomb*¹². Just as we use meters for measuring distances, seconds for measuring time, and kilograms for measuring mass, we use the *coulomb* for measuring electric charges. Since we do not buy and sell electric charges in the marketplace, nor see them tangibly, we rarely use this fundamental unit in our conversations or commerce. But it is indispensable for a fuller description of the physical world.

In considering the smallest parts of things or of any measurable entity we can imagine dividing and subdividing a given quantity over and over again. Recall that units of length and mass and time were arbitrarily defined. It is possible to envision a length of any arbitrary size. There is really no *natural* unit for any of these: that is to say, there is no such thing as a unit of length or mass or time in nature which cannot be further subdivided¹³. However, with electric charges there is a natural unit: An ultimate indivisible unit of electric charge exists in the physical world.

What this means is that any electric charge we find in the world will always be a certain number of these fundamental units. We can have any fractional amount of gallons of water or logs of wood, but the number of people in any place has to be an entire number and never a fraction. Likewise, the amount of charge in any context will always be an integral (not fractional) number of this natural unit. In technical jargon one says that charge is *quantized*.

¹² Technically, in the International System of Units a coulomb is defined as an ampere.second: $1 \text{ C} = 1 \text{ A}\cdot\text{s}$, where the ampere is the unit of electric current.

¹³ Some may say that this statement is not entirely correct, since we have what is called the Planck length which is of the order of $1.6 \times 10^{-35}\text{m}$. However, this is not an unbreakable strip of length. Likewise the Planck time (about $5.4 \times 10^{-44}\text{s}$: the time taken by a photon to traverse a Planck length) is not exactly an atom of time, like the hypothetical *chronon*.



Physicists were led to this rather interesting conclusion in the closing decade of the nineteenth century from the data of many observations and experiments. Johnstone Stoney (1826–1911) suggested that this indivisible natural unit of charge be called the *electron*¹⁴. Before the end of that decade, J J Thomson (1856–1940) established beyond a reasonable doubt from his experiments that this ultimate unit of electric charge is associated with a small particle with a very small mass: the particle itself came to be known as the *electron*¹⁵. Furthermore, the charge on the electron is negative.

Some Properties of the Electron: *The very small electron has many properties.*

Soon after the discovery of the electron as a fundamental entity, the world of physicists went on a hot pursuit of its properties. It was soon discovered that some substances were incessantly spewing out electrons from their core: these are the so-called beta rays of radioactivity. Ingenious ways were devised to determine how much charge the electron actually carries: in other words, the precise value of the electronic charge. This turns out to be an unimaginably small fraction of the coulomb physicists had previously defined¹⁶. Through other ways physicists measured the mass of the electron. This too is so small that anything we weigh on a common balance sounds mind-bogglingly massive in comparison¹⁷. Never before in human history had a mass so small ever been measured. Before long it was found that this little thing is an integral part of the ultimate brick of any piece of matter we call the atom: That is to say, the electron is a constituent of the atom itself.

But it is not like some pretty painting on a wall that electrons adorn the atom. Rather they are dynamic and essential members of the atomic landscape. They whirl around in mathematically constrained orbits with impressive speeds. Yet they clasp other electrons in other atoms to form stable molecules, creating the wondrous variety of substances that enrich the world. Most of all, they dance from level to level within the atomic edifice, and in the process generate electromagnetic waves. Thus, ultimately the light that opens up our vision to the beauty of the world and enhances our appreciation of all its wonders is a child of the electron, a ripple from electronic transitions within the core of atoms. Who could ever have surmised this by contemplating on the majesty of the rainbow or the glowing effulgence of the setting sun!

¹⁴ G Johnstone Stoney, Of the Electron, or Atom of Electricity, *Philosophical Magazine*, Vol.38, No.5, pp.418–420, 1894.

¹⁵ For more on the history of the electron, see Per F Dahl, *Flash of the Cathode Rays: A History of J J Thomson's Electron*, Taylor and Francis, 1997.

¹⁶ The charge on an electron is about $1.6 \times 10^{-19}\text{C}$.

¹⁷ The mass of an electron is of the order of $9.1 \times 10^{-31}\text{kg}$. See in this context, as a matter of historical interest, Robert A Millikan, *The Electron: Its Isolation and Measurements and the Determination of Some of its Properties*, The University of Chicago Press, 1917.



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The human spirit has composed great poetry, generated insightful thoughts, and splashed grand paintings to reflect the magnificence of the visible world. But it required the patience and painstaking probing of the inquiring mind, the methods and mathematics of modern science to fathom the secrets of light itself, and trace its origins to the dance of electrons in the substratum of matter. Those who decry modern science do not know what they are talking about.

Hidden for ages from the field of human knowledge, the electron turns out to be stupendously significant in what it accomplishes. This minute entity, imperceptible to our direct senses, is in fact one of the most important roots of perceived reality. No reflecting mind can be untouched by the marvelous ways in which Nature is enabling the universe to function.

Charge Conservation and Charge Symmetry: *Electric charges are created and annihilated in pairs.*

Recall that an important discovery of eighteenth century science was that matter is conserved: that is to say, the total amount of matter in a closed system will remain unaffected even when many transformations occur within the system. During the nineteenth century it was established that this is equally true for energy too. But then Einstein's theory of special relativity in the first decade of the twentieth century forced us to expand these principles of classical science by showing that matter can appear or disappear, provided that an equivalent amount of energy disappears or appears. Thus, it is matter-energy that, taken together, is conserved.

A conservation principle holds for electric charges also. No matter what happens, the total amount of electric charge within a closed system will remain the same. Now there is a new possibility here to consider. Suppose that there is a region where there are no electric charges: the total amount of charge there is zero. Now suppose that six units of positive and six units of negative charge appear there simultaneously. The total amount of charge in the region will still be zero. Yet charges have appeared out of nowhere!

This implies that the ancient saying to the effect that nothing comes out of nothing will have to be re-thought when it comes to electric charges. This is because electric charges can emerge or dissolve as pairs of equal charges of opposite signs in a region where there is absolutely no electric charge. Of course some energy will be involved in the process.

Indeed, this is how electric charges came into the universe in the first place: More than thirteen billion years ago when the Big Bang is estimated to have occurred bringing forth the physical universe, many things emerged. Among them were electric charges in pairs, so there was no violation of the charge conservation principle. Thus were born negative electrons and positive electrons too, positive protons and negative protons, and so on. The key idea is that



corresponding to every electrically charged particle of one kind there is another carrying an equal amount of the opposite kind of charge. This followed from the theoretical discovery of the positron by Paul Dirac and its experimental discovery in 1932¹⁸.

This is the wonder of it all: the very nature of the physical universe has been determined by the existence of electric charges in it. Yet, the total amount of electric charge in the universe is zero.

Electric Charges, Fields, and Potentials: *These are the roots of the world of electricity.*

As was stated, electric charges are attracted or repelled by other electric charges. Another way of looking upon this is by saying that electric charges affect their surrounding space in such a way that another charge placed anywhere there is pushed or pulled. We say electric charges create *electric fields*. In other words, an electric field is a subtle transformation of a region brought about by electric charges wherein other electric charges experience forces. The notion of field is fundamental in theoretical physics. It is due to Michael Faraday (1791–1867), who was not a mathematical physicist, but whose intuitive genius and experimental work led to some of the most major discoveries in science during the nineteenth century¹⁹.

Thus, wherever there is an electric charge there is an electric field surrounding it. Ordinary matter is replete with electric charges, but for the most part of equal amounts of opposite signs, so that the net amount of charge in a piece of matter is ordinarily zero. Consequently, the fields created by these charges mutually cancel out. But remove some charges from the atoms, and you get matter with a net amount of non-zero charge. This will create an electric field.

We can visualize the idea with an analogy. Consider a horizontal plank resting on a fulcrum. Place a small weight at one end and the plank gets tilted. If the weight is compared to the charge, the tilted plank is equivalent to the electric field. Now place a marble on the plank, and it will roll down towards the tilt-causing weight. Place a charge in the electric field and it will move towards (or away from) the field-causing charge. In metaphorical terms, fields are regions where there are high points and low: positive charges tend to move from high points to low; negative ones from low points to high.

There are discernible level differences between various points on the tilted plank. We say there are electrical potential differences between points in a region where there is an electric field. Positive charges move from higher to lower potentials, negative charges from lower to higher

¹⁸ See in this context, G Fraser, *Antimatter, The Ultimate Mirror*, Cambridge University Press, 2000.

¹⁹ See in this context, L Pearce Williams, *Michael Faraday: A Biography*, New York: Basic Books, 1965.



ones. What this implies is that by suitably placing electric charges in electric fields, we can generate forces, motion, and thus energy!

Electric Current: *The flow of electrons keeps technological civilization alive.*

The flow of water constitutes a slender stream or a mighty river: it is water in motion, often from a higher to a lower level. So too the flow of electric charges could be a slender stream or a mighty river of electricity. But where does one find so many charges and where can they flow? Since every atom has electrons in them, we have sources for charges. But they cannot be made to flow that easily because most of the electrons are attached to the atoms in the materials. But in some atoms one or more electrons can be stripped off by a gentle push. These are the good conductors of electricity: metals for the most part.

What this means is that if a metallic wire can be put in an electric field, i.e., if its ends can be connected to points at different electrical potentials, then it would be like having a row of marbles on an inclined plank. A rolling of the marbles with begin: a flow of electrons will ensue. Such a flow of electrons through a conductor is what we call an electric *current*²⁰.

It is impossible to live in the modern world without observing some effects of electric currents. The next time we turn an appliance on, and even simply switch on the lamp, let us close our eyes for a moment and reflect on the invisible rush of electrons through insulated wires, zooming through the hurdles of the intervening atoms, and moving on and on for as long as a potential difference persists. Put the switch off, and you annihilate the provocation by potentials, and the current ceases. Electrons are the silent slaves of the modern technological world: When we pay the electric bill, we are not paying for the electric charges (electrons) but for the work they do for us: heating, lighting, moving things, etc.

Since ancient times people have experienced the effects of frictional electricity: the kind that may be generated by rubbing wool on a piece of glass, that creates sparks and gentle electric shocks which we call static. It was not until the end of the eighteenth century that we learned how to generate a steady flow of electricity through a wire. The first successful device wherein two different metals dipped in a saline or acidic liquid generated a steady current was instructed by Alessandro Volta (1745–1827) who reported his invention to the President of the Royal

²⁰ To have an idea of the importance placed on precision in physics, consider this. The unit of current is the international ampere. It was defined as the current “that would deposit 0.001118000 grams of silver per second from a silver nitrate solution.” As precision in measurements increased, this is found to be equivalent to only 0.99985 A, if we take 1 A to be 1 C/s.



Society on March 20, 1800. That first battery, consisting of several metallic plates “instead of a momentary discharge provides a continuous flow of electricity”. Volta was convinced that electric current was generated by the contact of metals whereas other scientists argued that it had chemical origins, as in the Voltaic cell²¹.

In the course of the 19th century, physicists discovered several important properties of electric currents, and they devised elegant and efficient ways of generating currents. They measured and calibrated currents.

Thus, artificial electric current was born a little over two centuries ago. No one could have foreseen from its modest beginnings the spectacular role and importance it was to play in times to come. Today electric currents heat and light homes and towns, energize appliances, fuel factories, and do a million other things. Like the turning wheel, currents are dynamic and continuing. They will be there for as long as there is civilization on the planet. These electron-flows keep moving in small streams or as torrents, silently serving humanity in countless ways.

Electricity in Life: *Electricity is at work in living organisms.*

Another important eighteenth century discovery relating to electricity was what used to be called animal electricity. In an experiment by Luigi Galvani (1737–1798) it was found that the severed lower limb of a frog (which he had been studying in his laboratory) contracted in strange ways when touched by a piece of metal. Investigating this further Galvani thought he had discovered an innate electrical activity in the leg of the dead creature²². This was the beginning of the eventual recognition that electricity is at the basis of all life, though not in the way Galvani had imagined it. What is interesting is that a dead frog’s leg provoked suspicion of electrical processes in living organisms. There was disagreement between Galvani and Volta, the former believing that the electricity he detected had a vitalistic origin (i.e., peculiar only to life, and was not the kind found in non-living entities). Volta’s first battery was constructed in an attempt to show that Galvani was mistaken in regarding the electrical effect he found in a frog as a biological phenomenon.

Today we know that electrical impulses govern neural processes which are at the basis of our nervous system and of our brains. Neurons are cells that can be excited electrically. The excitations are caused by processes in cell membranes. Neuron activity in the brain is what propels these unique systems (brains) in the universe, leading to pleasure and pain and thought

²¹ For details on this controversy see Herbert W Meyer, *A History of Electricity and Magnetism*, Burndy Library, December 15, 1971.
²² D Johnson, J Johnson and J Hilborn, *Electric Circuit Analysis*, Prentice-Hall, 1989.



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itself: indeed they generate the whole range of perceived reality, not just for us, but for every living being.

We thus see that electricity comes into play, not just in our useful gadgets and umpteen appliances, but in the very core of life and matter, and in the universe at large. This recognition is not yet two and a half centuries old.

Previous Parts:

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