Neurobiology

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Lecture 1.9: Homunculus

Hi everyone, in the last video we looked at different parts of the cortex and the brain and what each part is doing. You may recall two particular parts the motor cortex and the somatosensory cortex. These were two strips in the cortex and in this video we are going to zoom into these two strips and see what different sub regions of these strips are doing and how they are related to different parts of the body. When we look at this mapping between the regions in the motor cortex or the somatosensory cortex and the body, a very interesting picture or very interesting mapping emerges and that is called the homunculus. We will also see how the homunculus was derived and what it tells us about the electrical activity in the brain. So we can look at this mapping from the somatosensory cortex to different parts of the body and this is what it looks like.

So just to recall this is the brain this is the front part of the brain. The somatosensory cortex is located in this strip in the parietal lobe and if we take a cross-section through the brain, a coronal section passing through the somatosensory cortex, then this is the image that we would get. This is one half of the image showing one side one hemisphere of the brain and here we can see that there is a mapping in different regions of the somatosensory cortex to different body parts. So for example this part here is getting the sensory information from the hip, from the trunk, from the neck, from the head, from shoulders, arms, wrist, hand, fingers and so on.

This is the touch information, the sense of touch that is coming into the somatosensory cortex and typically nearby areas in the body are nearby in the somatosensory cortex although it's not really like that. For instance the genitals are located close to the feet so there are some variations from how close body parts are in the body and how close they are in the somatosensory cortex but it broadly matches that. Now the interesting part here is how much area in the somatosensory cortex is devoted to a particular body part and we find that that the amount of area devoted in the somatosensory cortex is not directly proportional to the size of the body part rather it is proportional to how sensitive that body part is. For example the fingers which are very sensitive to touch which have a lot of touch receptors have relatively large area devoted to them as you can see here whereas the arm which is much bigger in size has a slightly lower or smaller area devoted to them. Similarly legs which are very big have relatively small area in the somatosensory cortex because legs are not very sensitive to touch.

Another body part that has a lot of real estate devoted in somatosensory cortex is a face and within the face particularly the lips have a lot of area devoted to them. Tongue also has a lot of area because tongue has a lot of touch receptors. So this is the mapping from the body parts to the somatosensory cortex and this mapping is called the somatosensory homunculus. Similarly we have a mapping from the motor cortex to different body parts. So motor cortex is located next to the somatosensory cortex just in front of it and this is part of the frontal lobe and if we again take a coronal section through the motor cortex and look at one half of it, it looks like this.

So similar to the somatosensory mapping now we have a motor cortex mapping to different body parts. Motor cortex is sending out motor neurons to control the muscles in different body parts and here the amount of area that is devoted to each body part reflects how much motor control we have in that body part. So again we have a lot of dexterity, a lot of fine movement in our fingers and it is not surprising that fingers have a lot of area devoted to them in the motor cortex whereas arms or the legs have relatively smaller area despite their large size in the body. Again face has a lot of muscles during making various facial expressions we are using these muscles so there is a lot of region devoted to them in the motor cortex for the muscles that are around the lips and the cheeks and so on. Tongue again has a lot of area because we are constantly moving the tongue while we are chewing or swallowing or speaking so there is a lot of fine movement in the tongue that is enabled by having a lot of real estate in the motor cortex.

Now on this picture I am showing you these funny statues these are from the Museum of Natural History in London. What they are showing is an artist's imagination of what we would have looked like if our body parts were of the same size or the body parts were proportional in size to the area that is devoted to them in the somatosensory cortex or in the motor cortex. And we will get this funny looking picture where our palms and particularly the fingers are very large or a face and particularly the lips are very large while the rest of the body is relatively small and similarly in the case of motor cortex. So this is our little sensory homunculus or the motor homunculus imagined as a person. Now let's try to understand how the homunculus was derived.

How did we get this mapping that we saw on the previous slides? This was actually made possible by the work of Wilder Penfield around 1950s. Wilder Penfield was a Canadian neurosurgeon so he was working with patients and before we discuss what experiments he did to make this mapping I want you to take a few moments to figure out what could he have done to find out this mapping between the different body parts and the somatosensory cortex or the motor cortex. Just take a moment to think about that. So Wilder Penfield was working with epilepsy patients and epilepsy is a very serious disorder in which the whole body gets epileptic seizures and that is because of overactivity in some part of the brain and there are some medicines that are used to treat epilepsy but if the problem becomes very severe then the last resort is to take out that part of the brain which is causing the epilepsy. So it is basically a surgical procedure in which a part of the brain is removed after opening the skull.

Now I mean you can imagine that this is a very drastic surgery and you don't want to remove an area that is still functional you only want to remove the defective part of the brain but how would the doctor know which part is causing the epilepsy. So what is done in this case is that the surgeon in this case would expose the brain like open the skull and expose the brain and then they would put an electrode and stimulate a small region in the brain and if that region in the brain is causing some symptoms of epilepsy so before epilepsy there is feeling called pre-epileptic aura if the person who is actually awake in this case while this is happening if the person reports that they are feeling this aura while a particular part is being stimulated then the doctor would know that that part is the defective part and then they would remove that part. You might be wondering how is the person awake while they are undergoing this kind of drastic surgery. Even though the brain is responsible for sensing pain throughout the body the brain itself does not have any pain receptors inside it so once you do the initial opening of the skull that of course would be painful and that has to be done under anesthesia but once the person recovers from that after that you if you poke electrodes in the brain or if you make any cut in the brain that won't cause much pain because the brain itself does not have any brain receptors inside. So while Penfield was trying to figure out which parts of the brain are defective and for that he was stimulating different regions in the brain he noticed that on stimulating certain areas if subjects reported that they felt sensation or they felt touch in a particular part of the body and in some other areas when he stimulated he the patients reported slight movements in those parts of the body so that allowed him to create this mapping between different parts of the brain and different parts of the body and that's how we got the somatosensory homunculus and the motor homunculus.

So Penfield's experiment tell us about the role of electricity in the brain and we can actually directly measure this electrical activity using different techniques that we have seen before for instance using EEG electroencephalography as shown here we can place these electrodes on the scalp and this allows us to measure the electrical activity that is reaching the scalp at different parts of the skull. Because this is electrical measurement we get very good temporal resolution but the spatial resolution in this case is somewhat lower because as this electricity is passing through the skull it gets diffused and each electrode gets signal basically from relatively large area within the brain. When we look at this electrical activity we can find different patterns of activity these patterns can depend on the state of the person for example five traces are shown here these are recordings from EEG from one of the electrodes and if the person is excited the activity may look like this if the person is relaxed there may be some oscillations like this in the alpha band of frequencies and if the person is drowsy the activity may be like this during sleep like this and during deep sleep perhaps like this. So these are different patterns of activity at a broader level that tell us about the state of the person. An interesting fact is that even the determination of whether a person is alive or dead is now done based on the presence or absence of brain's electrical activity.

So if you have an unconscious subject who is on ventilator who cannot speak and we have to know whether the person is alive or dead we would basically see whether their brain is showing any electrical activity or not. So in this part of the course we have understood the different patterns of components of the brain and now in the coming parts of the course we will try to understand how this electrical activity is generated in the brain and how this leads to various abilities of the brain.