Is Man a Machine? A Neuroscientist's Perspective.

Talk Given in A Celebration of Science and Faith

on the occasion of the 925th Anniversary of the Priory,

Malvern 23/4/10.

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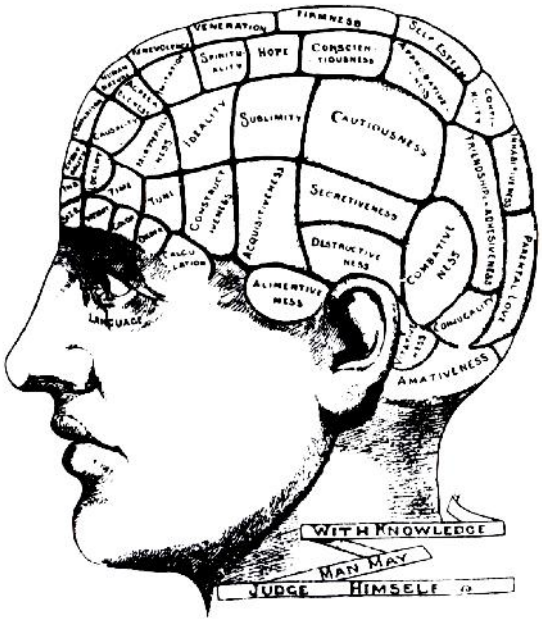
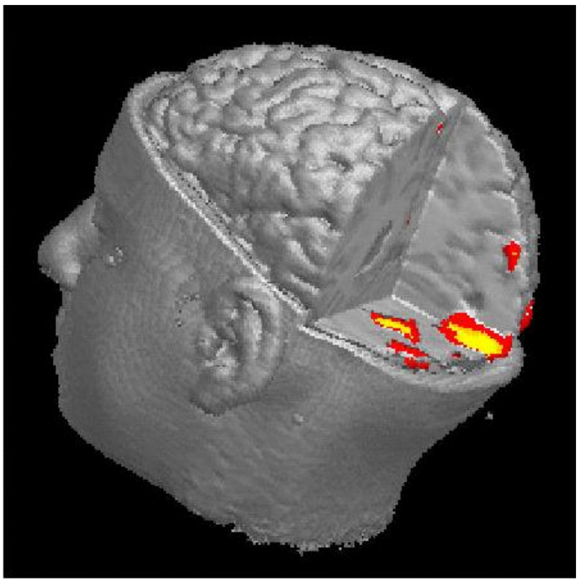
The last hundred years have seen an amazing explosion in our knowledge of how we, as humans, are made. Nowhere is this more true than in our understanding of our brains.
This advance in knowledge has taken us from Phrenology - attempts to predict a person's character from the bumps on their skull - to techniques such as f-MRI that allow us to investigate brain function in an awake behaving human's head. Each advance has brought the

Phrenology



Functional MRI



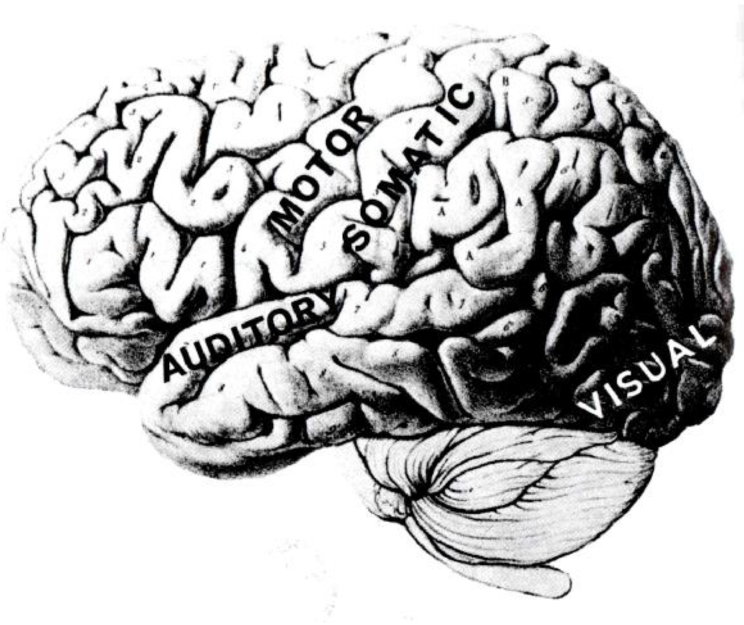
realisation that our mental activity - the mind - is more and more closely related to the activity of the nerve cells within the brain. This appears to be true of our emotions, consciousness, perceptions and so on - even decision making. All this raises the inevitable question: if our mental activity is so intimately linked to our brain function, and our brains act by means of electrochemical processes, does that mean that we are simply electrochemical machines? No less than Francis Crick, the co-discoverer of the double-helix DNA, opens his book *The Scientific Search for the Soul* with the words:-

> *"You", your joys and your sorrows, your memories and your ambitions, your sense of personal identity and free will, are in fact no more than the behaviour of a vast assembly of nerve cells and their associated molecules*".

Now Francis Crick was not the first to make statements of this kind, appearing to reduce humans to the status of machines. It is an example of what my late colleague, Professor Donald MacKay called "*Nothing* Buttery". And this talk is dedicated to the memory of Donald MacKay, whom I succeeded as Head of his Department of Communication and Neuroscience at the University of Keele, and whose ideas, as a biblical Christian in this field have been seminal to many of us.

What I want to do in the first half of this talk is to show you how neuroscience has been throwing light on this question - to show how closely our mental processes are linked to the activity of our brains, and then in the second half to look at how we can accept this without denying our humanity. We may be machines at the biological level, but we are much more than that. If you like: "*Much more* buttery".

For years our understanding of brain function was derived from studies of disease and injury. From these, a general understanding was reached that different functions such as motor or sensory - hearing, vision, and tactile sensation - were located in different parts of the brain. Damage to a particular area, as from a gunshot wound or a stroke, could impair that specific function. One particular example of brain injury, though, in 1848 caused a sensation. It involved an American railroad foreman who rejoiced under the



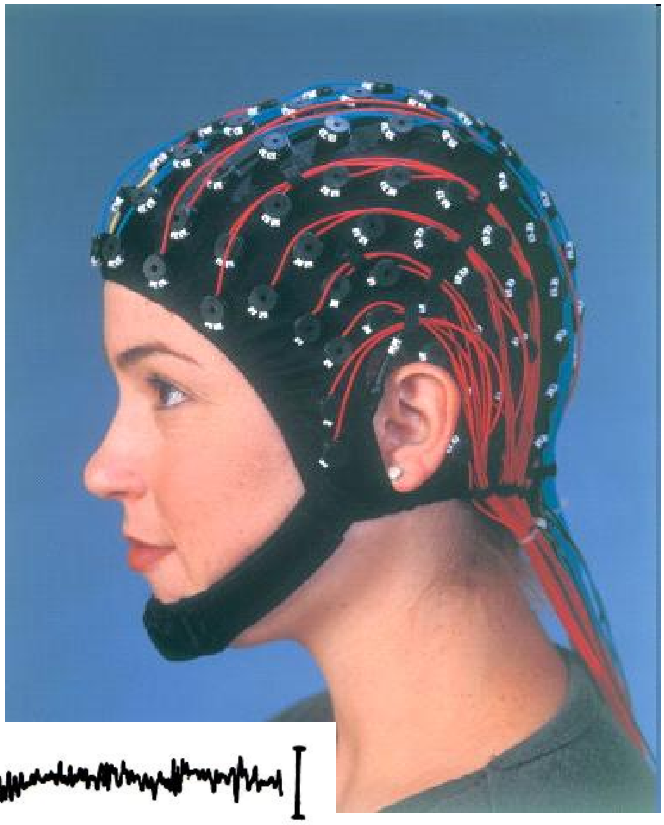
name of Phineas P Gage. He was dynamiting rock to build the railroad by drilling a long hole in the rock, inserting explosive which he tamped down with an iron bar several feet long. Unfortunately, the explosive went off prematurely, and blew the iron bar

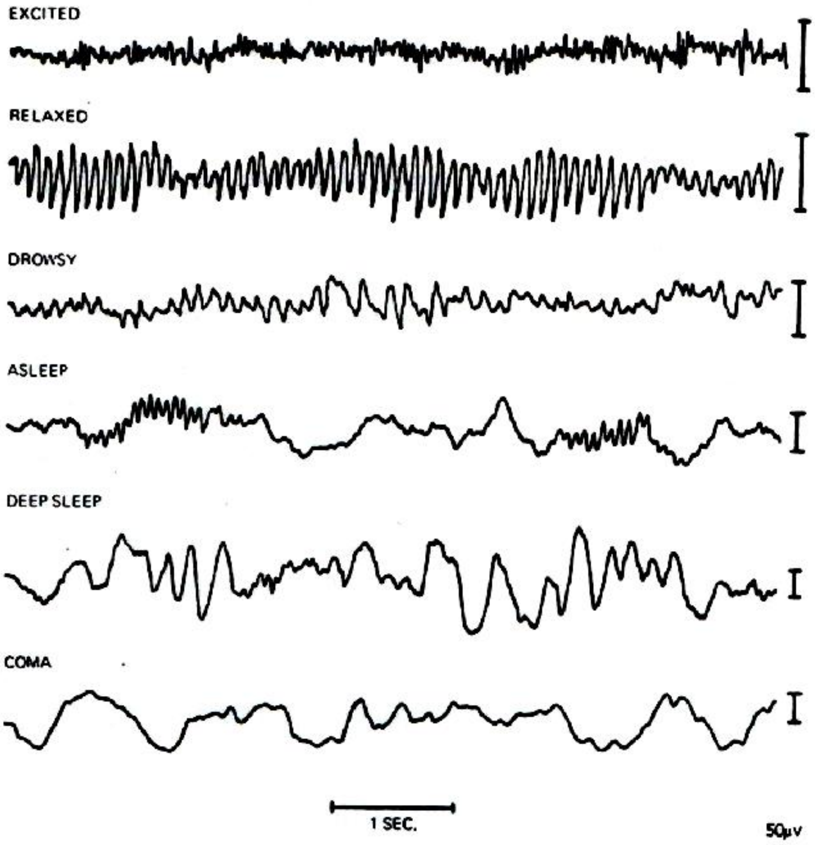
through his head entering at the cheek and leaving through the top of the head, destroying much of the frontal lobe of his brain. Amazingly, Gage achieved immortality not in the usual way, but by remaining very much alive. Eventually he exhibited himself and the iron bar at a travelling circus. He appeared very normal, could talk and walk and his normality even led to questions in the American press whether the brain had any function at all! What had changed, however, was his *personality*.

> *From being an 'efficient and capable foreman' Phineas P. Gage became:- 'fitful, irreverent, indulging at time at the grossest profanity (which was not previously his custom), manifesting but little deference to his fellows, impatient of restraint or advice when it conflicts with his desires, at times pertinatiously obstinate yet capricious and vacillating, devising plans for future operations which were no sooner arranged than they were abandoned ... His mind was radically changed so that his friends and acquaintances said he was no longer Phineas P. Gage'.*

So damage to the frontal lobes can change personality. This was actually taken advantage of therapeutically in the middle of the last century in the surgical operation of frontal lobotomy or leucotomy.

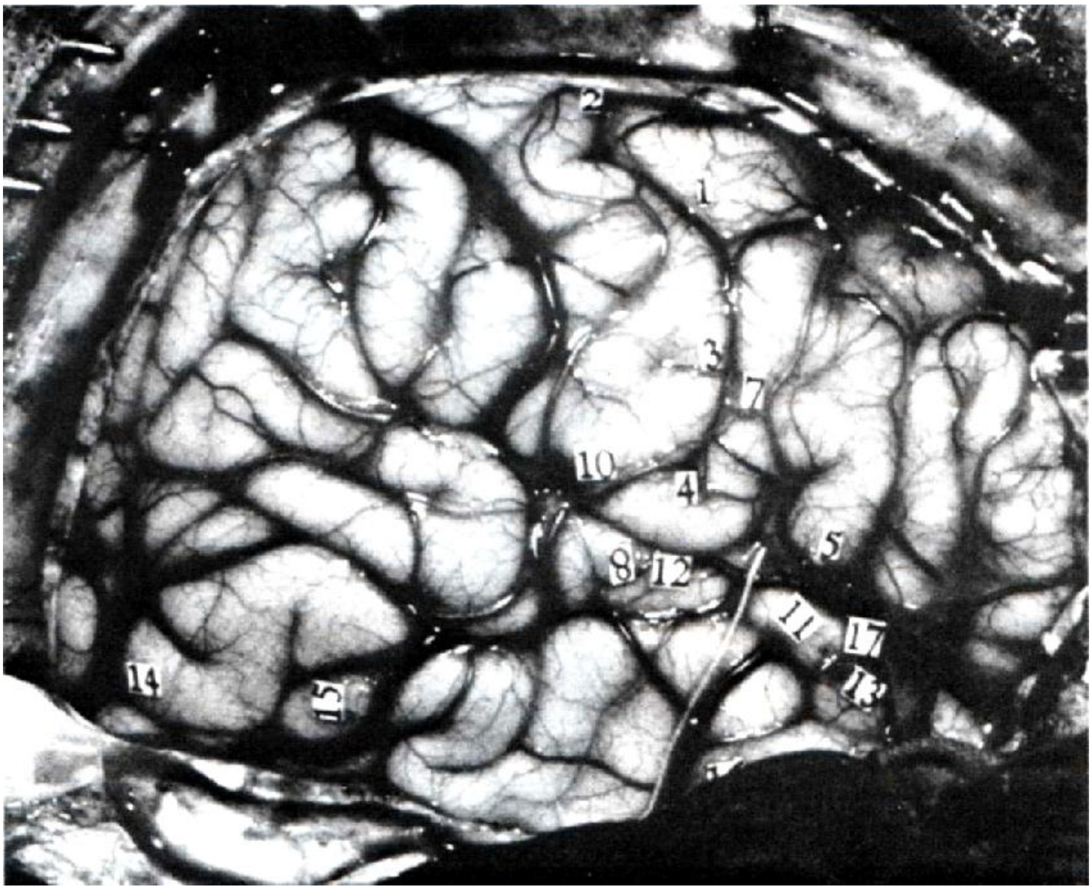
The next advance in brain science, that allowed us to look inside the unopened head was electroencephalography - EEG. From metal electrodes stuck on to the scalp of held in place like this, one can record what have been called "brain waves". These are the sum of the electrical activity of thousands of nerve cells within the brain. They are still used in the diagnosis and treatment of epilepsy. Interestingly, they can give an easily detected indication of our state of consciousness, from highly awake, to sleepy. If you recorded my EEG now, you would find it like the top trace: highly desynchronised and active.



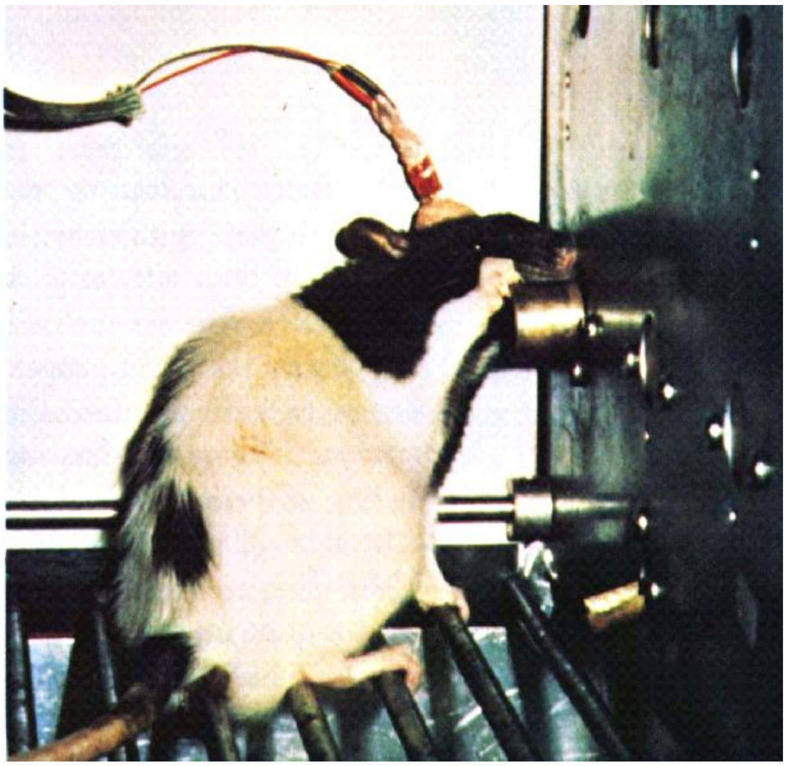


As you doze off a little, the waves become progressively synchronised so that if you recorded from someone at the back of this hall, you might find waves like these! It can be used as an index of anaesthesia in a paralysed patient. The trouble with EEGs, however, is that they cannot give us an indication of what is going on at the level of individual nerve cells. That came much later.

A different approach to establishing the function of the different parts of the brain, came from electrical stimulation. A Canadian neurosurgeon, Wilder Penfield, in the course of



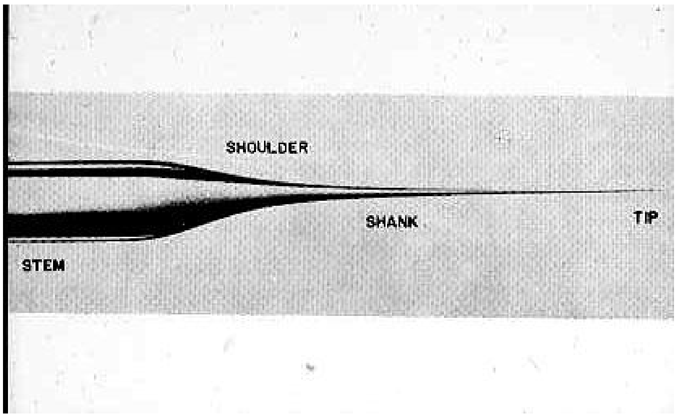
surgery to remove damaged areas of the brain to cure a certain form of epilepsy, operated on some patients under local anaesthesia so that he could make sure that the parts of the brain he was to remove were not crucial. He did this by electrical stimulation by electrodes placed on the surface of the brain while recording the patient's responses. In some cases, this crude electrical stimulation could evoke detailed memories - the slow movement of Beethoven's 7th Symphony or a child playing in the back yard. He was stimulating the temporal lobe where memory is thought largely to be represented.



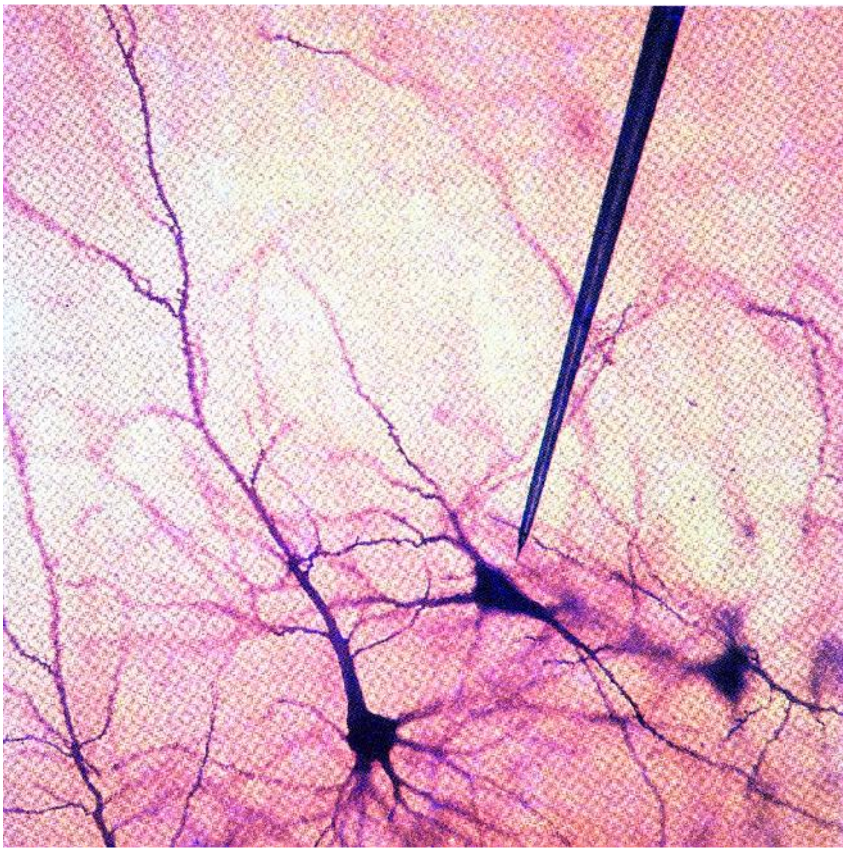
Another kind of electrical stimulation was carried out deep in the brain in animals with startling results. If electrical pulses were made to certain deep brain structures, the stimulation appeared to evoke behaviour associated with pleasure. If the electrical circuit was made through a lever that the animal itself could press, they soon cottoned on to the connection and used to stimulate themselves until they became exhausted. This is the animal equivalent of the one-armed bandit machines in our amusement arcades! Placing the electrodes a short distance away from the pleasure centres could evoke anger or rage. A dramatic example of this was staged by a Spanish neuroscientist, José Delgado. Here is José in a bullring being charged by a bull until José turns on the radio transmitter in his hand, stimulating one of these deep brain regions, and the bull loses its aggression completely. A newspaper report asked:

Have heaven and hell been located in the brain?

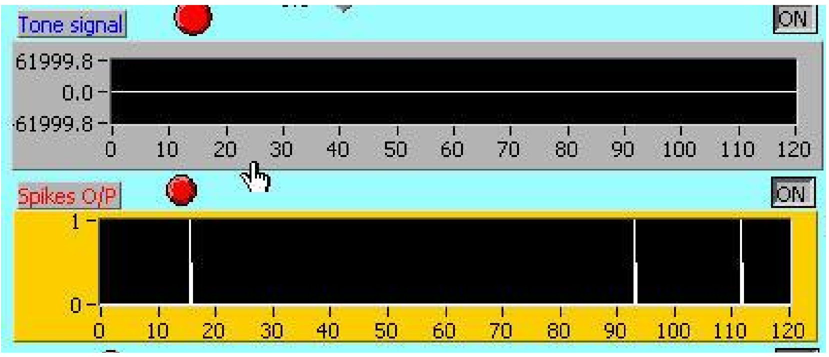
In the middle of the last century, the invention of the *microelectrode* allowed us to investigate the activity of individual nerve cells in the brain. A microelectrode is a thin tapered wire or glass pipette filled with salt solution and with a tip small enough to record electrical signals inside or just outside an individual nerve cell. This technique has revolutionised our understanding of brain mechanisms. There are more than 10,000 million nerve cells in the brain (more than there are people on earth), each nerve cell a few microns



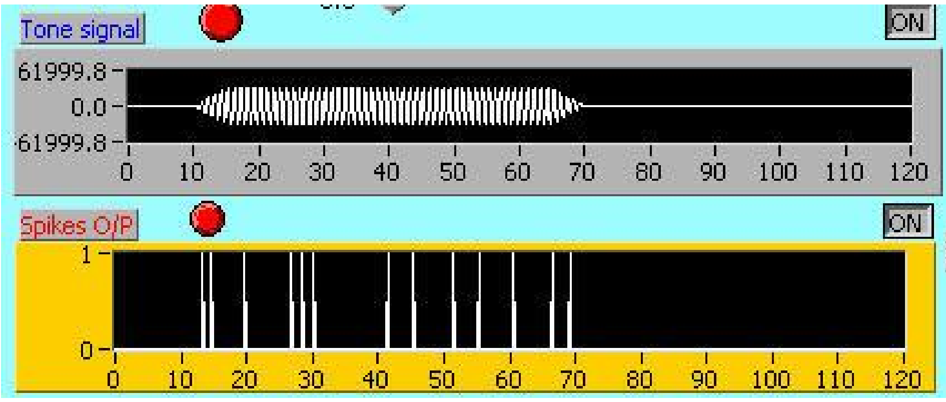
(thousandths of a mm) in diameter. You can get the tip of the microelectrode inside a nerve cell or nerve fibre or just outside and record the tiny electrical signals - nerve impulses - as the nerve cell responds, in which ever area of the brain you are interested in. As I was the first in the UK to record the nerve impulses from inside nerve fibres in the nerve of hearing, let me demonstrate the result from my own speciality, hearing. I am going to do that by means of a computer model that very faithfully reproduces what we obtain in an actual experiment.

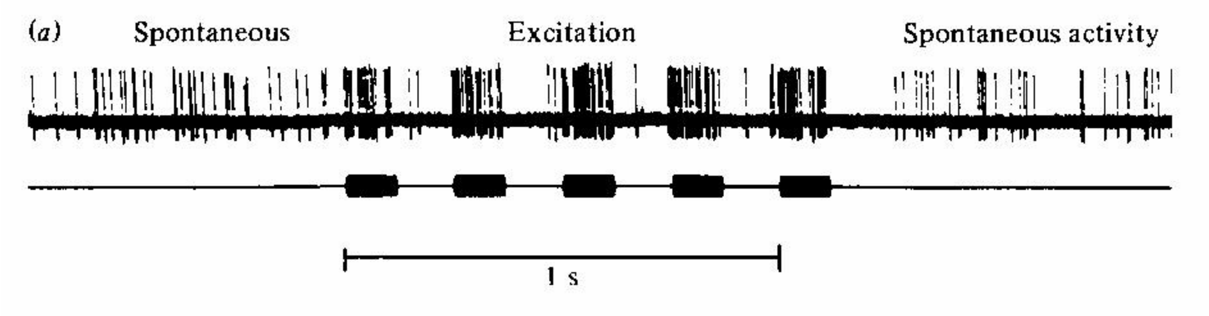


I want you to concentrate on the yellow window and ignore all the knobs and switches beloved of physiologists. This is a computer model of the behaviour of a single nerve fibre in the nerve of hearing from the ear to the brain. Notice the spikes on the screen. Each is an electrical pulse - a nerve impulse. You are listening to the spikes over the loudspeaker just as we do in the lab. As we record them with a microelectrode, each pulse is about a thousandth of a second long and about a thousandth of a volt in amplitude. There is no sound going into the ear, yet you notice that the nerve fibre is spontaneously active. It is ticking away randomly. This is true of 2/3 of the nerve fibres in your ear. And yet we do not hear anything. (In fact, it looks as if we lose this spontaneous activity, through disease for example, we experience abnormal sounds we call tinnitus). Now let us put a sound into the model ear. This is a pure

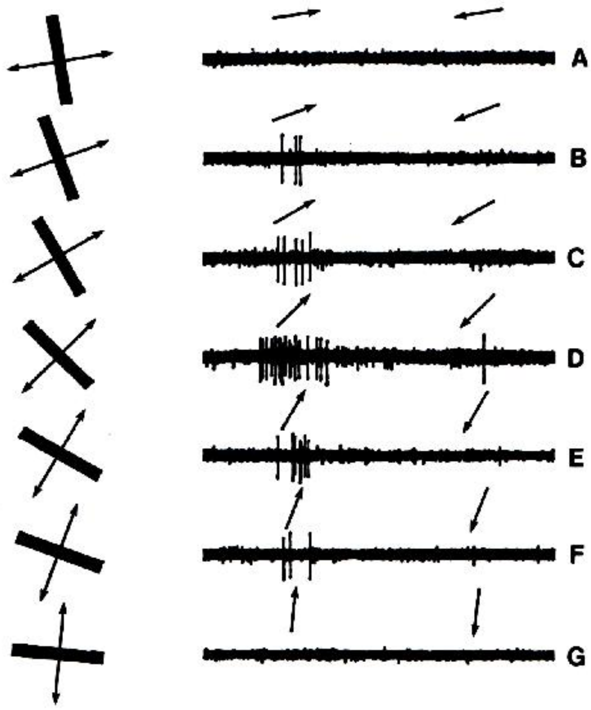


tone switched on here and off there. The nerve fibre responds by producing a burst of spikes - action potentials. The burst of spikes begins when the tone begins and ends when the tone ends. Make the sound louder and we get more spikes, less and we get less. This is the code used by the brain to signal the arrival of all sensory stimuli - in the optic nerve, to flashes of light, in the nerve of taste, to different chemi-

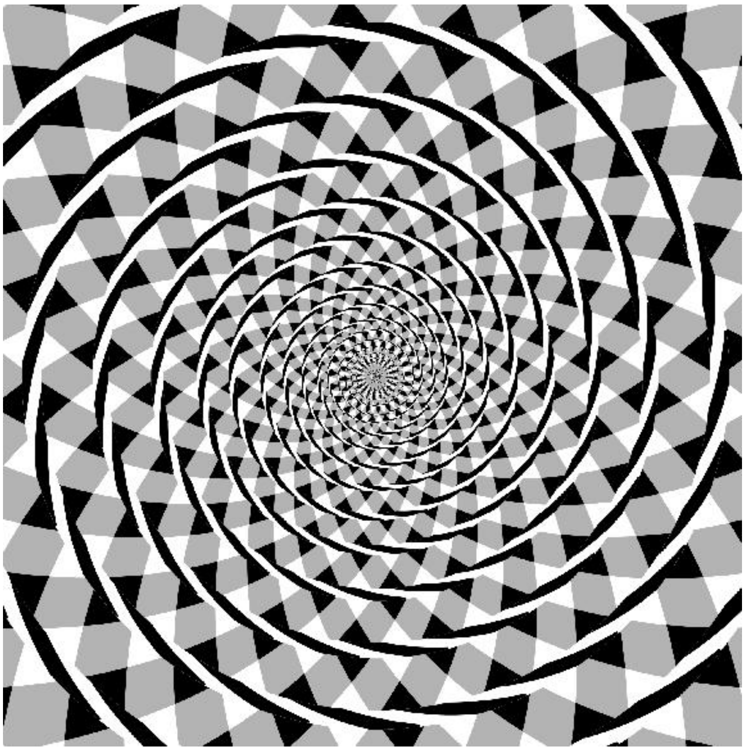




cals, in the skin nerves, to signal the presence of tactile stimuli. It is amazing to consider that the nuances of music are conveyed to the brain by these simple patterns of pulses! But the brain does not act like a hi-fi player for hearing, or a camera for vision. It uses quite different strategies for making sense of stimuli. The higher levels of the brain are specialised to analyse features of stimuli that are likely to be important for successful pattern recognition. In the visual system, for example, the visual cortex contains nerve cells that specifically respond when the visual image contains lines at a particular orientation or angle. Change the orientation of a

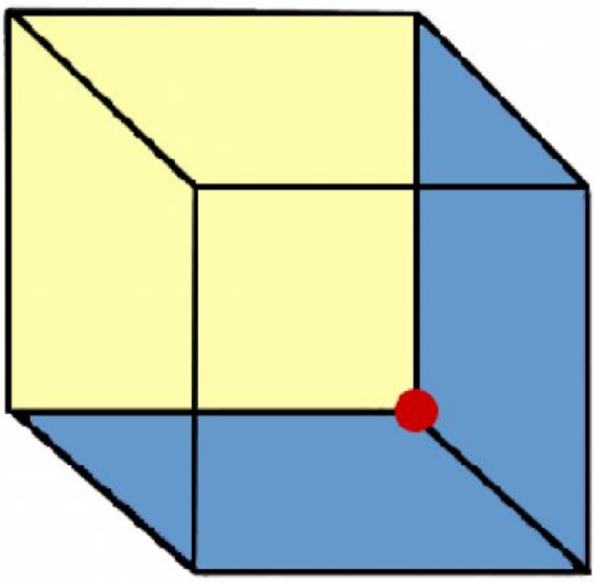


line falling on the retina of the eye, and the visual cortical nerve cell changes its response from nothing to vigorous to nothing again. It is tuned for a particular orientation. As a consequence of this way of analysing complex stimuli, we have a famous optical illusion called Frazer's Spiral. What is special about this, is that it is not a spiral but a set of concentric circles, as I can demonstrate by running the pointer round one of them. Now I have demonstrated that the figure is a set of concentric circles, what do you see? A spiral. It happens because the concentric circles are made up of short line segments tilted in towards the centre. These are analysed by the line detector nerve cells and the information generated by these is used by the higher levels of the brain to construct a model of the visual input. The only figure that fits is a spiral. Different parts of the visual brain selectively analyse different features of a stimulus - line orientation, angles between lines, colour, direction of movement etc. Furthermore, there are in the brain, areas that specifically analyse faces, or names. These specific functions can be affected by disease, especially strokes.

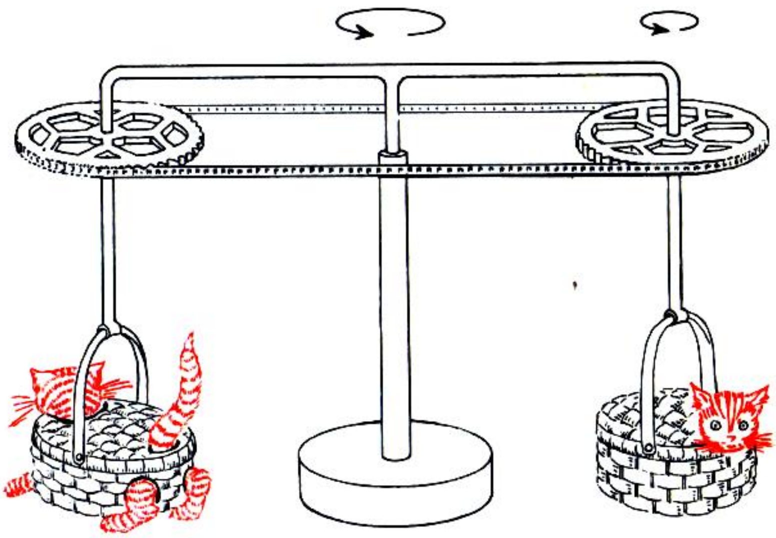


Thus, as we get older, our ability to name names can be affected. It is not that we lose the ability to make the sounds, but it is a problem specific to naming. Thus, one patient when asked to name a comb said "I don't know what it is called, but I use it to comb my hair".

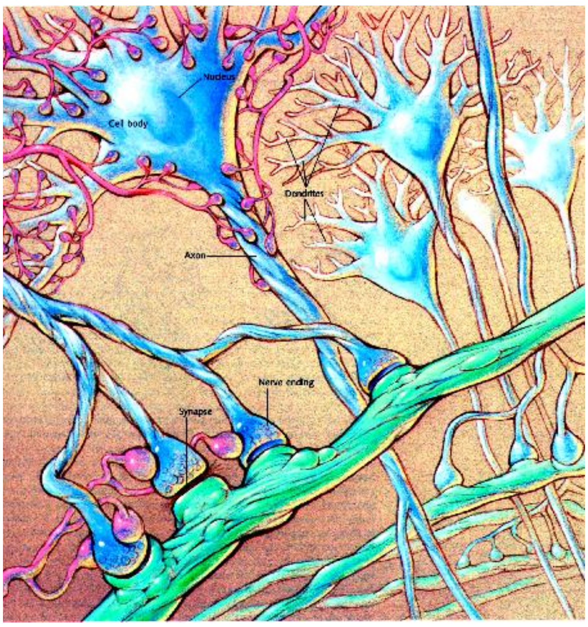
The brain then has the job of making sense of the multitude of information sent to it by the lower levels, to create a model of the outside world. Sometimes, it does not suc-



ceed, as in the famous Necker Cube. Blink, and the spot appears to lie on the front face, blink again and it lies on the rear. The upcoming trains of neuronal information are ambiguous.

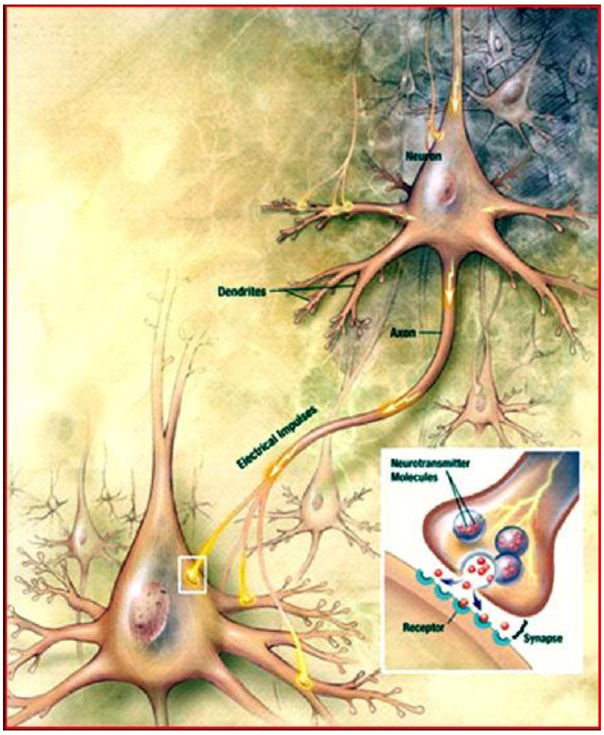


A remarkable recent finding is that all these properties are not hard-wired. They are plastic. Raise a kitten in the same visual world as its brother, but without the opportunity actively to explore it, it loses the ability to discriminate visually. Raise a kitten in an environment without horizontal lines, for example, and it loses the ability to distinguish them, which it can do so at birth. So use it or lose it. Exposure during development to a normal sensory diet is as important to the development of normal sensory function as is a normal food diet. The period over which the plasticity lasts is called the critical period, and can be quite short. That is why it is important to correct abnormalities in hearing and vision early in infancy if they are not to lead to permanent loss of function. And that is why we lose the ability to distinguish the faces of other nationalities (e.g. Chinese) if we have not acquired the ability for example by living in China during the critical period. Likewise with learning the sounds of a particular language.

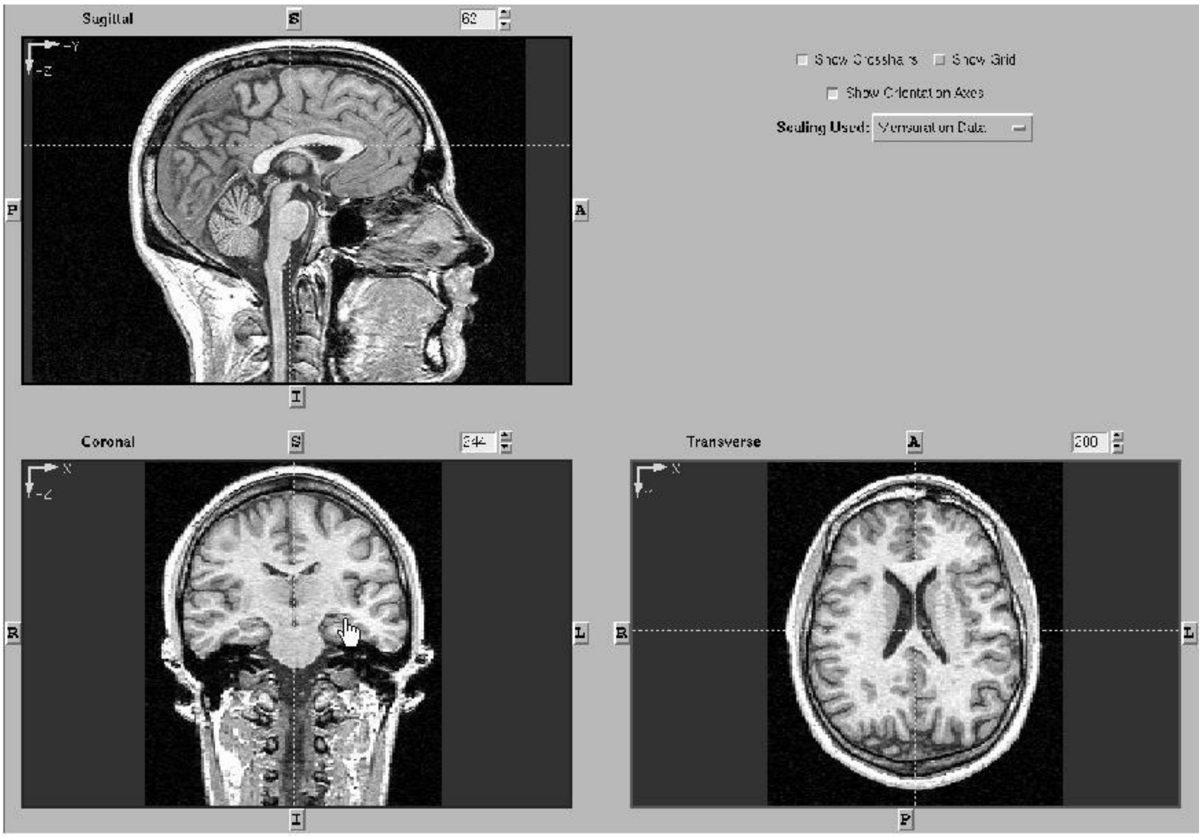


Microelectrodes can be used to elucidate the mechanism by which one nerve cell communicates its message to another nerve cell, at specialised endings of the nerves called *synapses*. Each nerve cell gives off thousands of synapses on hundreds of other nerve cells. Each synapse squirts a chemical - we call it a chemical transmitter - onto the next cell and causes it either to fire (excitation) or not to fire (inhibition).

These actions can be imitated by the same chemicals circulating in the bloodstream or can be specifically blocked by others, and this forms the basis of our very successful pharmacological approach to certain nervous disorders, like Parkinson's Disease, depression &c. It also accounts for the effects of illegal and so-called recreational drugs on human behaviour, and the way continued use of these drugs distorts the normal function.

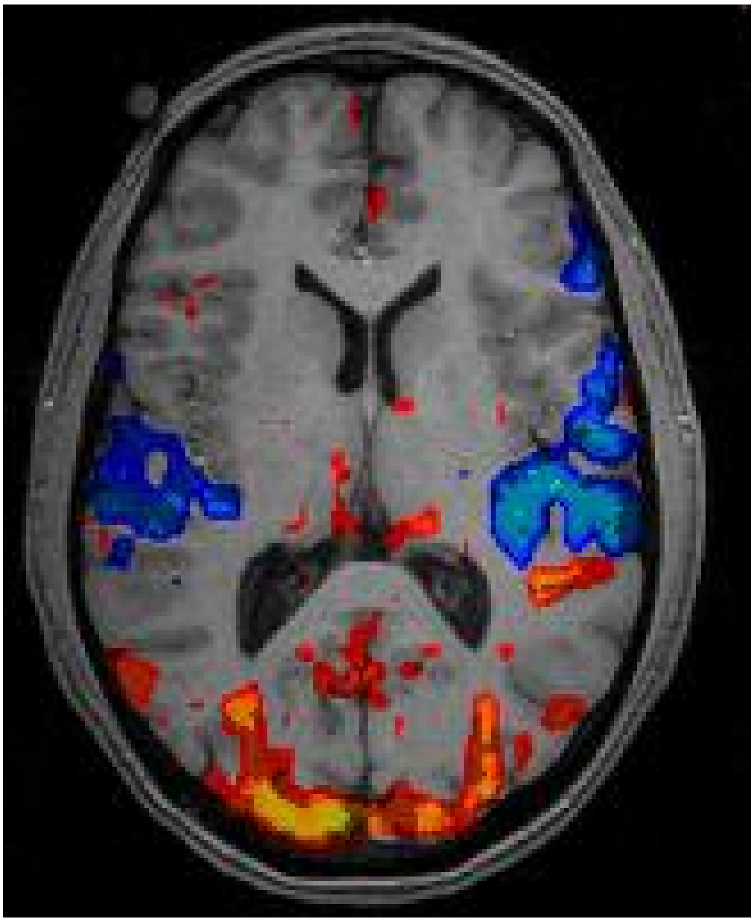


In the last decade or so, a new technique has been developed that allows us to study the awake brain without opening the head - MRI

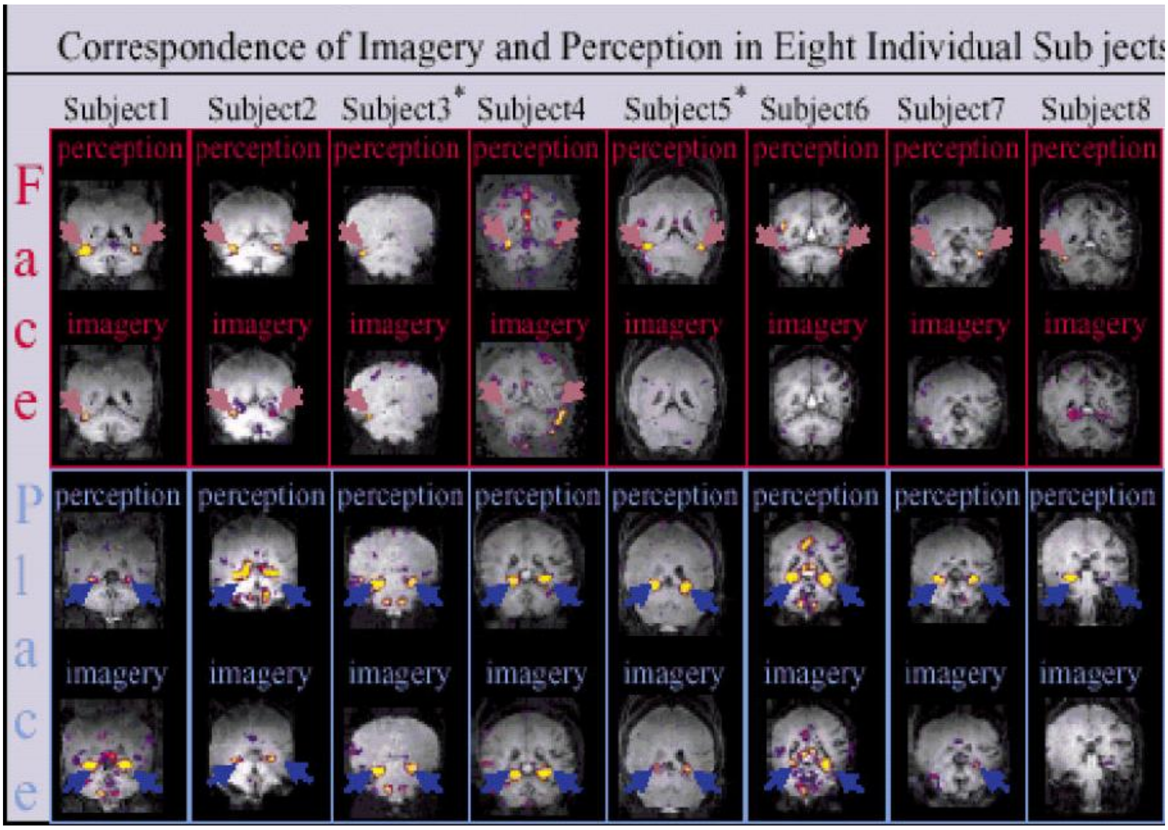


(Magnetic Resonance Imaging). This gives us remarkably detailed pictures of the inside of the head and the structures inside the brain. The computer doing the scanning can cut vertical or horizontal slices through the head, making diagnosis of strokes, tumours, brain haemorrhage and so on possible with great accuracy.

By using computer analysis of the images during periods of different stimulation or different thought processes, one can highlight the parts of the brain that become active during specific perceptions or thought processes. This is FMRI (Functional MRI). Thus in this picture, we have areas coloured red that respond to visual stimuli and blue areas that respond to auditory - areas for sight and hearing.

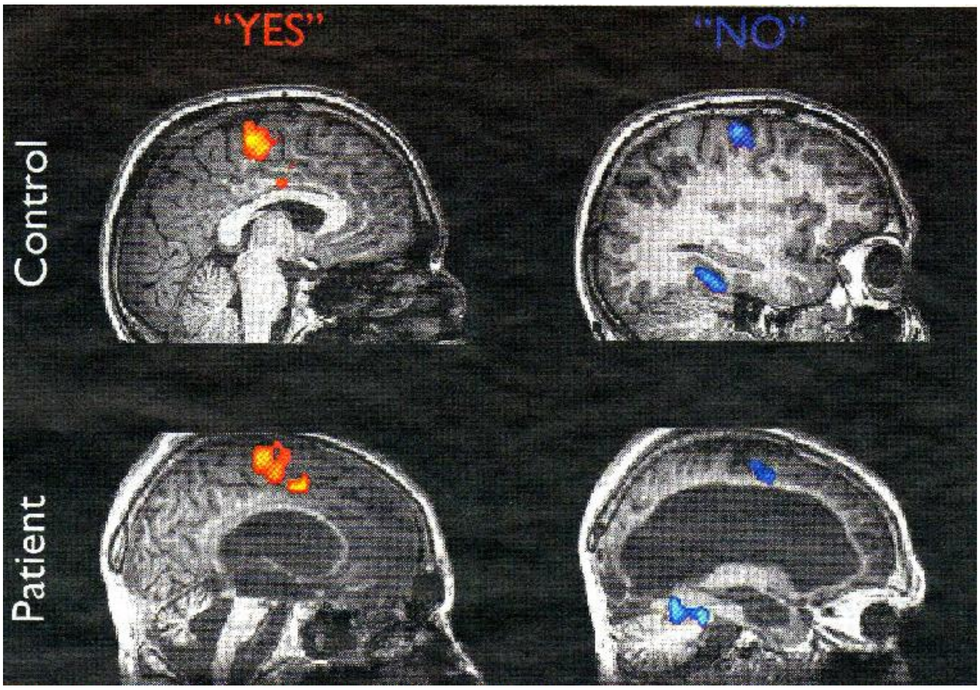


What remarkably these studies have demonstrated, is that the areas of brain that are stimulated by real stimuli - sights or sounds - are active when the subject *imagines* "in his mind's eye or ear" the same sights or sounds. Thus these are the f-MRI scans of 8 subjects. On the top line the pink arrows point to the brain areas that are



active when the subjects see a face; on the next line down the same areas are active when the subjects imagine the face. In the lower pair of rows, different brain areas are active when seeing a place and when imagining the same scene. So, actual perception and imagining the percept involve similar central brain areas.

These F-MRIs are so reliable that they have been used very recently to diagnose whether a patient in a vegetative brain state - to all appearances in a coma - is actually conscious but unable to communicate by movement. Asked to imagine a tennis game, one part of the brain is active; asked to imagine the subject's home, another. These can be used to signal "yes" or "no" and the same patterns are obtained in a normal subject and in the patient: the patient here is definitely conscious, not brain dead.



So how do we relate brain and mind? We have come to an important conclusion: That every conscious state of the mind appears to be related to activity somewhere in the brain. Mind and brain are very closely linked. This is true for consciousness, emotion, perception even personality.

But the reverse is not true. You can have activity in the brain without being conscious of it. We are not conscious of a lot of activity particularly in the lower levels of the sensory pathways. This has been brought home to us by the remarkable phenomenon called "blind sight". A patient who has suffered a stroke damaging the visual cortex cannot consciously see anything in the visual field connected to the damaged brain region. If, however, you can persuade the patient to point at a moving light he claims he cannot see, he can point at it remarkably accurately. So the neural pathways concerned with analysing the location of an object are not necessarily involved in conscious perception of it. Literally, blind sight.

So the connection between brain and mind is not one-to-one. You have to have activity in the brain to have mentality; but you can destroy areas of the brain without affecting mentality or have activity in them without being consciously aware.

How, then do we relate brain and mind?

This question has occupied generations of philosophers for centuries! One of the earliest was Descartes, who took a traditional theological approach of assuming the the mind was a separate "stuff" or material from the brain, and that interacted with the brain and vice-versa. The point of interaction for Descartes was the pineal gland for which no function appeared to exist. This traditional theory we call dualism: two stuffs interacting. While the involvement of the pineal is no longer held, dualism has had eminent support from neurophysiologists such as Nobel Laureates Charles Sherrington and Sir John C Eccles.

More recently still, however, the evidence for the close connection that I have outlined between brain and mind, has led to an alternative position called monism ("one stuff"). This is associated with the philosophers Schopenhauer and Ryle and importantly for us, scientists who are committed Christians such as Donald MacKay, Malcolm Jeeves, Brown and Murphy, and John Polkinhorne. Monism emphasises the *unity* of brain and mind in making up the personhood of the owner, with mind

Dualism vs Monism

“Two substances”	“Two aspects of one substance”
• Substance dualism • Emergent dualism – Eg: Descartes, – Sherrington – Eccles • Integrative dualism – Ward	• Dual aspect monism • Substance monism • Property dualism • Non-reductive physicalism – Eg: Schopenhauer – Ryle, – MacKay – Jeeves – Brown & Murphy – Polkinghorne

and brain being dual aspects, two ways of looking at, the person. One aspect is from *outside* the person - what the brain scientist sees - nerve cells doing x, y and z; and the other aspect is from *inside* the person - what the subject himself or herself experiences, thinks, believes. The philosophical pendulum has definitely swung in the direction of monism and does justice to the close links between brain and mind. But doesn't this position imply that our minds are purely mechanical - nothing but the activity of nerve cells, as we saw at the beginning from Francis Crick? And where does all this leave room for the soul?

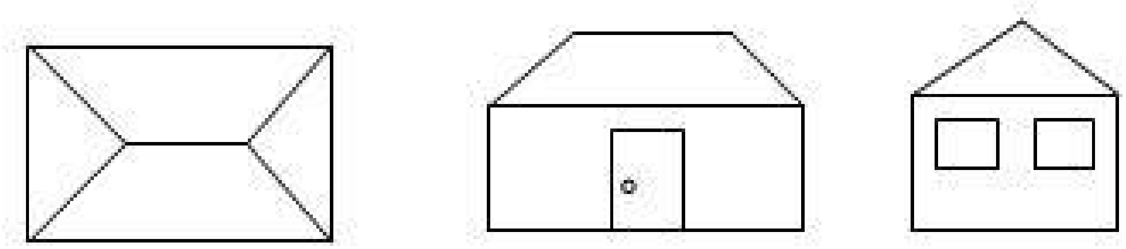
Monism does not imply that the mind is merely brain activity. Mind and brain activity are not identical; they are *correlated* and in a particular way, by the principle of *Complementarity*. Complementary aspects of a unity are so obvious a concept that it astonishing how often it is unknown to or ignored by folk who should know better like the media, Nobel Laureates and Professors of the Public Understanding of Science! So I am going to labour the point by a series of illustrations - 5 in all.

The first involves you using your eyes! Hold out your arm at arms length and point your finger at my nose. Hold your arm still, and close one eye. Then open the other eye and close the first. If you have kept your arm still, one eye should have seen your finger to one side of my nose, and the other eye should have seen it on the other. Now which eye is correct? Surely they both cannot be correct? How do you reconcile the two contradictory descriptions? The answer is that they are *complementary* - viewed from a different standpoint. Looking at the same thing or event from different standpoints, different viewpoints, can give more than one differing description, each entirely correct from its viewpoint. The brain of course knows this and puts the disparate information from the two eyes together to give us a third dimension - depth.

Or consider a *painting*. A chemist would give a description of the painting in terms of the chemical composition of the pigments, a physicist the wavelengths of reflected light. And each description would be correct from its particular viewpoint. But both descriptions would miss the point of the

painting if they said that "that was all there was to it". Saying that it was "nothing but" pigments on a canvas, would be to completely miss its *meaning*.

Or take an *architects drawing* of a house. You need at least three complementary views to



give the full details, no matter how complete each view is on its own.

Or take an illustration that may be more appropriate to brain and mind and more familiar to employees of Qinetiq - *hardware and software descriptions of a general-purpose computer*. A computer engineer can give a complete description of what is happening at the level of the electronics of a computer and that description can be exhaustive and complete in terms of cause and effect - nothing left out. And yet there is a complementary description of the same activity in terms of the software program responsible for the activity. The two descriptions are correlated, but you cannot expect to find in the electronics the roots of the equation that the computer is solving. Logic gate A passing signals onto another gate B on the one hand, and solving the roots of an equation on the other are two different, but complementary aspects of the computer's operation. Likewise, nerve cell A passing impulses on to nerve cell B and "I see a line" are two different but complementary aspects of the mind-brain unity. You cannot say that "all there is to it, is the activity of the nerve cells" - you would be missing the point.

For me, the most helpful illustration is the relationship between information and its embodiment.

Take the word HELP. It is information - meaning: "I'm in trouble, get me out of here", embodied in patterns of light and dark. But what is it exactly? Is it nothing but just patterns of light and dark? Well, it would look so for someone who did not know the language! But to conclude that it is nothing but patterns of light and dark would be completely wrong. What is the relation then between the message - help - and the medium embodying it - the patterns of light and dark? Is it one-to-one? No - you can rub out most (99%) of the black and still have the same message. It is just like the brain where you can rub out some parts and still retain the mentality. Does the ink cause the message or the other way round? No, to ask that question perpetrates a logical error typically encountered in complementary accounts because we are talking about logically different aspects or levels of description of the same thing. We need to avoid what Gilbert Ryle called a "category mistake". We need to adopt a careful symantic hygiene when talking about complementary levels. Thinking, experiencing, falling in love, are not properties of nerve cells, or brains for that matter. They are the properties of persons. Thinking, experiencing, falling in love, etc., are properties of what we call persons, and this is a complementary view of the electrochemical activity of the nerve cells within our brains. A computer cannot fall in love, nor can the three or so pints of grey matter between your ears. It is *persons* who fall in love.

The notion of embodiment is helpful here. The message - help - can be embodied in several different forms - as the dots and dashes of Morse code on paper as here, or as acoustic dots and dashes over a radio. Or, as flashes of light in signalling at sea. But the message would be the same. Embodiment is needed for the message to exist and take effect, and the em-

Advantages of the model of embodied information

- Removes the mystery, magic; “mind over matter”: one does not act on the other
- Helps to avoid spiritualism, religiosity
- Emphasises the importance of feeding the mind
- It helps to understand what is the “soul”
- It helps to understand life after death
- It helps to understand the importance of the body in Christian theology

bodiment can be of completely different kinds.

The idea that mentality - our mind - is information embodied in our brains I find helpful. It helps us to avoid a number of errors. First it removes the need for advocating different "stuffs" for mind as against our brains. This removes the element of mystery and magic often implied in dualism. In particular, it shows the pointlessness of trying to make a mystery out of "mind over matter", so beloved of the media. Just stop breathing for a few seconds and you have demonstrated mind over matter! They are two sides of the same coin, not different worlds.

Secondly, it helps to avoid spiritualism and religiosity - undue emphasis on mystery and ritual: replace Religion (with a capital "R") with a simple faith (with a little "f").

Thirdly, it helps us to see why biblical authors laid so much stress on feeding the mind with appropriate information:

> *Finally, brothers, whatever is true, whatever is noble, whatever is right, whatever is* ***pure****, whatever is lovely, whatever is admirable—if anything is excellent or praiseworthy—think about such things.*
>
> *Philippians 4:7-9*

Fourthly, what about the soul? The Bible uses the word in the OT often as a synonym for the mind:-

> *Love the LORD your God with all your heart and with all your* ***soul*** *and with all your strength.*
>
> *Deuteronomy 6:4-6*

In the NT, it seems that something more than the mind is implied:-

> *Love the Lord your God with all your heart and with all your* ***soul*** *and with all your mind and with all your strength.' Mark 12:29-31*

> *for you are receiving the goal of your faith, the salvation of your* ***soul****s. 1 Peter 1:8-10*

> *I saw thrones on which were seated those who had been given authority to judge. And I saw the* ***soul****s of those who had been beheaded because of their testimony for Jesus and because of the word of God. Revelation 20:3.*

It probably means something like our *personality*, our *personhood*, the *essential me*. Me viewed from the standpoint of our Maker. Not identical to the mind any more than the mind is identical to the brain.

Finally, we can perhaps begin to see a glimmer of what it means for life after death. It is not a ghost-like spiritual stuff floating away somewhere after the death of the brain, but the re-embodiment of our information into a new body, the resurrection body, maybe in the memory of our Maker. In short, the essential information of our being, embodied in the brains in our heads while we are alive, can be eternal.

Given therefore that the brain and mind are so closely linked, it is therefore no surprise that in the Bible, the body/mind complex is held of such great importance:-

> 1*Therefore, I urge you, brothers, in view of God's mercy, to offer your* ***bodies*** *as living sacrifices, holy and pleasing to God—this is your spiritual*[a] *act of worship.* 2*Do not conform any longer to the pattern of this world, but be transformed by the renewing of your* ***mind****. Then you will be able to test and approve what God's will is—his good, pleasing and perfect will. Rom 12: 1-2.*