Electricity of the Body

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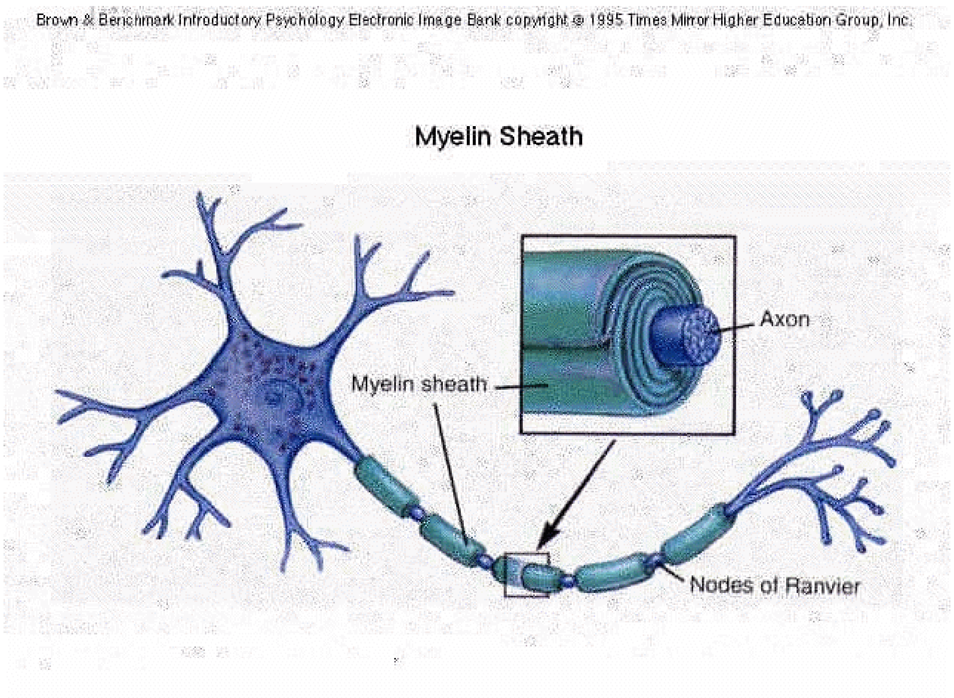
Electricity is a key part to our lives. Not just because we depend on it for entertainment and convenience, but because we wouldn't be functioning life forms without it. We have electricity running throughout our entire body but that's not to say that our body generates a lot of electricity. The human body can generate between 10 and 100 millivolts while a typical AA battery produces between .9 and 1.5 volts. There are other organisms in the wild that can generate much more electricity than humans, however. The electric eel generates on average 300 volts but can generate up to 600 volts. The electric catfish can generate up to 350 volts and the electric ray can produce anywhere from 8 to 220 volts of electricity. The difference between humans and these creatures is that we don't need massive amounts of electricity to survive whereas these animals need it to catch prey and protect themselves.

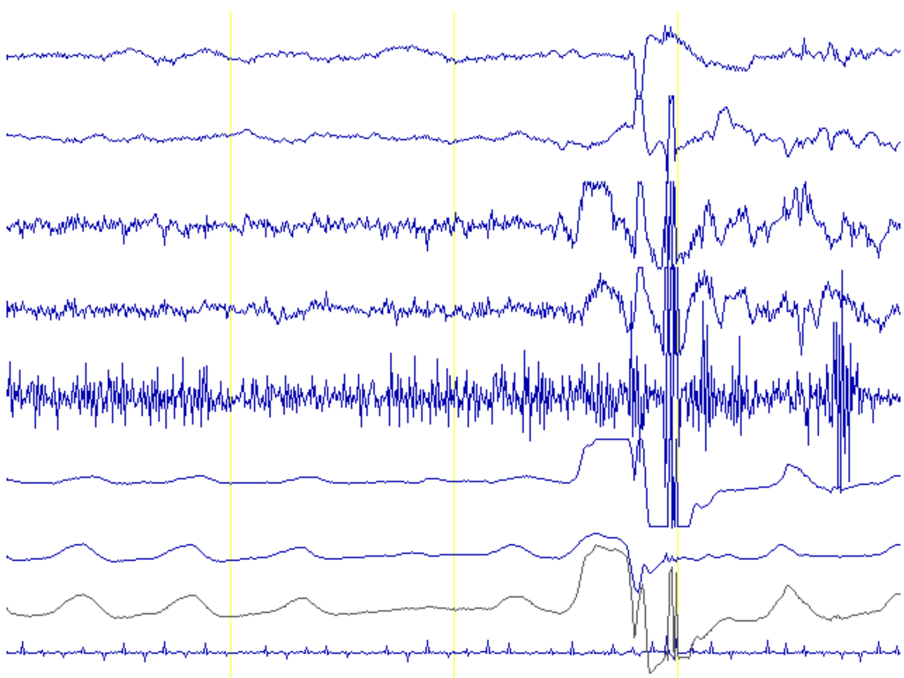
Electricity is formed in the body on an atomic level. Since the body is never at equilibrium for very long the atoms of the body are losing and gaining electrons and protons. In a cell there is a membrane which is surrounded by sodium ions, which have a positive charge, and chloride ions, which have a nega,.tive charge. When a cell is at rest, there are more chloride ions on the inside of the cell than sodium ions and more sodium ions on the outside than chloride ions. When an outside stimulant affects the body, this cell membrane opens causing chloride ions to be attracted to the negatively charged outside and sodium ions to be attracted to the positively charged inside of the cell. This swap of ions is a rapid switch in charge of the cell and when this happens to one cell it triggers the cell next to it to repeat the process. This happens between cells at an extremely fast rate that travels from the original stimulated nerve to the brain. The transfer of this charge occurs at speeds anywhere between 1 and 100 meters per second. The speed of this transfer differs between primitive and non-primitive life forms. Primitive organisms down very simple celled organisms have the slowest speeds. Non-primitive organisms contain a fatty substance called myelin that surrounds the axon which connects these cells. The current travels at rapid rates across the myelin sheaths and then at breaks in the myelin sheath there are myelin sheath gaps also known as "nodes of Ranvier." At these nodes of Ranvier chloride ions and sodium ions are in motion as at the cell membrane. Myelin conducts electricity poorly but it's these nodes of Ranvier that allow these currents of charge so rapidly. Following is a picture of a neuron and the connecting myelin sheath and axom:



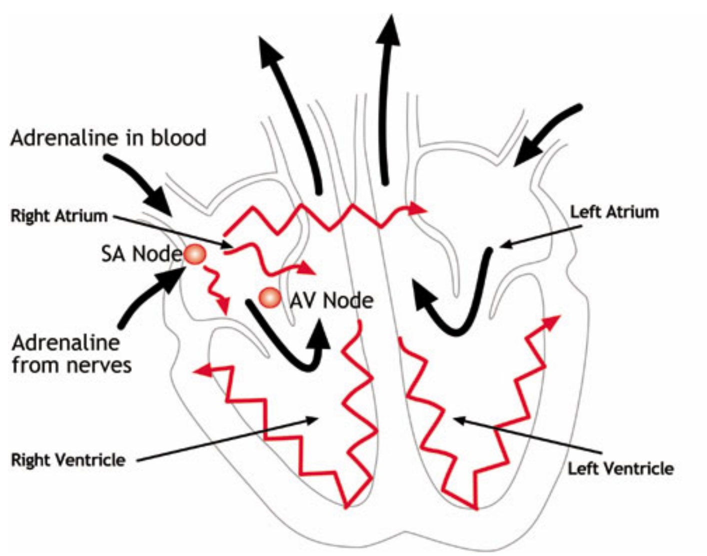
This change in the charge of the cells and all of the cells next to it continues all the way up to the brain where there is a bundle of 100 billion of these cells. All of these cells up to and including this point are nerve cells and all of these nerve cells are connected by an axon that transmits this charge along with other chemicals that are contained in the cells such as dopamine and epinephrine. These chemicals are released at areas called the synapse. The chemicals exit the neuron by the synapse which is basically a gap and triggers another neuron to pass along this message encoded in charge. The power of the electricity passing through the 100 billion cells and the axons that connect them is roughly equivalent to the power of a 60 Watt light bulb. Whatever has agitated these neurons in the first place has a significant "code" embedded in this traveling charge. Our brain recognizes this significant charge as something it has encountered before and so connects it with that memory. For example, if we smell something, we recognize it as being attributed to a something we have experienced and if we don't recognize it we build another memory that we will attribute that smell to later. So our brain recognizes these smells based on a memory or what it knows rather than the significance of the charge that it just received. These triggers of neurons begin in different ways depending on what the stimulant is. Neurons in the nose are triggered by chemicals interacting with naked neurons receptors to immediately start transferring charge through the brain. Meanwhile, neurons in the ear are triggered by vibrations in the air moving through different parts of the ear where, in the cochlea, it is changed into a charge that can be passed through nerve cells directly to the brain.

The way our bodies work is that the electric charge travels to the brain where it is interpreted and then our brains tell the different parts of our bodies what to do by sending an electric charge back to those parts of the bodies. This can be very interesting if we look at things that we do a lot that we don't even think about such as unconsciously tapping our foot. Our brain has become so used to sending electrical signals to these parts of our bodies that it does it on its own without any stimulation, or because of stimulations that seem extremely unrelated to the brain's response. This erratic and almost uncontrollable current of electricity is somewhat like a bad habit, and it requires us to consciously tell our brains to stop sending electrical signals to that part of the body. After a while of this behavior the brain will no longer automatically send electrical signals to that part of the body, it has essentially broken its habit. But that's not to say that it breaks it easily or that it won't continue to send electrical signals back to that part of the body once it has stopped being told to not send electricity there. All of this back and forth from the brain to the body has to occur at some specific area in the body, and that area is what has been designated as the nervous system. The nervous system is made up of all of the neurons that we were talking about strung together. All of the strings of neurons in the body below the neck meet up at the spinal cord which is a tube that travels through your spine which consists of all of these strands of neurons. The spinal cord is such a key part to the movement of electricity through our bodies that if it is severed, electricity has no way to reach the brain so the brain doesn't know what's going on in the rest of the body and can't send it electrical signals to tell it what to do. When this happens to the body it is known as paralysis. Paralysis, in its most serious circumstances, can leave a person with absolutely no movement below the neck, depending on where the fracture of the spinal cord occurs. The human body can rebuild itself granted the injury isn't too traumatic. The neurons that make up the spinal cord are able to repair themselves by reconnecting with the other neurons that they were severed from. This can only happen if the damage in spinal cord wasn't too destructive though and this process can take an extremely long time. But it's not unheard of for people who were paralyzed to regain full movement of their body. The brain just has to be reminded that it's supposed to translate the electrical information that it receives from these neurons and send a response back. Electricity travels back and forth through the spinal cord carrying messages to and from the brain, all the while each of the billions of individual neurons that make it up are going through the process earlier of releasing chloride ions and absorbing sodium ions. (Galambos 1962)

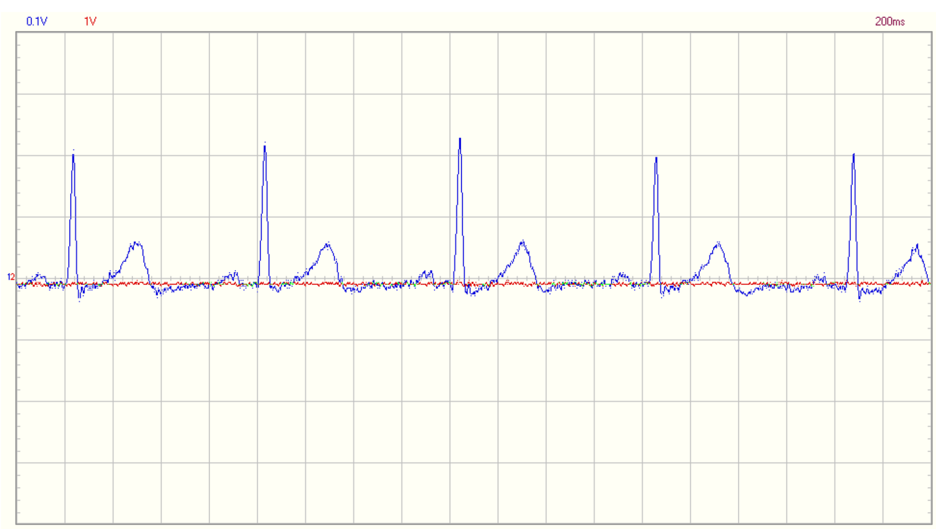
The neurons in the brain work more or less at certain areas of the brain. The more a certain part of the brain is stimulated the better it will work because the more "exercise" it has received. If a part of the brain does not get used much then it will not be as strong and the slower the electric charge will travel through the nerve cells and axons in that region. This difference in electrical energy in the brain allows for brain activity to be observed. The device that is used to observe brain activity is called an electroencephalograph or EEG. An EEG measures the amount of activity by what parts of the brain show the most electric activity after the body has been exposed to some sort of stimulant either physical or mental. This can be used to treat people who have personality disorders and help us understand how the brain works and develops in people with mental disabilities such as Down syndrome and autism. An EEG reading is shown below and the different lines represent different parts of the brain and how much electricity is present in them:



Another major location of electricity is centered in the heart. In the heart, electricity moves in a different way than in the brain or rest of the body. As far as electricity goes, the heart is independent from the rest of the body. The heart has its own cells that generate electricity called pacemaker cells. These pacemaker cells are located in the sinus node or SA node which is located in the right atrium which is in the upper half of the heart. The SA node causes electric impulses to be sent through the atria. From the atria, electric impulses can only be sent to the ventricles through the atrio-ventricular node or AV node. This electric impulse causes the atrium to contract which moves blood into the ventricles while the impulse is being distributed to the ventricles. When the electric impulse enters the ventricles it causes the ventricles to contract. Blood from the right ventricle is pumped to the lungs and blood from the left ventricle is pumped to the body. When adrenaline is pumped into the heart it enters at the right ventricle which causes the pacemaker cells to produce more electricity leading to more blood being pumped through the heart and into the lungs and body. It is very important that the electric pulse spreads throughout the heart and causes different parts of the heart to palpitate at different times. If all of the regions of the heart contracted at the same time there would be no pumping effect in the heart. This would result in blood not moving out of the heart constantly and life could not exist. So it is of the utmost importance that the pacemaker cells are located in a small SA node section of the heart. (Challice & Viragh 1973)



If the SA node tissue is scarred it can cause the heart rate to be abnormally low. Tissue scarring can result from chronic high blood pressure and from heart attacks and from aging in general. If scarring becomes a health issue an electronic pacemaker can be put into the heart that makes artificial electric impulses. Any disturbance in the heart's rhythm, which is due to fluctuations in the production of electrical impulses in the SA node, is called an arrhythmia. Bradycardia is when the heart beats slower than it's supposed to and tachycardia is when it beats faster than it should be. The electricity in the heart can be monitored by an electrocardiogram or ECG (also sometimes referred to as an EKG from the German elektrokardiogramm). An EKG is a recording of the electric waves that are generated during heart activity. The information gathered by an EKG can help doctors determine if a patient has a heart problem. The EKG displays the electricity moving through the heart during a couple of heart beats. The electricity isn't being generated constantly or else your heart would explode. This can be observed by a heartbeat because this somewhat shows that electricity is being generated at certain intervals. So the EKG reflects this by showing the electricity being greater at some points than others during a single heartbeat. An example of an EKG reading is below:

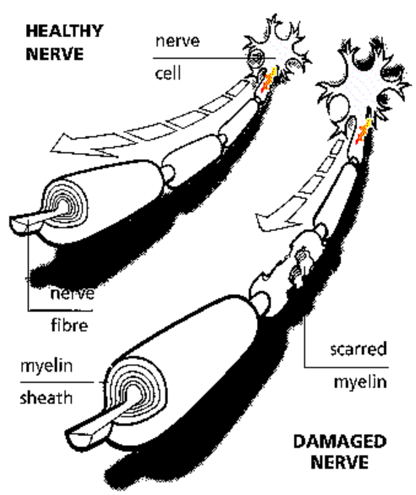


If a person has a smaller peak at the point of most electricity in the heart than is typical, then their SA node is possibly scratched and they may need a pacemaker. If a person's peak is higher than it should be then they may be getting too much adrenaline pumped into the heart, possibly as a result from stress or drug use.

Electrophysiology is a subspecialty of cardiology that focusses on cardiac arrhythmias. An electrophysiological study of a heart can provoke arrhythmic events and map electrical circuits of the inside of the heart. This can help diagnose whether the patient is in need of implantable device or cardiac ablation procedure or not. Almost all heart problems that are a result of electrical problems within the heart can be treated with either medicine, a device such as a pacemaker, or a relatively simple procedure. All of these treatments can be performed at the time of the electrophysiological study. A cardiac ablation procedure is used in instances of tachycardia to disrupt an abnormal circuit in the heart. The procedure involves a catheter with, usually, heat on one end. This is used to make tiny scars on small areas of tissue that contain the abnormal circuit or circuits. People who receive cardiac ablation are able to get back to their normal lives within 24 hours of their procedure. It's not always as easy as this though. Sometimes the arrhythmia is caused by some other heart disease or dysfunction in which case treating only the arrhythmia will be useless because the pacemaker cells will just malfunction again in the near future. Because of this, most electrophysiologists must collaborate with cardiologists in order to determine how the heart is functioning as a whole.

Neurons can work at different efficiencies and speeds. The speed that the neurons transport electric charge is dependent on how well our bodies are functioning and what we put into our bodies. The chloride and sodium ions are not in the neurons magically, they get there by us ingesting them. The cells take the amount of these ions that they need, which is a small amount relative to how much of these ions we consume, and the rest goes to other parts of the body that need them or the blood stream. We don't consume these ions in their ionic form of course, but they are in many of the salts that we ingest. This is only one example of why what we eat and drink is important, but the quantity of what we consume is also very important. If we consume too much of these salts, it can lead to an ionic imbalance which may lead to problems beyond those of electrical problems. The extra ions from the various salts we consume can be deposited in a couple of different places in the body. They may be deposited in the kidneys which, over time, become kidney stones, or they may be deposited around the bones and joints where the ions weaken the bones by having anions draw positively charged calcium ions away from the bone; this is called osteoporosis. When these ions are deposited around the joints over time they begin to stiffen the joints. Another problem is high blood pressure which leads back to the pacemaker cells. If someone has high blood pressure their heart has to work harder. This causes the pacemaker cells to have to work harder and if there isn't anything to allow them to work harder such as adrenaline then they simply can't produce the amount of electricity that they need to and this leads to strokes and heart disease.

There are many diseases that attack the neurons and what connects them (the myelin sheath and axon). Pelizaeus-Merzbacher disease or PMD is one of these. Patients who have been diagnosed with PMD have spots in the myelin sheath that are missing. This causes electricity to leak out of the myelin sheath and essentially become lost. This means that that information never gets to the brain and so the brain cannot respond. Patients with PMD have impaired motor abilities and intellectual function depending on how serious they have the disease. Another disease that attacks the myelin sheath is multiple sclerosis or MS. PMD and MS both involve gaps in the myelin sheath. The difference is that people with PMD are born with gaps in the myelin sheath while people with MS have their immune system attacking their myelin sheath. So patients with MS have their bodies attacking itself in such a way that the brain can't receive or convey messages. MS is more dangerous than PMD because PMD can be treated while MS gets progressively worse throughout the person's lifetime. Parkinson's disease is another degenerative disorder of the central nervous system. Parkinson's differs from the previous two examples in the way that it occurs within the brain. There are certain neurons in the brain whose job it is to produce dopamine along with convey electrical information. Parkinson's disease targets these dopamine-producing cells and kills them. Early stages of Parkinson's result in shaking and difficulty in moving the body. Cognitive and behavioral issues often arrive in later stages of Parkinson's. Parkinson's is most common in individuals over the age of fifty. For all of the these diseases there are not any known causes other than the possibility that the diseases have a genetic origin. Here is a picture of what PMD does to the myelin sheath:



We could not live without this flow of electricity running throughout our bodies at all times and if this electric current is, for any reason, disrupted, then we can tell very easily by a drastic change physically, mentally, or emotionally.

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