Parts of the brain - the cortex

The brain has different parts, different areas made up of different types of neurons arranged in different structures. This might not be so obvious looking at stardard pictures of the brain, like the one in Fig. 1, you are mostly looking at the cortex, which forms the outer surface of the mammalian brain. Even the cortex, however, has different areas, as we will discuss in this section.

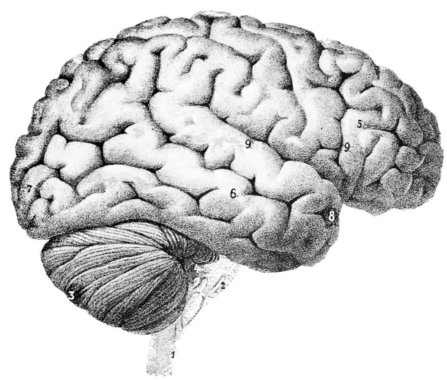

Figure 1: **A picture of the brain**; when we look at a human brain we mostly see cortex, though in this case we can also see the cerebellum, labelled 3. Figure from `wikipedia`

The different parts of the brain have different functions, but we don't think any of these functions is 'thinking'; that is the function of the whole brain, the product of the cooperative action of all the diverse brain regions. Here we will have a quick tour of different brain parts, their structure and their function; some of these regions we will revisit in more detail, others not, but the main point here is to give a feeling for the variety across regions of the brain and the types of specialization they exhibit, in their function and in how they perform it. This account will be somewhat mammal, or even human, focussed.

The cortex

The cortex, or more specifically the *cerebral cortex* forms the outer layer of the mammalian brain. In the human brain it contains 14-15 billion neurons and the extent of the cortex is one of the distinctive feature of the human brain, Fig. 2.

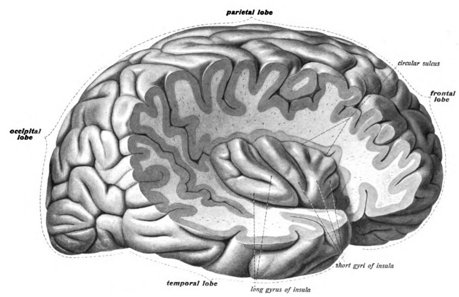

Figure 2: **The cortex**; the cortex, in grey in this picture, is an outer layer; in primate brains, and particularily in human brains, the cortex has become very folded in an effort to fit more in, space is short because we need a lot of cortex to be smart, and our heads are smallish because of contraints on human anatomy related to standing upright limit the size of head that a baby can have at birth. The grooves are called sulci, the ridges are gyri. Figure from `wikipedia`

The cortex is thin, two to five milimetres thick in humans and arranged in layers. Most of the cortex has six layers, Fig. 3, distinguished by different types of neurons and different connectivity patterns. Connectivity isn't homogenous either, across the surface of the cortex it is divided into columns, with cells inside a given column having many of the connections within the column.

Broca's area

Broca's area is perhaps not the obvious place to start when discussing brain regions, it is an area of the cortex responsible for some aspects of speech. However, it does make sense to discuss it because of its historical status in the history of our understanding of how different part of the brain are specialized to different functions.

Alot of our early understanding of the brain came from studying patients with brain lesions; modern neuroscience often seems very focussed on animal studies and this has allowed us to make progress in understanding the brain

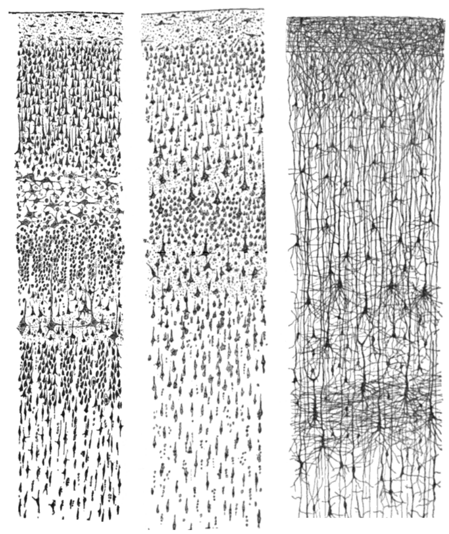

Figure 3: **Layers of the cortex**; in these illustrations by Cajal we see different cortical layers, the middle and left how soma and the right the dendrites; when Cajal did his drawing he would stain the cells to make some visible, only a random subset take up the stain, otherwise they couldn't be easily distinguished by microscope and different staining chemicals showed different parts of the neuron. The left is visual cortex, the middle is motor cortex. The middle panel shows motor cortex and the Figure from `wikipedia`

in a precis way, but information from patients still helps guide our subject by linking brain function to our experiences and abilities.

Louis Victor Leborgne was a patient of the nineteenth century neurologist Pierre Paul Broca; he is usually known by the name 'Tan' because at 30 that was the only word he could say. Interestingly, Leborgne could understand language and could express understanding and emotion with the intonation of how he said 'Tan', that was the only word he could produce.

There are two well-known fictional characters based on Leborgne, Garp, from John Irving's novel of the same name, who differs from Leborgne in his ability to understand speech and Hodor from *The Game of Thrones*, particularly in the HBO TV series; although Hodor's limited speech was ultimately attributed to nonsense magical events, he shows precisely the behaviour described above, he could understand speech and express emotion though intonation, but could not say any word but 'Hodor'.

Sadly Leborgne died, in 1861, soon after he was visited by Broca; an autopsy reveals that he had a very specific lesion in his brain caused by syphilis; a picture is shown in Fig. 4. This lead Broca to suggest that this area was responsible for the production of speech and that lesions to this part of the brain cause *expressive aphasia*, aphasia means a problem with speech and in expressive aphasia the problem is with the production of speech. This was confirmed by subsequent patient, including another studied by Broca, Lelong, who only had five words. Another part of the brain, Wernicke's area, was soon identified with *fluent aphasia*, an inability to understand speech while retaining access to words. A patient with fluent aphasia can have a large vocabulary but produces what is called 'word salad', lots of words included many which are not related to the subject of speech.

These days, this neat division of the speech areas into Broca's area and Wernicke's area, and aphasia into expressive and fluent aphasia, is considered to binary; the function of these areas in language and their ability to respond to insult is complex. Nonetheless it is amazing to think that the linguistic ability, which we experience as a unitary ability, can be subdivided into different abilities and these abilities are localized in different areas. The neurologist Alexander Luria even discovered that his patient Lev Alexandrovich Zasetsky who received a severe brain injury in the second world war, had problems with nouns to a far greater extent than he had problems with verbs.

Figure 4: **A picture of Broca's brain**; the lesion is clearly visible. Figure from `cambridge.org`

The motor and somatosensory cortices

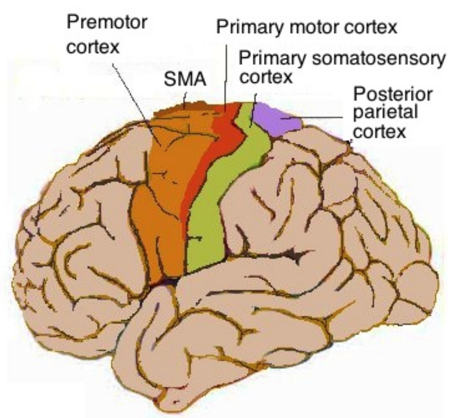

Figure 5: **The motor and somatosensory cortices**; the primary motor cortex is in red, the primary somatosensory cortex in green. Figure from `wikipedia`

Sticking to the cortex, in the first half of the C20 the neurosurgeon Wilder Penfield pioneered a technique in neurosurgery, still important today, of waking the patient up during the surgery and stimulating parts of the brain: because the brain itself has no sensory nerve endings this is painless, though it must be alarming. This allowed him to work out which parts of the brain could be operated on, or removed, while causing the least damage to crucial abilities. As a consequence to this he discovered and mapped out the motor and somatosensory cortices, Fig. 5. Touching parts of the motor cortex cause movement in the patient, touching parts of the somatosensory cortex cause fictive sensations. Different parts of each correspond to different parts of the body, see Fig. 7 and the amount of space dedicated to each part is proportional to how useful the information is, rather than how big the part is, as illustrated in Fig. **??**.

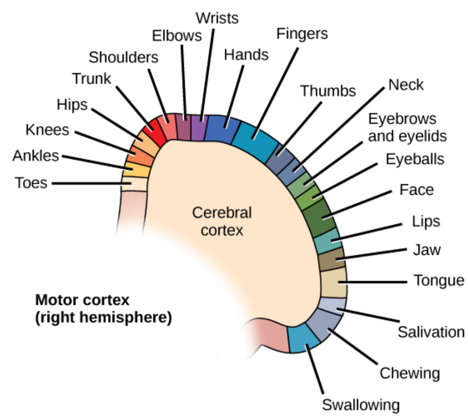

Figure 6: **The motor cortex**; the map from cortex to parts of the body for the motor cortex, a similar map exists for the sensory cortex. Figure from `wikipedia`

This specialization of the sensory cortex is not restricted to the somatosensory cortex, there are also parts of the cortex dedicated to vision and hearing; the story with smell and taste is more complicated. These are all primary sensory regions, they do initial processing on the sensory information, but further processing, further along the pathway, often includes the mixing of different pathways. It is easy to see this happens by thinking how much easier it is to hear what someone is saying if you can also see their lips, something we have all become familiar with during the pandemic.

The cortex and memory

The gradual realization that different parts of the cortex had different functions lead scientists to assume that memory, particularly long-term memory had a location in the cortex. This lead to a series of studies by Karl Lashley

Figure 7: **The sensory homunculus**; this shows parts of the body proportional to how large an area is given over to it in the sensory cortex. I can't remember where I got this figure from and so I can't attest to its accuracy, you see other versions with smaller genitals, but that may be a bowlderisation, there is no corresponding female figure either, possibly for the same reason, or possibly because female neuroanatomy is less well studied, a problem common in neurology, neuroscience and psychology. This is discussed in this context in [**?**].

who taught maze tasks to rats and then lesioned parts of their cortex, see for example [**?**]. He discovered that cortical lesions did affect rat performance in the maze, but that there was no clear relationship between where the lesion was and the consequence for memory, leading him to suppose that memories were randomly deposited across the cortex. We know now that accounts of cortical memory are not so straight-forward, there are areas of the cortex linked to certain types of memory and areas of the cortex more likely to store memories than others, but it does indicate that there is no easy way to describe the localisation of cortical function.

Summary

The cortex is the outer layer of the brain, although it looks homogenous at first glance different areas have different functions. Based on a patient mostly known as Tan, Broca discovered an area of the brain associated with speech, damage to this area causes expressive aphasia. Conversely, damage to Wernicke's area caused fluent aphasia, a lack of meaning rather than a lack of words. The motor control and somatosensory perception of different parts of the body is also linked to distinct brain areas, one for moving your left pinkie, another for processing feelings from it, for example. In fact there are cortical areas for primary processing related to hearing and vision as well, but the localization of memory is less clearcut.