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[Essay]

On Artificial and Animal Electricity
Alessandro Volta vs. Luigi Galvani

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Abstract

Two Italians, Alessandro Volta (1745–1827), a physicist, and Luigi Galvani (1737–1798), an obstetrician and physiologist, separately conducted experiments on dead frogs using metals that made their legs twitch. Volta concluded that electricity was an artificial and external phenomenon, dependent on the metals and unrelated with the frog's body; Galvani concluded that the frog's movement proved that there was such a thing as animal electricity that, even after life, remained stored in nerves and muscles. At stake was a metaphysical debate: Was it possible to restore a body's movement after death? Could electricity unveil the mystery of life, conveying immortality? The use of electricity in order to promote health, in an invasive way, in direct contact with the body, has seen significant advances in medicine, but a serious reflection on its non-invasive and indirect benefits and disadvantages, remains virtually unaddressed. How does electricity affect our space perception and orientation, our body, and its surrounding environment?

1. Introduction

In the eighteenth century an increasingly intense debate on the nature of electricity emerged. By 1791, in the centre of that debate were two Italians: Alessandro Volta (1745–1827), a physicist from Como, and Luigi Galvani (1737–1798), an obstetrician and physiologist[1] from Bologna. Volta defended his assertion that there was only one kind of electricity shared by any and all existing matter (organisms and objects); whereas Galvani contended that there were two kinds: animal and common electricity.[2] In order to prove their theories they both conducted experiments on dead frogs, using metals that made frogs' legs twitch. According to Volta, these experiments led him to conclude that electricity was an artificial and external phenomenon, dependent on the metals,

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[1] Pera (1992), p.xxii, p.64.
[2] Pera (1992), p.146, 152.

and unrelated with the frog's body. To Galvani, the frog's movement proved that there was such a thing as animal electricity that, even after life, remained stored in nerves and muscles. At stake was a metaphysical debate: Was it possible to restore a human body's movement after death? And did that mean that electricity could unveil the mystery of life, conveying immortality? Aware of this debate, Mary Shelley (1797–1851) dramatised this possibility in her well-known literary novel, *Frankenstein* (1818). Victor Frankenstein, a scientist, attempts to construct a human body out of several other different parts of dead bodies (of both humans and animals), and then, using electricity, brings that 'body' to 'life'. Still, that 'body' appears to result as monstrous, not only because its structure is abnormally big, but also because it sets out to kill Frankenstein's close ones.[3] Concerning the matter at hand, *Frankenstein* raises interesting questions: What makes a body a unit? How do the different parts articulate in order to form a whole?

Electricity, though it started being used in society as a divertissement, was very quickly claimed to have beneficial effects on one's health.[4] Many experiments were conducted publicly to an audience's delight, using many different animals; but in 1730, Stephan Gray (1666–1736) took one step further and conceived an experiment (repeated also in France by Charles Du Fay (1698–1739)) that marked a transition between electricity as entertainment and as a potential scientific subject. Gray's famous experiment consisted of suspending a child from ropes and electrifying him. From this, a curious observation emerged, noted down by Du Fay: the child, when touched by someone, seemed to produce a 'crackling Noise', causing both 'a little Pain resembling that from the sudden Prick of a Pin, or the burning from a Spark of Fire'.[5]

Throughout the eighteenth century, electricity was frequently referred to as 'wonderful' and as a 'virtue' ('the virtue of electricity').[6] After the door was opened to experiments with humans, the potential benefits of electricity did not go unnoticed to medicine and many at the time claimed it as a good solution to several afflictions such as gout, irregular menstruation and amenorrhea, tertian fever, asphyxia, rheumatism, paralysis, hysteria, toothache, headache, chilblains, mental disorders, haemorrhages, diarrhoea, deafness, blindness, venereal disease

[3] Shelley (2008).
[4] On electrotherapy use and the relation of new technologies with medicine, see Morus (2011).
[5] Pera (1992), p.6, 7.
[6] Pera (1992), p.2, 3.

and infertility.[7]

Rather than just confronting Volta and Galvani's positions, we are interested in going further, highlighting their contribution for a better understanding of what electricity is. We assert that there is a delicate, subtle, crucial, and still misunderstood relation between electricity and the human body. The invasive use by medicine, in what concerns a direct contact with the body, has seen significant advances and produced remarkable benefits, but when it comes to electricity's non-invasive and indirect interaction with the human body, we have hardly scratched the surface. Until now, on one hand, a serious reflection on what electricity is (one of the primary forces in the universe, along with gravity and magnetism) and how it interacts with the human body has been disregarded; on the other hand, its common daily use has been abusive, excessive, careless and thoughtless. The prevailing speculative and unscientific use of electricity that is claimed to have taken place in the eighteenth century[8] has continued until today. It is important to address the consequences of the lack of interest in the topic[9] and how it reflects on our health (human body and surrounding environment) in order to unveil what questions need to be asked. What makes our body a unit, as a human body? How does the body articulate with its surrounding environment in order to form a whole? Can electricity contribute to answer these questions? What is the relation between electricity and living matter?

2. Physics vs. physiology: the body as an open system

William Gilbert (1544–1603), from England, is credited as being the first one to coin the term 'electrics', from the Greek ήλεκτρον (*ilektron*), 'to refer to any substances with properties of attraction and repulsion'.[10] An astronomer, (and at one point Elizabeth I of England's (1533–1603) physician), he was aware that amber, a fossil resin, was known for centuries to have this property that 'if rubbed even just with a dry hand, behaved oddly like a magnet, attracting bits of

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[7] Pera (1922), pp.20–22.
[8] Pera (1992).
[9] As I. Bernard Cohen says: 'Until recently the early history of electricity has remained the almost exclusive province of historians of science, never becoming a primary topic of interest to philosophers to the degree that occurred in mechanics, heat, atomism, and other branches of physics.' Pera (1992), p.xi.
[10] Simon (2004), p.12.

straw, dry leaves, and other light bodies'.[11] He therefore believed that attraction and repulsion were vital forces, 'making the earth, magnets, and other electrics in some way alive, even though they appeared inert'.[12]

Later on, Isaac Newton (1642–1727), the highly acclaimed British scientist, proposed that the 'subtle and elastic' ether filling the universe also imbued the nerves and that these were solid filaments. To this, Descartes counterpoised the image of nerves as hollow tubes through which the vital spirit coursed.[13] It is against this scientific background that the Volta–Galvani controversy takes place. The topic relating electricity and the human body was in the limelight of scientific circles, and even two of the most influential scientists and intellectuals, Newton and Descartes, did not share the same perspective about it. Throughout the eighteenth century, the topic became highly discussed among scientists, and both multiple perspectives and new concepts arose. The Volta–Galvani positions represent two archetypal 'opposite' perspectives on a widely discussed topic that has known many intermediate viewpoints. Here, we do not consider them exactly as opposite because to start with, as we will try to show, although they were conducting very similar experiments, their initial main concerns were different. Volta was a physicist and a Galvani a doctor. Pera (1992) states that, although at a certain point Volta and Galvani tried to find a compromise between their perspectives, this was a failed attempt from the outset, because both had an 'all or nothing' kind of attitude. Above all, we consider that what was truly at stake was that their background education, and main interests, as physicist and doctor, respectively, made them frame similar experiments in theoretically different ways. Their conclusions are, therefore, not 'opposite' because they never took place along the same orientation to start with. This may seem a simple observation, but the consequences for our understanding and use of electricity today, because they were perceived as opposite at the time, are not simple. For now, let us briefly describe what the Volta–Galvani controversy was.

At the University of Bologna, Galvani was a professor of anatomy and obstetrics, doing research on the role of nerves in muscular contractions: a highly discussed physiological topic at the time that he started doing serious research, in 1780. By 1786, Galvani had recorded the following experiment: he suspended dead frogs' legs across an iron railing with their spinal cords pierced

[11] Pera (1992), p.3.
[12] Simon (2004), p.12.
[13] Simon (2004), p.12.

by iron hooks, so they were hanging. When the hooks touched the iron bar an event occurred:

> […] the frogs began to display spontaneous, irregular, and frequent movements. If the hook was pressed against the iron surface with a finger, the frog, if at rest, became excited – as often as the hook was pressed in the manner described.[14]

Was the agent of the contractions internal or external? Since there was no sign of electric stimulation around, Galvani concluded that the frog's muscle was a repository of animal electricity, stored in the muscles, released by the will, or by external stimuli, causing movement.[15]

Volta defended a position that, besides the gravitational force that Newton described, there was a different force of attraction at a distance. Gravity regulated the macrocosm, but there were other 'nonmechanical' forces, and we should not be frightened by this multiplication of forces in the sense that we could admit that there is a single law of forces from which others could be deduced: 'other types of attraction in smaller bodies and over shorter distances.'[16] Volta's main concern was movement, but the movement of electricity itself, as he is quoted in Pera: 'electrical motions are either caused by the pressure of some fluid, or have no other cause than the one mentioned, namely the attractive force of electrical fire.'[17] And in normal conditions, if there is equilibrium between the fluid and the forces:

> […] there are no signs of electricity. But when, for any reason, an imbalance occurs – that is, an increase or decrease of forces – the imbalanced body the sum of whose attractive forces is thus augmented or diminished, 'craves' or 'is craved' by new fire.[18]

At all times the bodies keep their electricity and the imbalance can be caused by rubbing, percussive pressure, heat and induction.[19]

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[14] Pera (1992), p.81; Simon (2004), p.13.
[15] Simon (2004), p.13; Pera (1992), p.80.
[16] Pera (1992), p.42.
[17] Pera (1992), p.42.
[18] Pera (1992), p.43.
[19] Pera (1992), p.44.

Theoretically, Volta was framing his experiments as a physicist and Galvani as a doctor. As Pera (1992) puts it, Galvani saw the frogs' contractions and sought their explanation in an *electrobiological* and not only *electrophysical* context (as Volta), having tried to show that the first was supported by the second.

> […] to him the primacy went to biology and physiology, not to physics or even to chemistry, a science held by Galvani to be incapable of explaining the causes of death and, presumably, even less of explaining vital phenomena. Thus, in Galvani's eyes, the frog was not just an ordinary *physical body*, but a *living organism*.[20]

This is, in our view, the most important observation to understand in the Volta–Galvani controversy, though at the time it was perceived as a scientific controversy between two opponents: 1) it does not imply two opposite perspectives; 2) therefore, in the end, there was no winner. Both had different goals to begin with, and, although the experiments were similar, their perception and evaluation of those experiments were heavily conditioned by their goals: Volta was interested in better understanding the movement of electricity itself and Galvani was interested in if and how electricity was the cause of movement (life itself) in the human body. To Volta, there was no animal electricity, the nerves had:

> […] merely a passive disposition toward an electricity that is always extraneous, in other words, artificial. The nerves react to this electricity as simple Electrometers, so to speak; indeed, they are Electrometers of a new breed, incomparably more sensitive than any other Electrometer.[21]

At the time, new arguments and experiments came along to unite supporters on both sides, until Volta was declared as the winner of the controversy[22] by 1800, when he officially presented an instrument in order to back-up his theory: the pile.[23] His inspiration to conceive it was the torpedo fish but,

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[20] Pera (1992), p.163, 77, 118.
[21] Pera (1992), p.113.
[22] Pera (1992), p.170.
[23] Pera (1992), p.153–163.

> not even in this case it is proper to speak of animal electricity, in the sense of being produced or moved by a truly vital or organic action […] Rather, it is a simple physical, not physiological, phenomenon – a direct effect of the Electro-motive apparatus contained in the fish.[24]

He therefore attempted to recreate, artificially, a device that would be an 'artificial electric organ', 'a perpetual electrical force', and in doing so, he invented the forerunner of the battery, the pile. He layered several round pieces of metal vertically, alternating copper with zinc, each separated by cloth or cardboard soaked in brine to increase connectivity. When the top and bottom were connected by a wire, an electric current flowed through the pile, generating a continuous flow of electricity. Until that time, electricity was generated artificially, but only as a discontinuous or intermittent phenomenon. The pile proved a theoretical principle that animal electricity did not exist because, if it did, it would not be possible to recreate it through a device, i.e. artificially. To understand electricity's movement was to understand electricity as a whole, as a phenomenon.

Galvani died in 1798 and therefore he did not live to question Volta on the pile. But in our view, the pile invention cannot possibly be a defeating event to Galvani's main concerns. As we have seen, to Volta electricity was a unitary phenomenon and to Galvani there was animal electricity and common electricity. Volta was a physicist and Galvani a doctor. Because Volta was interested in electricity's movement, he built a device creating a dynamic, repeated ad infinitum (self-sustained) movement, i.e. a closed system. For Galvani, because his main concern was to understand electricity's dynamic in the human body, its movement could never be infinite (as the human body is not), and his theories attempted to provide answers concerning the dynamics considering movement as finite, occurring in an open system, i.e. the human body. The odds were not on Galvani's side since his goals were as ambitious as they were highly praiseworthy. Still, Volta's name was granted to what is known today as the electric unit 'volt' and Galvani's research orientation, along with Galvani's theory, got lost in time – and perhaps the efforts of his nephew, Giovanni Aldini (1762–1834), to make Galvani's name remembered did more harm than good.

[24] Pera (1992), p.162.

Shortly after Galvani's death, Aldini staged spectacles for wide audiences showing animals, or just their heads, 'coming to life' after an electrical discharge was applied, where their eyes would light up and they would appear to move and jump off the table 'by themselves'. At one point he started using human bodies of 'executed murderers fresh from the scaffold, or their heads snatched from the guillotine'[25] in order to prove the existence of animal electricity.

We do not aim to deny Volta's virtues but we do defend the view that there is no winner in the Volta–Galvani controversy, and that is important to understand because the fact that a winner was declared led us to ignore Galvani's bold concerns. Although, perhaps, he failed to contribute significant advances to explain the relation between electricity and the human body (movement and life itself), the fact that he identified that relation and dedicated himself to it, is highly relevant for our understanding of the human body, its relation with its surrounding environment and the body's health. It reminds us that there is a lot to be done. Added to that, and contrary to what happened in Galvani's time, nowadays we are constantly surrounded by electricity (by electrical forces), and the invention of lamps, public illumination and many electric devices have come to increase the body's exposure to non-invasive electricity by direct contact, exponentially. Its effects and impact in our bodies, and in our health, is not well known yet. Moreover, the human body, despite being an open system permeable to the environment, also has its own electricity that constantly interacts with electricity outside our physical body. Research is conducted mainly concerning electricity's behaviour in the brain, but our question is: Considering the human body as a whole, and not just as brain, how does it relate with electricity? How does it affect movement, the way our body moves and orients itself in space?

After the Volta–Galvani controversy, and mainly after Volta had been declared the winner, two different conceptions of the human body arose – and here also Volta got ahead – one that conceives the body as a closed system, and the other as an open system. Volta's pile, which originated the chemical battery and its dynamics/movement, sustains itself as a closed system; Galvani asserted the existence of animal electricity and common electricity. Volta's device, in order to prove his theory, was the pile; Galvani thought about movement taking place in a human body, and from there he tried to create a theory that could

[25] Simon (2004), p.13.

explain it. To Volta, because theory was first and the device second, he was able to artificially build not only a theory but also a physical object (a machine) that supported his view. To Galvani, his observations of the human body came first, and from there he attempted a theory, having nothing to show in the end except the same human body with which he had started.

Both approaches in what concerns the human body can be related with our concept of health nowadays. Volta's interest in the movement of electricity itself, as an independent, artificial, self-sustained phenomenon, is related with the conception of restoration of health through chemicals (pills) and electroshocks based on the idea that they are able to generate their own electrical movement which imposes itself on an existing one (that of the sick body), either eliminating or balancing it. Galvani's aims in conceiving the human body as an open system relates (in a strict understanding of scientific conventional medical orientation, and therefore excluding homeopathy) with the work of Franz Mesmer (1734–1815), Jean-Martin Charcot (1825–1893) and Sigmund Freud (1856–1939).[26]

Apart from one approach being predominantly physical (Volta) and the other biological (Galvani), there is a difference in their scope, scale-wise.[27] The physical approach focuses on electricity's movement at an invisibly small scale, and the biological approach focuses on a scale that coincides with our physical body.[28] With time, biology tended to condense its research scale, getting closer to physics and chemistry; and the concept of health nowadays, according to the predominant scientific medicine, is mainly concerned with pills and/or cells (and its interaction with bacteria, viruses, etc.) which has led to new fields of research in biology and interdisciplinary branches that closely connect medicine and biology – a powerful combination unequivocally encouraged and reinforced by the pharmaceutical industry because of its commercial potential.

In order to stress the importance and the relevance of associating our conception of health with the human body considered as an open system, we will start by returning to a concept that was known both to Volta and to Galvani – 'electrical atmospheres' – and then approach the work of the German biologist, Jakob von Uexküll (1864–1944).

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[26] Simon (2004).

[27] Magner (1979), in particular Chapter 7 'Microscopes and the Small New World', pp.155–178.

[28] Though its limits are hard to establish, as is whether there is an inside or outside as well since it is an open system. Maurice Merleau-Ponty (1908–1961) has extensively discussed this, Merleau-Ponty (2005).

3. Frankenstein: electricity and health benefits

Benjamin Franklin (1706–1790) was the one who conducted several important experiments concerning lightning bolts and was the first to conclude, in 1749, that lightning shared the same characteristics as electricity and therefore corresponded to an electrical phenomenon (Law of Electric Electricity).[29] By that time, the existence of negative and positive poles was already known, and also that some materials were conductors and some were non-conductors. Furthermore, there was the Law of Electrical Atmospheres, which said that:

> If a conductor, not insulated, be brought within the *atmosphere*, that is, the sphere of action, of any electrified body, it acquires the electricity opposite to that of the electrified body; and, the nearer it is brought, the stronger opposite electricity doth it acquire, till the one receive a spark from the other, and then the electricity of both will be discharged.
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> […] If this Conductor does not communicate with the earth, but is insulated, and approached to the excited Electric as before, then not only the side of it which is towards the Electric, but the opposite one also, appear electrified; with this difference, however, that the side, which is exposed to the influence of the Electric, has acquired and Electricity contrary to that of the excited Electric, and the opposite side an Electricity of the same kind with that of the Electric.[30]

What we have here is a description of how conductors behave (not insulated and insulated) when they come into contact with other conductors, i.e. the behaviour of their own electricity, or, in other words, how electricity moves inside a conductor. A conductor, like the human body, is an open system and therefore its internal dynamics interact with any external stimulus, both altering (inside-out) and being altered (outwards-in). This, of course, became an important law for Galvani because it described the interaction, reaction and movement of electricity between two open systems, which simultaneously

[29] Pera (1992), p.28, 29.
[30] Pera (1992), p.30.

change each other (and their surrounding atmosphere) because of its interaction. The Law of Electrical Atmospheres can more easily be related to animal electricity (organisms) than with artificial electricity (devices) in the sense that it acknowledges that conductors have electricity inwards, which moves in a certain way, and also that inward movement affects other conductors, also creating movement in its turn. Concerning bodies and movement dynamics, and how both are essential for us to form our concept of space and actually be able to orientate ourselves, it is important to mention Uexküll.

Galvani was interested in studying muscle and nerve behaviour, and therefore wanted to understand better how electricity contributed to the movement of the human body (and perhaps if/how it sustained life itself). To Uexküll, nerve and muscle (skin[31]), and the ability of the human body to move, were at the root of what enables us to move in and through space (orientation).

> With the first movement of our limbs, our inner experience begins, and the first direction-signs are manifested. Space is at once formed, and it is made up of the possibility of movement in all directions […] plus the plans of direction; the actual movements are traced out in space as definite series of direction-signs.[32]

This means that, according to Uexküll, in order to comprehend space it is important to address the human body, and its movement, considering its nerves and muscle behaviour and consequently (if we think of Galvani) how electricity is a possible cause for movement. Can electricity interfere with the way we move and therefore with the way we orient ourselves in space?

Being a biologist, Uexküll considers the human body as a living organism and as an open system that relates to other organisms:

> Matter is always in motion, and since substances cannot all be at the same time in the same place – i.e. cannot possess the same local signs – they get in one another's way, and, in their movements, mutually influence one another.[33]

[31] Uexküll (2011), p.3.
[32] Uexküll (2011), p.20. Direction-signs are local signs that allow us to identify a change of quality in 'motion', i.e. the quality of direction; Uexküll (2011), p.6. Local signs are areas that respond to external stimulus; Uexküll (2011), p.3.
[33] Uexküll (2011), p.45.

Uexküll himself is aware that physics and biology share similar concepts but, again, he is the first to try to clarify that, even if the concepts are the same, in the end they are not because the goals of both sciences are different. In the following quote, Uexküll makes an interesting assessment of the concept of force, describing how it is different for a physicist and a biologist (and we can almost think about Volta and Galvani who, performing similar experiments, did not share the same perspective):

> Force is primarily nothing but a sensation that is connected with the movements of muscles. As an inevitable conclusion, the muscular sensation was exalted into the cause of the movement of our limbs, and then transformed into the cause of all movements whatsoever.
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> When we lift an object, we measure our force by the muscular sensation, but we also ascribe to the object an equal and opposite force, which we overcame.
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> For a long time, physics worked with the concept of force as the cause of motion and as the cause of the inhibition of motion. Weight, elasticity and hardness were defined as forces. Moreover, there were forces of chemical tension, magnetic and electrical forces. A non-spatial quality was thereby brought into spatial activities, and this enormously increased the difficulty of defining concept clearly.
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> Only through the explanation that motion was the sole cause of motion was the concept of force gradually eliminated from physics. The word itself fell out of use, and in its place was substituted the word *energy*, which merely indicates the kind of motion. The movements of substances carried out in space were described as kinetic energy; by potential energy, we understand motion stored up within substances.[34]

This means that, left alone, forces (including electrical forces) and motion become non-spatial qualities, and the proof of that is given when physics replaces the word 'force' with the concept of 'energy'. Force assumes the existence of a body (substance) associated with it in order to be expressed, presenting itself as a requisite; energy became a concept that indicates

[34] Uexküll (2011), p.47, 48.

movement, independently of a body. We could then say that what confers spatiality to electrical forces is the body, the living organism.

Uexküll clearly states the different perspectives of a physicist and of a biologist:

> According to the physicist, there is only one real world; and this is not a world of appearance, but a world having its own absolute laws, which are independent of all subjective influence. The world of the physicist consists (I) of places, the number of which is infinite, (2) of movements, the extent of which is unlimited, and (3) of moments, having a series without beginning or end. All other properties of things are referable to changes of place by the atoms.
>
> The biologist, on the other hand, maintains that there are as many worlds as there as subjects, and that all these worlds are worlds of appearance, which are intelligible only in connection with the subjects. The subjective world consists (1) of places, the number of which is finite, (2) of movements, the extent of which is limited, (3) of moments, in a series that has both a beginning and an end, and (4) of content-qualities, which are also fixed in number, and have laws which are likewise laws of Nature.
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> For a biologist, the world of a physicist has only the value of a world created by thought; such a world corresponds to no reality […][35]

We can easily relate this distinction with Volta and Galvani. By the early 1780s, Galvani suggested the hypothesis of an identity between the nervous fluid and electrical fluid (though he was not the first one to do it). He knew that there was a missing connection between the use of electricity for therapy and a serious physiological study. Electrotherapy was being used but there were no meaningful studies on its effects, proper use or effective benefits. To Galvani, it was important to try to establish a link between them, and so his method was that the theoretical-experimental part should support practical applications. Therefore, he did not defend the use of electricity for all illnesses but confined himself to those best explained by theory, namely, paralysis. Volta had a different approach and attempted the translation of a theory into an instrument.

[35] Uexküll (2011), p.70.

‘If an instrument could be derived from theory, then there is at least one reason to believe the theory works.’[36] He was a physicist, with physic’s unitary proposal of electricity, trying to create devices that prove a given theory. Galvani, the physiologist and obstetrician, was observing the human body and trying to find ways to explain how it moved (‘perhaps due to electricity’).

Thinking of electricity, artificial or animal, one important feature to consider is how it influences a determinate sense of unity or how it relates with several parts that may, or may not, result in a unity. In other words: How does electricity contribute to the organisation of a given body (artificial or animal)? Uexküll states:

> Organization means a unity in which the different parts are combined into a whole through the agency of a common activity. This holds good for the organization of our body as well as our mind.[37]

An interesting case study that reflects on this topic is the monster presented in Mary Shelley’s *Frankenstein*. Victor Frankenstein is a man who enjoys studying old scientific theories that explore how to imbue inanimate bodies with life. At a certain point, he is able to create a human-like figure.[38] This figure looks slightly out of proportion, monstrous, and does not seem to form a whole,

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[36] Pera (1992), p.53, 54, 24, 45, 46.

[37] Uexküll (2011), p.17.

[38] We use the word ‘figure’ having in mind Johann Wolfgang von Goethe’s distinction between *Gestalt* and *Bildung* mainly presented in his work, *The Metamorphosis of Plants* [*Versuch die Metamorphose der Pflanzen zu erklären*, 1790]. In German, *Gestalt* can be translated as ‘figure, shape, form, build, conformation, design, statute’, and *Bildung* as ‘creation, generation, formation, cultivation, education’. Both concepts are key to Goethe’s metamorphosis theory and, consequently, to his morphological thought, which he uses to describe how we approach things in order to know them. In short, though a plant (a living thing) has a shape or a figure (*Gestalt*), what makes us say it lives is that it ‘is self-sufficient, that its parts are inevitably interrelated, and that nothing mechanical, as it were, is built up or produced from without, although it is true that the parts affect their environment and are in turn affected by it’, Goethe (1989), p.80. This means that from a living thing, a plant or an animal (as Goethe says), it is expected not only that it has a figure but also the ability to show that its various parts ‘develop from a wholly analogous organ, which, although remaining basically the same, is modified and changed through progression’, Goethe (1989), p.80. Therefore, it has the ability to generate itself, from the inside, because of its inner force. In this sense, we could say that at the beginning, as Frankenstein is presented to us, *it* comes alive because energy (from the exterior) is applied to it but the creature itself has no inner force, i.e. the ability to move *its* own body. This would set the base for an interesting discussion on ‘will’ and on ‘free will’, based on a distinction between ‘energy’ and ‘force’, having as key element the body, but that is a discussion for another day. For more on Goethe’s metamorphosis theory and its distinction between *Gestalt* and *Bildung* see Goethe (1989), pp.30–81; Brady 1987, pp.257–300.

since it comprises different body parts from several different bodies. Still, through the 'virtue' of electricity, this figure comes to life. But can we say it is a human being or, to put it more simply, is it a living organism?[39]

In order to establish what a living organism is, biology relies on the theory of function or on morphology.[40] The theory of function is based on analogy and tries to establish a connection between traits or organs that seem similar in two different organisms. Morphology is a science that attempts to describe the framework of organisms, ascribing greater importance to the position of the organs in the animal bodies than to their function; therefore, morphological principles of the animal are only discoverable in the architectural plan by comparison. Morphology is the science that has originated the possibility of animal classification and is based not in analogy but in homology, where it is admitted that the same organ can have a different form or function in different animals.[41]

We can then say that, although according to theory of function Frankenstein's monster is a living organism, if we take on morphological principles, and compare him with several other human beings, he is not. Perceptively, his structure may be similar, i.e. his different parts and the way they connect seem to make him be able to function as a living organism, but his framework, his figure, does not form a whole. To put it in a different way, his body, as Uexküll showed us, does not have the ability to form space and he is therefore a device, a closed system. He has energy but no force. Perhaps that is why he has no place in this world and the setting where the final event takes place is in the South Pole, a place where human life is almost impossible. Throughout the story, the monster kills several characters almost mechanically (endlessly and repeatedly), until he finally kills his own creator, Frankenstein. Having done that, he decides to put an end to his own life, which is almost a paradox, because the fact that in the end he has the ability to self-destruct could

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[39] On how parts and whole relate, and how that is linked with perception, the work of Edmund Husserl (1859–1938) is an important reference. Orientation on this topic is provided by Hopkins (2010), particularly in Chapter 7 pp.151–180, Chapter 8 and Chapter 9.

[40] Uexküll (2011), p.110–113.

[41] 'Morphology' was coined by Johann Wolfgang von Goethe (1749–1832), who produced several scientific writings fully describing what morphology is. On this topic see Goethe (1989), in particular his essay 'Preliminary Notes for a Physiology of Plants', pp.86–96. Also on Goethe and science see Amrine, Zucker and Wheeler (1987); Fink (1991); Molder (1995); Uberoi (1984). For an account on the evolution of Biology as a science see Coleman (1990), in particular Chapter VI 'Function: The Animal Machine', pp.118–159.

be said to prove that he is a living organism, in the sense that his life has a limit; but then again, even batteries fade out. The decisive element in concluding whether or not he was a living organism is not function but morphology. Functions relate with parts that are interconnected and perform well or badly. Morphology relates with the framework, with the figure as a whole. The monster, as though he was a part of Frankenstein, dies too with Frankenstein's death. What changes everything is that, when Frankenstein dies, the monster is not instantly dead as soon as Frankenstein has his last breath, as though he were disconnected. Frankenstein dies and the monster decides he does not want to live any more. The ability Shelley gives to the monster of choosing to self-destruct is what makes out of him a living organism. The proof he was a living organism after all (and not a device) is the possibility that is revealed to the reader at the end; that the monster has to decide and act upon his own death – which is tragic, but then again Shelley was a Romantic.

The use of electricity to heal, as therapy, has been slowly discovered but nowadays it may be said to be involved in most procedures, diagnosis exams or rehabilitation (e.g. pacemaker, defibrillator, promotion of bone fusion, relief of symptoms of osteoarthritis and muscle rehabilitation). In a different way, its many applications in the invention of different technologies that proclaim to make human life easier – giving us more time to live a healthier and better life – also proliferate (e.g. refrigerator, washing machine and computer).

Electro Convulsive Therapy (ECT), commonly known as electroshocks, is perhaps the most well-known case of a much-disputed procedure that involves electricity.[42] According to what we have seen, the question with ECT is that it disregards the body as a living organism, as a whole that accesses space and finds its own place through movement. Although an effort is made to locate the exact part of the brain where shocks have better chances of succeeding, this relies on function and not so much on morphology (even if several different brains are compared). The human body, and all its afflictions, should not and cannot be reduced to the brain[43] because the body is not a closed system. Any attempt to solve an affliction that has as its principle merely physics, will not

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[42] On a summary of potential benefits and disadvantages of ECT see Royal College of Psychiatrists (United Kingdom), http://www.rcpsych.ac.uk/expertadvice/treatments/ect.aspx, retrieved on 30 December 2012. Valuable references are provided: Ebmeier et al. (2006); Eranti and McLoughlin (2003); Rose et al. (2003); Scott (2004); UK ECT Review Group (2003); Department of Health Statistical survey (2007).

[43] Clarke and Jacyna (1987).

result as a whole. The brain is not a closed system with closed electrical dynamics which will be balanced if confronted with an exterior, imposed and different electrical dynamics. This is a perspective of the human body, and its electricity, according to physics and according to Volta where it is presupposed that the body is a device, i.e. mechanical, repetitive and endless, trusting that perhaps one part may function and be 'healed' despite some other part becoming damaged. If the human body is perceived as an open system, as an organism with electricity, permeable to electricity from the exterior, in a constant exchange (in-out-in-out), then, like Galvani and Uexküll, this makes us realising that we do work as a whole and therefore we have a limit. Even if ECT can impose a different electric movement, its effects will be temporary since they are disconnected from the body and from the body's space perception, which, being also an electrical atmosphere, will eventually affect the physical body permeable to the exterior. It would work if the body could close itself to exterior stimulus, but then again this would mean that the body would lose its natural awareness and openness. The body would become heavier and 'bulkier', as though it were truly matter and not an intertwining of matter and mind. A sense of lightness of the body takes place when body and mind are closely interconnected. The heaviness or lightness of the body affects our space perception and the way we orient ourselves in space. As Uexküll puts it, '[s]pace as we think of it is the space with which the physicist deals, while intuited space as we look at it is the space of the biologist'. Space is, for a living organism, intuitive space, on account of our ability to transform space into a continuous series of places.[44] A psychic approach of the human body which aims at restoring its health while considering it as a device (as a closed system), and interacting with it through chemicals or electroshocks, creates a space perception where the body, as a whole, has no place. It may be a unit, but not a whole in the sense that its parts are not interconnected, morphologically speaking – and from this results a heavier and 'bulkier' body. A biology approach of the human body attempts to create a balance of different parts resulting in a whole; this implies understanding that, for that to happen, the body needs not only to be in space, but also to have a place. Therefore, those parts that aim at connecting are not only the different parts of the body (physical body and mind) but also the body and its surrounding environment.

[44] Uexküll (2011), p.42.

Curiously enough, what we see nowadays is an attempt to converge these two perspectives where men and devices intertwine exponentially at a fast pace. Are we artificial or animal? If we start to incorporate devices in our bodies, are we living organisms or machines? Will we have a distinct framework (figure) that allows us to be compared with others or will our body be a device that performs a function only? Is it time to ask if we are about to become a set of different parts struggling to be whole? And if so, will our bodies move differently? Will our concepts of space change? Will we be able to orient ourselves in space and find our own place?

4. Electricity use, architecture and urban environment

Nowadays, in our surrounding environment, electric light is everywhere. We live immersed in an 'electrical atmosphere'. We claim that the concept that was declared obsolete back in the eighteenth century has now become relevant again. Electricity's benefits for health in medicine have been studied for a long time, and its use is cautious and restrained. There is a general awareness that it is a powerful force (or energy) and therefore a careless use can have serious consequences. This may be so because its use interacts with the human body invasively, by direct contact, and any inaccuracy easily gains visibility (e.g. a scar, a burn). But the potential benefit or detriment to the human body of the electricity's use in our surrounding environment is not known.

In our immediate surrounding environment, the domestic space, electricity has made its way, and in the last hundred years, it seems it has come to stay.[45] We went from a low level of light inside the main living space to abundant light in every room of the house. This has certainly brought many changes to the act of seeing, but also to our daily rhythms, to the way we use the space of our own house (or the houses of others), and to the way we orient ourselves inside a house.[46] A sense of ownership of space is more apparent if we walk round our own house in the dark rather than with the lights on. In the dark, the space of the house becomes a place, our place, and we become whole with it. Too much light, excessively strong for our eyes, desensitises the body and changes our space perception. Intuitively we know this; any romantic date promotes a low use of light and the event usually disregards the use of electricity, rekindling the human

[45] Dillon (2002).
[46] Tanizaki (2001).

eye with candlelight, because it is believed to excite our body sensitivity.

In public spaces, including in the workplace, electric light has also become abundant and over-illumination has become the rule, at least between 1950 and the late 1990s.[47] Since then, the topic has gained a little bit more attention but there seems to be resistance to accepting some of its findings,[48] to have an actual impact in our surroundings or for its conclusions to be taken seriously: there is over-illumination and that has serious impacts on health, contributing to illness (e.g. migraines, mild headaches, tiredness, altered heart rate and agoraphobia).[49] Have we become that attached to electricity?

Over-illumination brings discomfort, and those who are more aware of its disturbing effects try to avoid it either by lessening their time of exposure to it or by moving faster through a space that needs to be navigated. Fast-food restaurants know there is a specific reaction to over-illumination and they use it in order to promote the ‘fast’ food concept, literally. Excessive light desensitises the body (hence the combination of strong, familiar flavours with large portions as secondary gratification) and it promotes the kind of physical discomfort that makes you eat faster – even if you are not consciously aware of it. Romantic restaurants, or ‘good’ restaurants, are more expensive not only because of the quality of the food, but also because, in order for you to enjoy your food, they use less light to heighten your sensibility – this also means that people will take longer to eat, which will lead to fewer meals served per night, and therefore one more reason to charge higher prices.

With these two examples, we have shown that the use of electricity conditions our body movement and intuitively changes our perception of space, either by making us feed ourselves faster than we normally would or by enabling us to enjoy a good meal with a loved one, slowly. In a fast-food restaurant, eating fulfils a function: to keep the body running (alive) as a unit, so we do not break apart (literally); in a good restaurant, we could say that eating is a morphological experience for the body, where space is owned.

There is also the situation where public transportation places are over-illuminated (e.g. underground stations, airports and railway stations) but also workplaces, supermarkets, gyms, schools, universities and hospitals. The use of electricity in public spaces like these is a topic that should be taken very

[47] Simpson (1990).
[48] Basso (2001); Boyce and Boyce (2003); Clements-Croome (2006); Russell (2008).
[49] Nagi, Yasunaga and Kose (1995); Hazell and Wilkins (1990).

seriously because these are places that cannot be avoided for a human being living in society. Also, contrary to your own house where you can choose to lower or heighten the use (and intensity) of electric light, in these spaces someone has conceived its use for you (usually opting for an excessive, over-abundant and careless use of it), disregarding the impact on the body of the kind of lamps, their intensity, the interaction of natural with artificial light, the kind of equipment and technology in the room, which predominant colours the walls or certain objects are, or which function the space is intended to play.

> Despite evidence to the contrary, the lighting industry has perpetuated the myth that low lighting levels and contrasting brightness are harmful to the eye. Ignoring the phenomenal adaptive power of the eye and the need for exercise to retain its elasticity, evenly distributed high lighting levels (necessary only for the most critical seeing tasks) have become standard in most architectural spaces regardless of the activities for which they are designed. [...] the assumption that visual comfort is synonymous with visual acuity has led to a doubling of recommended light levels approximately every decade for more than half a century. In seeking solutions to the energy crisis recent studies in the USA indicate that three to ten foot-candles provide sufficient light for reading and that an excess of that amount can be tiring to the eye. However, sixty to seventy foot-candles are now common practice in American schools, libraries, and offices. The glare of excessive brightness and the monotony of wall-to-wall luminous ceilings have been the consequences of a grossly exaggerated need for more and more light. The necessity to conserve energy will inevitably reverse this trend. Hopefully, in the end the foot-candle syndrome will reveal the qualitative trade-off value and environmental enrichment potential inherent in sacrificing foot-candles for the dynamics of coloured illumination. Its application to affect perceptual, emotional, and psychic responses to spaces designed for activities in which high degrees of visual acuity are neither necessary, desirable, nor appropriate, promises to be a major dividend from this alternative to prevailing illumination engineering practice.[50]

[50] Preusser (1976), p.89.

Still, there are public spaces that are more aware of the use of electric light than others. For example, in a big supermarket the use of over-illumination is common and that is an advantage to the supermarket because that allows the supermarket to sell more. The body has a tendency to orient itself towards light. If there is light everywhere, creating a flat-surface atmosphere, it has a disorienting effect. Where to walk and where to walk first? It is hard to feel that you have a place in an over-illuminated space, and you almost experience 'Physically' (Physics) your physical body – as we have seen before, the kind that makes you experience the body as heavier and 'bulkier'. Excessive light, because it desensitises and disorients, dulls body movement, it sedates your physical body (nerves and muscles), and that is why most people sleepwalk through supermarkets; but not only that. Because you are desensitised, and you tend to sleepwalk, you have a harder time working out what you feel like taking home, or exactly what you do feel like eating (even if you did know before entering the supermarket), and since you are there for longer than you would think, you take several different options so that you can decide at home. In a supermarket, over-illumination highly contributes to your brain 'reading' the message that that space is meant to fulfil a need – so that you accomplish a function successfully – and it is not meant for you to linger. The underground station (or airport, train station, etc.) accomplishes the function to get you from point A to point B. The supermarket feeds you. Gyms, schools and universities, workplaces and hospitals are particularly difficult challenges in what concerns electricity use, perhaps because they should be highly aware of the importance of its careful use, and they do not seem to be. How can you practice in an over-illuminated gym, and feel like staying there practicing and attending regularly, if the environment is sending a message to your body that you should leave as fast as you can? The same goes for schools, universities and workplaces where most people spend most of their waking hours. Perhaps the most serious and challenging situations, hospitals and health-care environments, are structures that not only are expected to incorporate many sub-functions, and therefore different spaces inside a same structure (operating room, waiting room, recovery, etc.), but also deal directly with the re-establishment of a healthy body.

A question therefore arises: Considering the body, the house and free space[51] how do they relate with electric atmospheres? Are our bodies and our

[51] Bollnow (2011), written in 1963; in particular 'Forms of individual space: Three areas of dwelling', pp.267–285.

surrounding space converging to a closed, unitary system? Is it possible that our living organisms are converting into a unity instead of being a whole? Are we becoming Frankenstein's monster?

To understand our bodies and surrounding space as atmosphere enables us to perceive ourselves as immersed in an electric atmosphere, where we constantly experience its force, not only interacting with it but also actively contributing to it. The living organism movement is therefore meant to have the body open and permeable to the exterior in order to fully experience its force as a dynamic system.[52]

As our public spaces have progressively become more illuminated, our apartments have progressively become smaller. And if at a certain point the use of excessive electricity in our domestic space was enthusiastic, the tendency seems to have decreased. Perhaps because in most public spaces we experience over-illumination, perhaps because excessive light flattens space into a surface and, if you already have a small space, you do not need to experience it as even smaller. Also, we seem to experience two very different situations in public and domestic spaces: there is a tendency to sleep walk in public spaces (even on the street, particularly where there are many publicity signs), making us look as if we are in a trance and desensitised; and, concurrently, we either close ourselves in our apartments with the Internet or we create a bubble in public spaces by listening to music, playing games or watching a video, and in all these mediums we are hypersensitive to every action and every detail. Outside, we are desensitised and inside, in our home-bubble[53] and our technological bubbles, we are fully exposed. In both cases, electricity plays a key role since no technology works without electricity. We are electricity and we do not seem to be willing to let go of it, anywhere, anytime.

Is it possible to believe that we can reverse this situation? Is it legitimate to want to reverse it? Should we conclude that our natural evolution has led us to give up place and embrace space (is space embraceable)? Regarding our bodies, should we aim for function and forget figure? Are we all converging to one unit

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[52] Colour use is actually what can contribute to defend the body's natural openness – hence our extreme sensibility to the colour of our clothes (particularly to certain colours on in particular days) and animals' use of colour as a key survival feature. On this, Goethe's scientific writings provide an important framework. Though not explicitly, Goethe explored this in his novel, *Elective Affinities* (1809), and it is closely related with his scientific writing on colour, *Theory of Colours* (1810), Goethe (1989a). See also Bollnow (2011); Böhme (1989); Böhme (2006).

[53] On the concept of bubble and how living organisms create their own bubble, see Uexküll (2011). His main contribution to this topic was the concept of *Umwelt* 'surrounding environment'.

and losing the ability to compare ourselves with others, and hence our desperate need to distinguish ourselves through the colour of our hair or through what we post on Facebook? How does that affect our identity as human beings?

In our opinion, although no process is fully reversible, assuming how the situation presents itself nowadays, we defend first of all that it is important to bring into awareness the relation between body, space and electricity. If there is awareness, then many areas of expertise will need to develop further studies in order to find the best solutions.

The body needs to recover its place in public space and strategies need to be found in order for this to happen. If this happens, domestic place will, perhaps, be more permeable and open to interact with the exterior. Excessive use of electricity in our surrounding environment, by over-illumination combined with the excessive use of electricity in the technologies we are constantly in contact with, makes us experience our bodies in space in a totally different way from that of a hundred years ago. It is not relevant here to be nostalgic, or label it as better or worse than before. What is relevant to understand is that it is different, and because it is different, new problems need to be addressed. We seem to be stuck between the infinite disorienting possibilities of the outside world and the infinite, equally disorienting, possibilities that technology has provided us with,[54] which on one hand fulfils the promise to give us more time to do other things, but on the other hand seem to be more and more time consuming.

We need to rethink the concept of atmosphere, of electric atmospheres, rehabilitating it in order to get a better grasp of how we can promote a healthier relation between our bodies and the surrounding space. That implies conceiving our bodies as *in* space and not as a 'weight' that adds to it. And, for that, we need to experience electricity, the force of electricity, not as physics (not as space) but biologically, as animals, permeable and open, that create their own space and exist in nature.[55]

The human figure is now overshadowed by its over-illuminated surrounding environment, in an increasingly flat-surfaced space, and it struggles to survive.

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[54] *Hikikomori*, a phenomenon that was first identified in Japan but that is not exclusive of that country, where people lock themselves in their rooms and refuse to leave, using only technologies inside their houses or their own room, may be a consequence of what we are describing here. On this, see Soeiro (2013).

[55] The work of German philosopher, Hermann Schmitz (b.1928), greatly contributes for this orientation, clarifying the interaction between body, surrounding environment and space and how this knowledge can be used for therapeutic purposes.

An urgent question needs to be addressed: How can human life be sustained? Is it relevant for its survival to preserve its figure? What is life?

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