Neuroeverything?

Colin Blakemore spoke about neuroscience and its growing capacity to locate specific functions in the brain.

Location in the Brain – the Beginnings

The notion of trying to locate in our heads the origins of the most noble aspects of human behaviour is not a new one. You're all familiar with this kind of picture (fig.1); this a phrenological map of the human brain, based on a very serious suggestion by a Viennese physician and anatomist, Franz Joseph Gall at the end of the 18th Century that functions must be localised in the brain. It was a fallacy that the size of the bumps on your head correlate with the size of underlying brain structure; they do so very poorly and only in certain parts of the skull. For instance, the front of our head's shape is largely determined by air-filled spaces underneath the skull and has very little to do with the shape of the brain below. The worst aspect of this sort of approach was the absence of any notion of statistics. So Gall often based claims on two, or even one, observation. For instance, for the area which he called the organ of amitiveness – nothing to do with brain, by the way, it's just an enlarged bit of skull – he discovered during a soirée while interviewing a particularly engaging young lady.

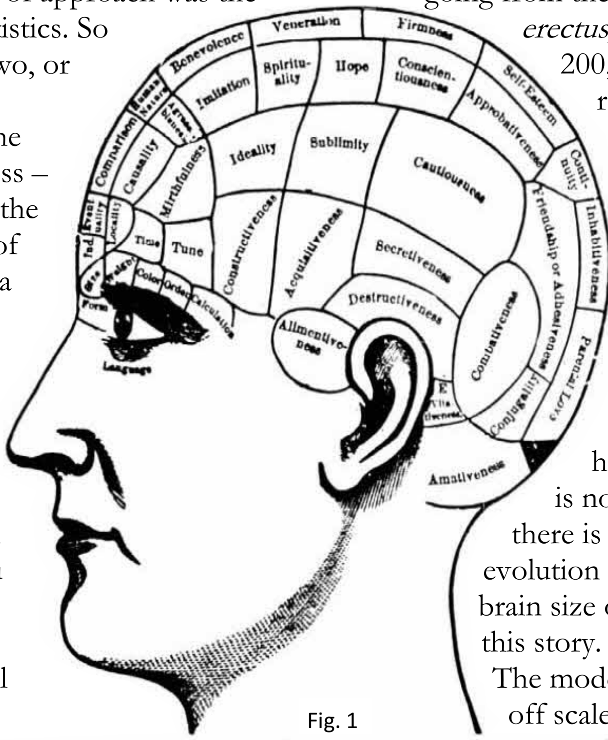

Fig. 1

Nowadays the sorts of things that people would ask if they were looking for localisation of brain function would be: 'How well can you see? Can you hear? Can you distinguish different accents that are spoken? Can you feel this touch on your skin?' There is just a creep back towards thinking that things like hope and spirituality and so on might be interesting things to look at in terms of brain localisation, because localisation is a kind of key to functional organisation. Hence the interest in, for instance, the god-spot. For is it really fundamentally different to say that there is a bump on your head that corresponds to spirituality and to say there's a red little blob in a MRI scan that turns on when someone is praying, let's say, which might correspond to the localisation of a kind of prayer centre? So we're creeping back towards this kind of approach which hasn't been fashionable for a long time. In the American version of this, by the way, there is an area for Republicanism.

Relative Brain Size

On facing page 9 there is a graph showing the relative brain size – corrected for body size: the encephalisation quotient –- for a whole lot of primates (fig.2). There are South American monkeys, African and Asian monkeys, apes, gorillas, chimpanzees and so on and then hominids, different species of early human beings, going from the very earliest through to *erectus,* which survived until about 200,000 years ago. They are ranked side by side in terms of relative brain size, so the smallest one is an Old World monkey of some sort, then we've got an ape – actually it's a gorilla. Gorillas have a relatively small brain, the absolute brain size is large but gorillas are very big and heavy so relatively their brain is not that big. But you can see there is a general trend through evolution towards a gradual increase in brain size over the 20 million years of this story. The interesting thing is this. The modern human, *homo sapiens,* is off scale compared with the others.

The total number of nerve cells in the human brain is estimated, very accurately now by literally counting them all, as twice the number of any other brain. Some species have much bigger brains. Elephants and whales have much larger brains than human beings, but the cells are bigger and are more widely spaced, so human beings have twice as many cells as any other species. Four times as many as chimpanzees, for instance. So it really is an extraordinary thing that happened in the transition between *homo erectus* and modern man. That transition took place about 200–250 thousand years ago. There are no intermediate examples in the fossil record.

You might say it's hard to understand how such an enormous change can have occurred; it would be like going from a reptile to a bird in a single individual. It's not how we normally see evolution. But in genetic terms it would have been very easy to achieve. You can make mutations in mice that can double or quadruple the size of their brain in a single generation, because the size of anything in your body is just determined by how many cells you make during development and that's simply determined by how many times the stem cells that produce you go on dividing. So the stem cells that are going to make your brain have to know – which is a real mystery – when to stop dividing to make a brain of just the right size, whether you're a mouse or a human being. The total duration of generating cells is much longer in human beings than in animals with small brains and we don't know how that's regulated, but it could be by a single gene.

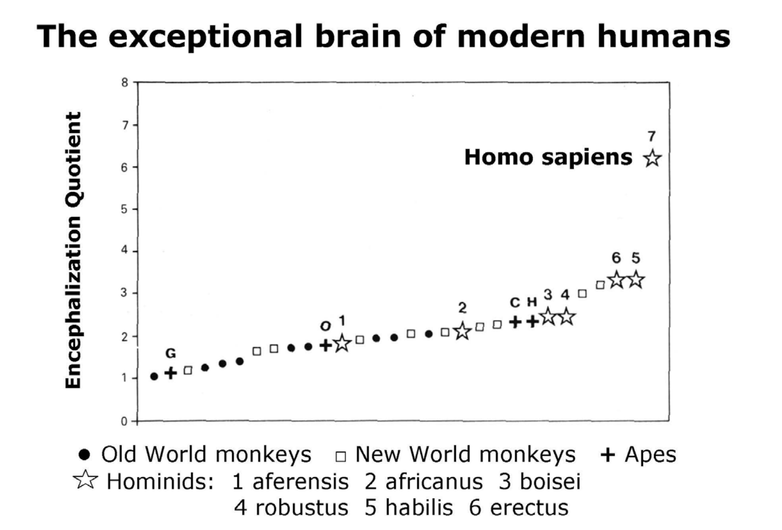

Fig. 2 Martin, RD (1984) Body size, brain size and feeding strategies

The Big Human Brain

Now, those who are interested in the special nature of human beings and its potential mystical origins will be having their 'Ah-ha!' moment at seeing this and saying there must have been some sort of intervention, divine intervention, in the evolutionary process at this point, which generated such a unusual creature. A Darwinian would look for other explanations in terms of the selective advantages of a big brain. I think both of those approaches are dubious. I have thought in the last couple of years about how a simple Darwinian approach could explain our big brain. It would be easy to explain how it was suddenly generated but why wasn't it immediately suppressed by natural selection?. You see, brains are very expensive organs to maintain. Your brains are consuming about 25% or more of the oxygen and glucose circulating in your blood. They're hungry organs and that's why, in general during evolution, brains have been kept very small; they've been kept as small as is compatible with running the body they belong to. There's been no obvious tendency for brains at the ends of evolutionary lines suddenly to explode and get much bigger. Presumably it's happening all the time, because of the ease of genetic mistakes that do that, but they're wiped out by selection. So that is a puzzle: why weren't our big brains eliminated by the evolutionary process?

So what are big brains good for? Well, it's obvious, big brains are clever. In general, very loosely, there is a correlation between brain size and the richness of the repertoire of behaviour in animals. You have to be very careful in making that point these days, partly because of the work of people like Nicky Clayton at Cambridge, who has inexorably worked through the list of things that psychologists said were uniquely human. Things like episodic memory, memory of personal experience, deceit and such. He has shown that scrub jays, birds of the crow family, can do them all.

Big brains are clever brains. Perhaps, but certainly not without knowledge or experience. If you think about the things that you do which you would think of as being clever – like reading and writing and doing maths or whatever, or understanding politics or reading *The News of the World* – all of those things require experience and learning and changing your brain. You can't read and write without having learnt how to read and write, you can't do science or maths without having studied them. So, it's not enough just to have a big brain, it's actually got to have information pumped into it and organised within it, which is basically what education is all about.

Location in the Brain – Ongoing Research

Let's go back to the phrenology question. What do we know about the localisation of functions in the brain? What was known in the middle of the 19th century, as soon as scientists stopped worrying about bogus phrenology, was that there were certain areas in the same place in all individuals, pretty much in the same place, concerned with absolutely basic automatic functions, robotic sort of functions like controlling the movement of the muscles. There is a strip that runs down the middle of the brain. If you get damage to that – it is quite often damaged in stroke – then it produces a paralysis and inability to make skilled movements. Directly behind it, the next strip along receives information from the body surface and the deep tissues. Those two areas are interconnected so when things touch you, or when you get feedback from muscles, it can modify your movements. At the back of the brain there is the very well known visual area – the pole of the occipital lobe. If that gets damaged – again it can be damaged in stroke – it produces blindness. And then there is a region in the temporal lobe for hearing, for understanding sounds.

There is lots of evidence for that strict localisation. Anatomical evidence for where the nerve fibres come from, the effects of damage, the effects of electrical stimulation of the brain. We now know that the whole of the cortex is filled with specialised regions, many of them actually continuing the processes that are started in these early sensory areas, particularly extending the analysis of visual information. About a third of your cerebral cortex is devoted virtually exclusively to vision and there are comparable areas for hearing and for touch.

In a fairly recent study (fig.3), each of the coloured regions of the brain shows the result of a different stimulus in the brain-scanning studies. The person was put into the scanner, different things were shown to them, and each coloured region shows the part of the brain that was most activated by one particular thing compared with another. We have areas for static, simple basic movement, and for biological movement. So what is the purple bit on the right for? The answer is *verbs.* That purple region lit up when people listened to spoken verbs or read verbs displayed on the screen. The point I want to make is that the capacity to understand language could have evolved in relation to a kind of processing stream for detecting and analysing movement. Many verbs are verbs of movement or concerned with movement and probably in primitive languages most verbs would be like that, rather than abstract things. And it's not just spoken verbs, which is the essence of language, it's written verbs. We've only been writing for 5,000 years, so this could not be genetically determined., it must be based on individual acquisition of knowledge.

Consciousness

Thinking of neuroeverything, one of the issues is whether brain research will ever tell us about the basis of conscious experience. Francis Crick published a book a few years ago, basically a rallying cry to neuroscientists saying now is the time to get interested in consciousness. If we could just define which nerve cells were active when you're conscious, whether their activity took a particular form, different from when you're unconscious, that correlate of consciousness would be a very useful bit of information.

The discovery – and this is an

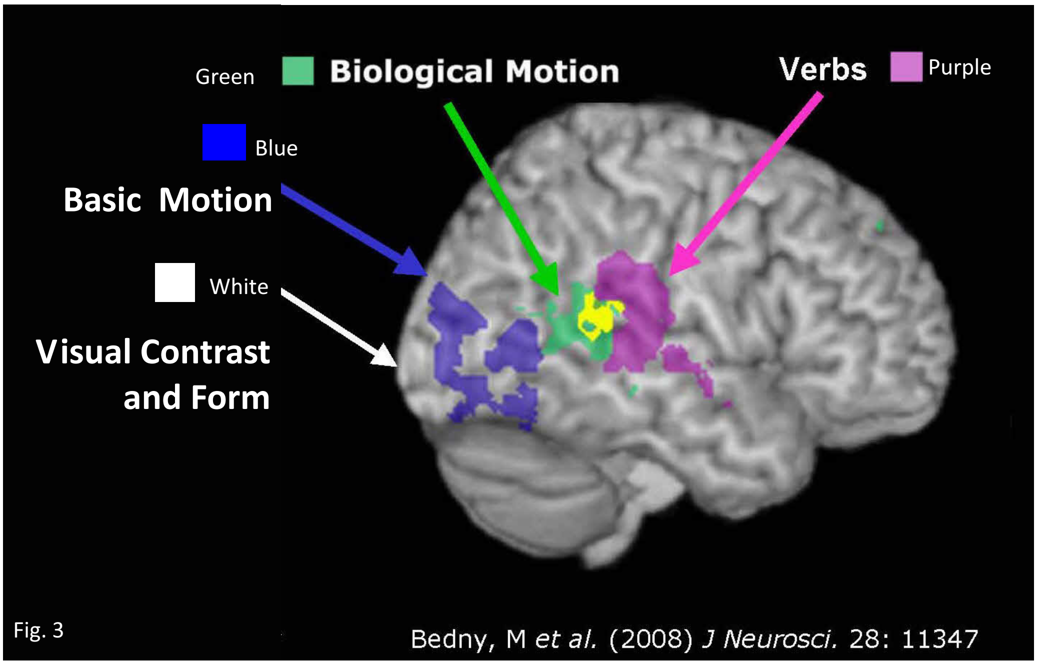

Fig. 3

experiment done in my lab – that there are different bits of the brain which respond to looking at objects and looking at faces made us interested in what would happen if you looked at this (fig. 4). It is a well-known figure, which of course part of the time looks like a pair of faces and part of the time looks like a chalice, a white chalice in the middle. You look at it and it flips backwards and forwards every few seconds between the two. Of course, any change of consciousness could have nothing to do with the physics of the outside world – the image was always the same – it had to be something happening in the brain. So what we did was put people in the scanner and said: 'Press the button when it has just changed into a face,' and 'Press the button when it has just changed into a chalice.' Then we looked in their brains, focusing just on those two regions, and asked: would the change of consciousness correlate to anything happening in these areas? And it does, especially in the face area. The face area turns on. In fact, if you just looked at that face area with your computer alone, you could estimate with something like 90% reliability whether the person was seeing it as a face or seeing it as a vase.

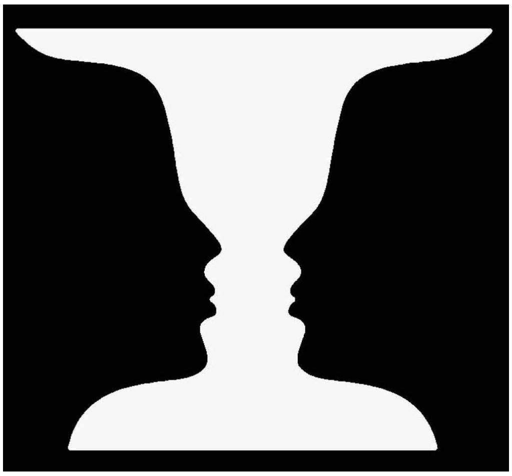

Fig 4

Memory

Memory is obviously the most immediate and vivid example of the influence of personal experience on you, on your make up. You are the constellation of memories you have of the past, to some extent. We know quite a lot – not all – about how that's done. We know it depends on this thing called the hippocampus underneath your temporal lobes. Interestingly, it took quite a long time for people to show really convincing evidence from brain scanning that this region of the brain was active during the formation of memories, but there is a very good example of that produced by Eleanor Maguire at the Imaging Centre in London. She asked: what happens to this region of the brain in people who develop their memories and have quite exceptional memories for places? So she looked at London taxi drivers and found that the back part of the right hippocampus is enlarged in taxi drivers. You might say, 'Aha! maybe it is people with big hippocampuses who are attracted to the job of being a taxi driver.' No. She showed that the hippocampus gets bigger as they learn, as they do this long period – two years typically – before they take the examination to become a licensed taxi driver, The Knowledge, as it's called. The brain can grow. There's now lots of evidence for this. If you learn any particular task – juggling or computer game-playing or playing the violin or whatever – the brain reorganises incredibly rapidly over the course of a few days. And the grey matter can get thicker, the white matter can get thicker.

Based on individual experience, we have to think of our brains as being highly modifiable, the most modifiable bits of our body. That's a complete change in thinking about how our brains work over the last thirty to forty years. New nerve cells are being born in the hippo- campus. There are stem cells in our hippocampus even now, in yours, making new nerve cells, and, by the way, one thing that drives them is physical exercise.

Neuroeverything?

I've tried to give you a flavour of this amazing and still very rapidly changing field of science. Even though it is easy to laugh at some of the hype and some of the simplistic interpretations, increasingly neuroscience is going to impinge on all the aspects of how we think of ourselves and the world as being special, as being spiritual creatures, as being morally determined, maybe, in some cases, being believers in God. We are going to see brain research increasingly illuminating how those things happen in our head and I think that has to make us at least re-assess the explanatory power of science in informing us about ourselves and the undeniable capacity of science to inform us about the outside physical world.

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