Bumps or holes: the seat of the soul
A leaf from the history of neuroanatomy

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The mind-body problem

Neuroanatomy has a long and complex history. One could discuss the deep divide between the dualists, who believed, and some still do, that there is mind on the one hand, and matter on the other, and the monists who ascribe the former to activity of the latter. In the sixth century BCE Pythagoras, and later Plato (428-348 BCE) and his student Aristotle (384-322 BCE), advocated the distinction of the physical body from a soul, or spirit or mind, responsible for intelligence. However Plato did have a concept of the rational part of the soul being in the head, a nice round object close to heaven and therefore logically spiritual. This shows how difficult it was, and still is, to distinguish the mortal and divine parts of ourselves.

Perhaps the classic epitome of this view is provided by René Descartes (1596-1650 CE). Although he distinguished between body and mind, which corresponded to consciousness, he did, Platonically, admit that intelligence was related to the brain. He described the pineal as the control centre of both body and mind, so perhaps he was teetering on the brink of monism! More up to date was John Eccles (1903-1997) who, in spite of his ground-breaking Nobel prize-winning basic electrophysiology, maintained to the end that the brain was one thing, the soul another.

In contrast is the monist view, now essentially a materialist monism, that within the body is the whole of oneself, whether this be termed soul, spirit or mind. It is the approach of most modern scientists, including us neuroscientists, but can be traced back to Democritus (ca 460-360 BCE) and Epicurus (342-270 BCE). Nowadays we think of more recent exponents of what we may call materialism, such as Charles Darwin (1809-1882), Thomas Henry Huxley (1825-1895) and, right up to date, Richard Dawkins (born 1941 and still annoying some people and satisfying others with his scholarly and unambiguous writings).

The seat of the soul

But if we accept a monist approach to the mind-body problem, we have to decide where the mind is. I bet that every reader of *Anastomosis* would put it somewhere in the brain. But as Shakespeare said in *The Merchant of Venice*: “where is fancy bred, or in the heart, or in the head?” For the Sumerians and Assyrians it was in the liver, but the idea of the feelings, the emotions, being related to the heart is longstanding. Ancient Egyptians described the heart sending channels throughout the body, including blood vessels and nerves. Their embalming rituals involved more care being given to preserving the heart for the afterlife than the brain, which they simply sucked out through the nose. Later, Aristotle still believed the heart was the seat of the mind, although his mentor, Plato, had placed part of that role with the brain. Aristotle’s argument was that there was no blood in the brain, so it could not contain the mind, although it was important as a cooler of the blood. We still even talk of heartache and a host of other relations between emotion and the heart. Maybe our conscious awareness of the effects of the sympathetic nervous system on cardiac function when faced with situations from aggressiveness to fear, from fight to flight, will ensure that the heart retains a central focus for our emotions, and why hearts figure on millions of Valentine’s cards each year, and carved on trees by young lovers!

Where is the brain in all this?

But we are dealing with the history of neuroanatomy, so how did the brain get involved in all this? And what part of the brain? Indeed when did we start thinking about the brain as an organ? In 1862 archaeologist Edwin Smith bought a papyrus in Luxor in Egypt, which was finally translated by James Breasted in 1930. It turned out to be what we still accept as the first real bit of medical documentation, including surgical practice and wound care. In some of the cases described are references to “Brain". The papyrus was written around 1700 BCE, perhaps based on more ancient texts by Imhotep, the physician founder of Egyptian medicine, and also the architect of the Sakkara step pyramid south of Cairo, built around 2600 BCE. The author described a number of surgical cases. Case 6 was “a gaping wound in the head, fracture of the skull and opening of the meninges”. He described the convolutions of the brain as being like corrugations on molten copper. Case 6 was "an ailment not to be treated."

Hippocrates (about 460-370 BCE) and members of his Greek school observed clinical cases like the Egyptians hundreds of years earlier. They changed the concept of physical and mental control of the body from being by the heart to it being firmly in the brain. They concluded, for instance, that epilepsy was a disturbance of the brain, that brain damage led to seizures on the contralateral side of the body, and could even cause aphasia. Further, the brain was involved with sensation and was the seat of intelligence. As mentioned above, although proclaiming dualism Plato also accepted the brain as the seat of the rational mind.

The holes in the middle

Herophilus (335-280 BCE), the "Father of Anatomy", continued the trend for the seat of human intelligence to be in the brain rather than the heart, but in the cerebral ventricles, in fact in the fourth ventricle, close

to where so many cranial nerves depart. Incidentally he showed that it was important to differentiate the cerebrum from the cerebellum and suggested that each had a different role. He also dissected eyes and gave detailed descriptions of their laminar structure and sensory and motor innervation.

Erasistratus (304-250 BCE) moved away from the ventricular theory when he claimed that the more convolutions on the cerebellum, the better an animal's motor skills, and that the most intelligent animals, such as man, had lots of cerebral convolutions too. Galen (130-200 CE) disagreed: donkeys had very convoluted brains, but were stupid. He made major discoveries about brain anatomy, but was less hot on the physiological side. He did however prove Aristotle wrong about the brain being a mere blood cooler, for he discovered that the brain was warm, not cold. It was perhaps the organ controlling sensation and even cognition. However, the important structures were the ventricles. He discussed at length the "pneuma" formed in the ventricles which then circulated to the brain substance and coursed through the nerves to the eyes and elsewhere. Such was the power of Galen's philosophy that there followed over a thousand years when it dominated neurological thinking. For example, Nemesius, Bishop of Emesa in Syria around 400 CE, went so far as to attribute specific functions to each of the cerebral ventricles, with perception at the front (lateral ventricles) to cognition in the middle (third ventricle) and memory at the back (fourth ventricle).

We know of the interest of Persian philosopher-physicians in anatomy, and particularly neuroanatomy, a subject which Shoja and Tubbs recently (2007) described in detail in the Journal of Anatomy. Of relevance to our discussion, Abū Bakr Muhammad ibn Zakarīya al-Rāzi (Rhazes; 865-925 CE) disagreed with Galen that neurological disease could be ascribed to ventricular pathology, and emphasised the role of the hemispheres themselves, whereas Abū 'Alī al-Ḥusayn ibn 'Abd Allāh ibn Sīnā (Avicenna**;** 980-1037 CE) supported Galen's ventricular doctrine. There was little original progress at this time though. Much later, in the sixteenth century, we still find more or less plagiarised versions of the ventricular story in contemporary woodcuts or engravings, such as those by Gregor Reisch in 1504 in which he labelled the anterior ventricle *Sensus communis, Imaginativa* and *Fantasia*, the middle ventricle *Cogitativa* and *Estimatia*, and the posterior *Memorativa* (Fig. 1). Others followed even later (Figs. 2, 3) such as those by Hieronymus Brunschwig (1450-1512), and especially Robert Fludd (1574-1637) in which the middle ventricle was related to *Mundus Intellectualis* with *DEUS* surrounded by a star-shaped pattern, an eminently dualist approach.

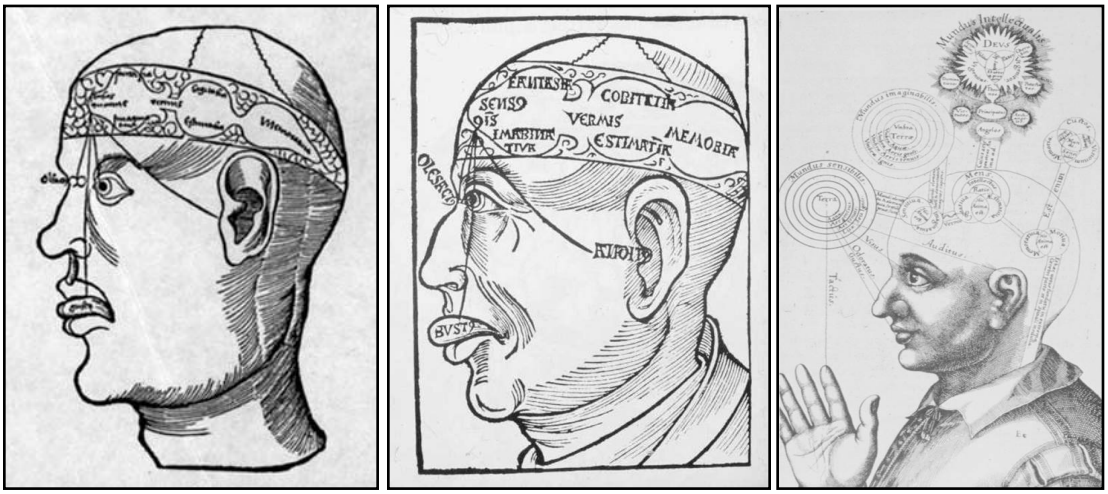


Fig. 1 Drawing of the cerebral ventricles and their functions by Reisch, 1504; Fig. 2 Brunschwig's very similar interpretation of the ventricles; Fig. 3 Fludd took the interpretation of the ventricles and the soul to its ultimate extreme

In 1490 Leonardo da Vinci drew inaccurate sketches of Galenic ventricles, but some 15 years later produced wax casts of ox ventricles and transposed them to drawings of a human brain (Fig. 4). He produced much more accurate three-dimensional views of the ventricles than the simplistic ones of previous authors, but did not take the plunge to deny that they were part of cognitive function, as had been accepted since Galen.

From holes to bumps

Andreas Vesalius (1514-1564) became a keen anatomist even as a medical student in Paris. He admired Galen, but his own dissections of human bodies from churchyards and gallows made him realise than Galen had been a fine anatomist, but of non-human animals. In 1543 he published *De corporis humani fabrica*, one of the finest anatomy books ever realised. He tackled the problem of the ventricles and the mind by dissecting them carefully in various species (Fig. 5). Human ventricles were not that different from non-human ones, but did animals have souls? This anti-Galen stance after 1300 years shocked the world. No less than Jacobus Sylvius, Versalius' teacher in Paris, and he of "fissure" fame, called him in 1549 "a certain ridiculous madman,

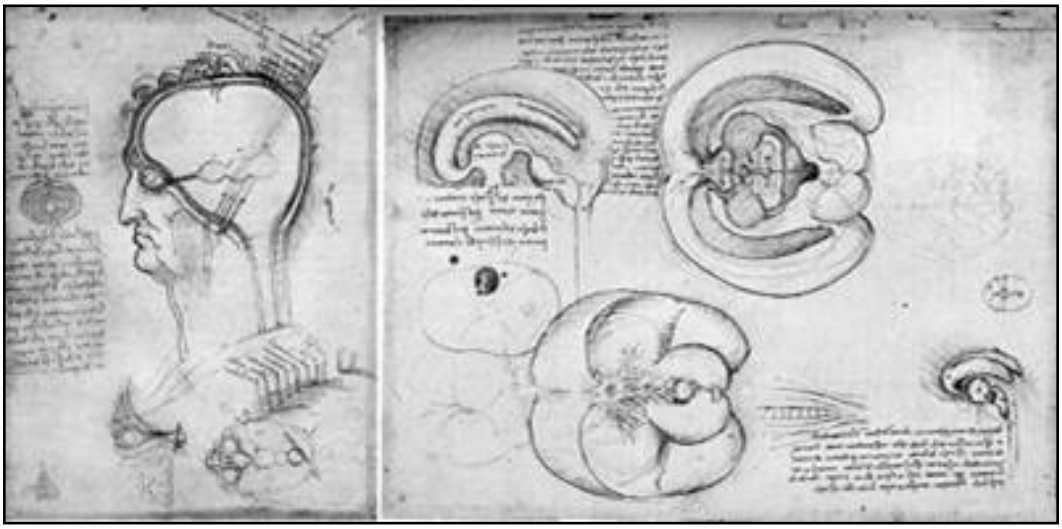


Fig. 4 Leonardo da Vinci began with a rather Reischian view of the ventricles (left panel) but after dissecting an ox he obtained a better anatomical feel for them by using wax casts (right panel). However he did not renounce his attachment to the 1300 year old views of Galen.

one utterly lacking in talent who curses and inveighs impiously against his teachers". So much for someone wanting to rock the boat. For René Descartes (1596-1650), remembered for *Cogito ergo sum* and Cartesian dualism, the body was a machine. The soul was something other. He thought of animal spirits flowing from heart to brain and then into nerves.

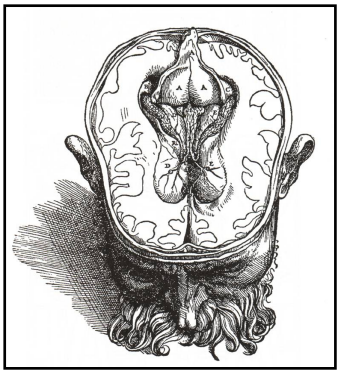
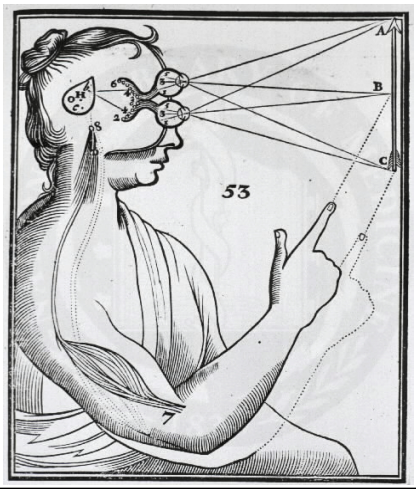


Fig. 5 The real anatomy had to wait until Vesalius

But he did attempt to bring body and mind together where it seemed likely: in the brain and in the midline, so he chose the pineal for this function (Fig. 6). Interestingly, Descartes described a pain reflex (Fig. 7). Put your foot in a fire: the flame burns the skin, which pulls a string, which opens a pore in a ventricle letting "animal spirit" flow through a hollow tube to a leg muscle, and the foot withdraws. Although the physiology differs somewhat, he was describing reflex arcs that were to be so important for the modern dualist Eccles.



So what happened to consolidate the place of the brain substance rather than the ventricles in body, and mind, control? An important figure, although somewhat ridiculed now, was Franz Josef Gall (1758-1828) the father of phrenology. He began with the idea that traits of personality could be related to physiognomic features visible on the outside of the head, such as protruding eyes or even bumps palpable on the scalp. So phrenology was born, preaching that personal mental characteristics were reflected in the outer shape of the skull, but at least this had the merit of suggesting that the underlying

brain had specialised regions for special functions. However, it is difficult to see how the brain could influence the outside shape of the skull. Furthermore, Gall did not relate the skull phrenologically to simple functions such as vision, audition or motricity, but to things like love, benevolence, aggressiveness, self-esteem, and even respect for God (Fig. 8). Interestingly, the Church took exception to what they saw as monism: how could the mind be in the head? Even Napoleon objected. We may smile at phrenology today, although the electric phrenometer (Fig. 9) existed into the twentieth century to try to modernise the "science"of phrenology, and there are records of a British Phrenological Society in 1967. LN Fowler and Co produced the famous china phrenological heads that you can still find, expensively, in antique shops and cheaply as fakes. Phrenology is not completely dead, as you can find caveats on the Internet that the "serious student" must get a genuine Fowler head, as there are faculties "in the wrong places" in the fake ones! In the end the idea of the brain substance being divided into functional organs is still what most of us believe. In the nineteenth century the idea of cerebral localisation grew. Luigi Rolando (1773-1831) published drawings of the cortical surface labelled with numbers. They referred to phrenological activity, but at least he was dealing directly with the brain substance, and neither bumps nor holes.

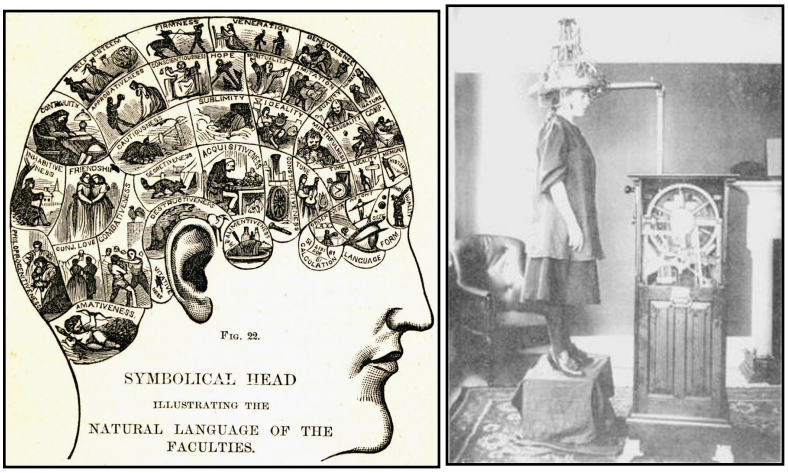


Fig. 8 A late nineteenth century version of phrenology by Lorenzo Fowler (1811-1896) of New York. There are some interesting activities ascribed to parts of the brain as reflected in bumps on the skull. For instance, not only love, but conjugal love. It is amazing that "alimentiveness" should be so close to the hypothalamus, but that language should be next to the eyeball. The fact that there is a centre for "weight" may give those who have a problem therein some comfort; Fig. 9 The electrical phrenometer of 1907

Getting into the brain itself

Paul Broca (1824-1880) was one of the people to have the most lasting influence on cortical localisation with his famous patient "Tan", who suffered from right hemiplegia and aphasia. At Tan's autopsy Broca described a lesion in a specific part of the left frontal lobe (Fig. 10). He collected a number of other similar cases, enough to convince his contemporaries, and us, that there is a "Broca's area" in the frontal cortex, usually on the left, which is related to speech.

A hundred years ago, in 1909, the German neuropathologist Korbinian Brodmann (1868-1918) published his famous monograph on localisation in the cerebral cortex (Figs. 11, 12). Using sections stained with the new method of Nissl, he proposed about 50 different numbered areas in the human brain with clearly differentiated histological features and related to different functions, but basic functions like vision, somatosensation and motricity, unlike Gall's more philosophical organs. He had worked with Oskar Vogt (1870-1959), who was interested in the fibre architecture of the cortex (Fig. 13), and met Alois Alzheimer (1864-1915) who inspired an interest in neuroanatomical problems.Brodmann refined and

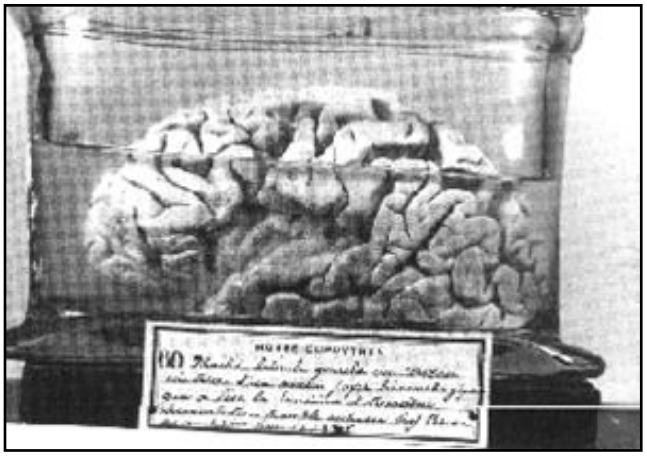
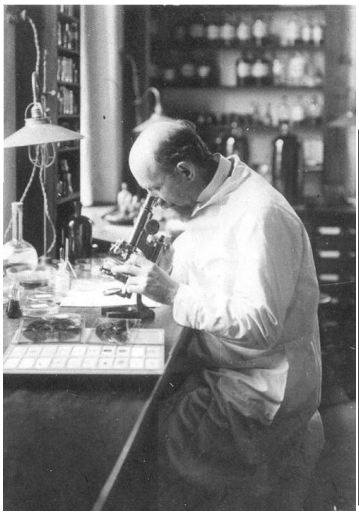
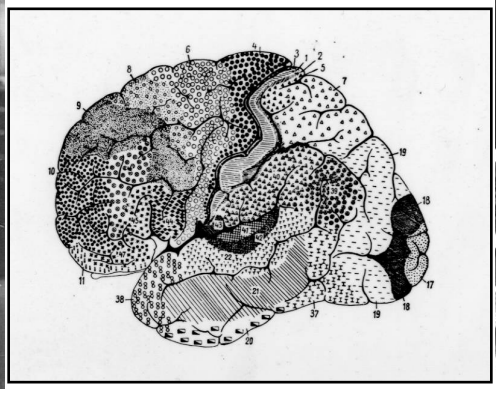


Fig. 10 Tan's brain showing the frontal lesion

extended previous observations on cortex, integrating ideas on phylogenetic and ontogenetic influences with his own theories of adult cortical structure, function and even pathology. Brodmann's major results on cortical maps of many mammalian species, including man, were published between 1903 and 1908 and compiled in his 1909 monograph. To this day his

maps form a basis for localisation of function in the cerebral cortex, and his numbered areas are still widely used. His maps of the cerebral cortex must be among the most commonly reproduced figures in neurobiological publishing. Brodmann was not the first to produce cortical maps. Joseph Bolton described histological localisation of the visual area of the human cerebral cortex in 1900, and Santiago Ramón y Cajal published studies on human cortex between 1900 and 1906. Alfred Campbell also produced histological studies on the localisation of cerebral function in 1905. But Brodmann's areas have stood the test of time, although there have been various attempts to produce different schemes, such as that of Constantin von Economo and Georg Koskinas in 1925.





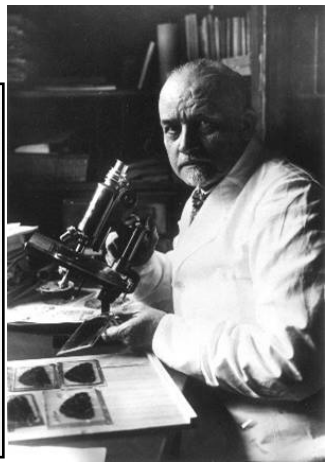


Fig. 11 Brodmann with a pile of human brain sections; Fig. 12 A lateral view of the human brain according to Brodmann with the numbers from his 1909 monograph; Fig. 13 Vogt with similar sections, but stained for fibres we must assume

Where do we stand today?

There is almost no limit to the overwhelming evidence that the mind and the brain are coexistent, whether it be from the studies by Alzheimer that senile dementia is related to abnormal structures, plaques and tangles, in the cerebral cortex or the observations of Wilder Penfield (1891-1976) who directly stimulated the human cerebral cortex during surgery for epilepsy and localised various activities, notably memory.

Which maps we choose to use, and how much we attribute a function to an area of cortex, there is no going back to the idea of higher cerebral function being outside the brain, or in any other organ, not even in the ventricles. The bumps have it over the holes. However, as we progress in trying to correlate structure with function, we see that it is not as easy as saying "the visual cortex is for seeing". Over the years we have discovered visual function well outside the primary, and even secondary, visual cortices of the twentieth century. One may think of the work of David Hubel and Torsten Wiesel, Semir Zeki, David Van Essen, and Jon Kaas, among others. And that is true of most functions that have been investigated. Cortical areas cooperate for functional purposes and what would the cortex be without the cerebrospinal fluid from the ventricles? Or indeed what would the brain be without the heart or the liver? As technology allows us to observe the human brain working in different functional scenarios, first with PET scan, then via SPECT to functional MRI, we begin to see that there is certainly division of labour, but that the key word is collaboration, between cortical areas, between cortex and subcortical centres, and between the brain and rest of the body.

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