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Biology of Belief

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"For what a man had rather be true he more readily believes."
Bacon

"You believe that which you hope for earnestly."
Terence

Introduction

I became interested in belief for several main reasons. In the first instance it was why my non-science friends had such difficulty with science and why there was quite a strong anti-science movement. It was a real puzzle for me as I believe science to be the best way to understand how the world works. This led me to the origins of science with the Greeks and the unnatural nature of science. Related to the general absence in the belief of the scientific method was the belief in what I regard as the unbelievable, from angels to aliens to levitation and telepathy. How could people believe in things for which there seemed to be no reliable evidence? And then there was religion which affected me personally.

I have always found it a puzzle as to why people believe in things for which there is no real evidence. Such beliefs are universal – cultural anthropologists have yet to find a single society that does not have a longstanding and well-developed system of paranormal beliefs. And our society is much the same if one includes religion, astrology, psychoanalysis, and many alternative medical treatments. We do not adhere to David Hume's principle that 'no testimony is sufficient to establish a miracle, unless the testimony be of such a kind that its falsehood would be more miraculous than the fact which it endeavours to establish'. Just the opposite; such beliefs are our natural way of thinking and may be part of our genetic makeup because they are adaptive. We have a fundamental need to tell ourselves stories that make sense of our lives. We hate uncertainty and for major life events find it intolerable.

The word ‘belief’ is not easy to define (Schacter & Scarry 2000). Neither philosophers nor scientists have succeeded. Distinguishing belief from knowledge is essential but not easy. One does not believe that this is a page in a book – it is common knowledge about the world. In general, belief is about things that affect our lives, especially causes. Belief is essential for making sense of the world and explaining the causes of events that are important for us. They are also about moral issues, good and evil actions and people. A characteristic of belief, unlike common knowledge, is that one always assigns it a true and false value; how right or wrong it is. But it sometimes comes close to knowledge – for those who have seen ghosts, that is knowledge, to the others it is unbelievable.

A major feature of belief is that it is used to guide how we behave and so it is at the very core of our existence. One can think of it as an explanatory tool. When one refers to someone having a belief we think we can reliably predict how that belief will determine their behaviour in particular instances. This view is technically called the intentional stance. This also implies that the person is aware of their own beliefs. Beliefs are held in one’s memory and can be recalled. We express belief even when, all too often, we do not have the evidence, knowledge, facts, to support them. Moreover, emotions can undoubtedly influence our beliefs.

In 1739, David Hume put forward his doctrine about causality. Our idea of causality, he claimed, is that there is a necessary connection among things, particularly actions. However, this connection cannot be directly observed, and can only be inferred from observing one event always following another. He thus argued that a causal relationship inferred from such observations cannot be rationally inferred. This is a problem for philosophers alone as it is obvious what the cause is if I cut my hand with a knife. More relevant, causal beliefs are indispensable to human behaviour and particularly technology.

There is a nice paradoxical quote from Tertullian: “I believe because it is impossible.” And Hume argued that it “is an act of mind which renders realities more present to us than fictions”. His example is that of two readers of a book, one believes it to be a true history while the other just a story. Again that three plus three is six is not a matter of belief. Probably the same could be said of all, well nearly all, of mathematics since it can in every case be demonstrated. There cannot be anyone who could dispute the validity of Euclid’s planar geometry unless they were to totally abandon rationality. When we believe something there is an element of uncertainty.

Belief is a property of the brain which is made up of nerve cells and whose function is totally dependent on the signals between the billions of nerve cells. But what is the function of the brain itself? Just one, to control movement, so this must be at the core of any attempt to understand belief. Movement was present in our ancestral cells which gave rise to multicellular organisms some three thousand million years ago. They could move either with whip-like structures that are a bit like oars, flagella and cilia, or by amoeboid movement, the cells extending processes at their advancing end and then pulling themselves to where these attach. This movement was a great advantage in finding food, dispersal to new sites, and escape from predators. A key point is that the protein molecules that produced these movements are the precursors of all muscle cells. Muscle-like cells are found in all animals including primitive ones like hydra, a small fresh water creature with just two layers of cells arranged in the form of a tube which uses the movement of its tentacles to capture prey.

In higher forms like flatworms and molluscs, muscles are well developed and the ability to move is a characteristic of almost all animals. One only has to think of such forms as diverse as earthworms and squirrels. Again this ability to move is fundamental to animal life – not just finding food and shelter but the ability to escape from enemies. And this is where brains come from. The first evidence for brain-like precursors are the collection of nerves that are involved in controlling movement like the crawling of earthworms or flatworms. Getting the muscles to contract in the right order was a very major evolutionary advance and required the evolution of nerves themselves. Here we find the circuits of nerves that excite muscles in the right order that are the precursors of brains.

The first advantage of the ability to move was most likely dispersal and so finding new habitats, but once the ability to move had evolved it opened up the possibility of new advantages such as finding food and avoiding danger. For the first time it became necessary to perceive the nature of the environment in order to decide when and where to move. There was a need for senses. Light sensitive cells are present among single cell organisms so it is not too difficult to imagine light coming to control movement and then later came the eye. Of course there were other sensory systems such as could detect touch, light, temperature and odours. All these had and have but one function and that was to control movement. Emotions came from helping us make the appropriate motor movements like flight or attack. And that is why plants do not have brains. They are very successful but they do not need them for they neither move significantly or more importantly, exert useful forces on their environment. No muscles, no brain.

Consciousness, in the sense that we are aware of what we are doing and can decide how to behave, I propose, has only one function and that is to control movement. There is no human or animal emotion that is not ultimately expressed as movement; in fact the argument is somewhat circular for what else is human behaviour? Sense organs have but one function, to help decide how to move. The evolution of the brain that gave us beliefs is no more than an expansion of the original circuits that controlled movement in our ancient animal ancestors.

Animals

There are overall cognitive similarities in mammalian and especially primate cognition; they all remember their local environment, take novel detours, follow object movement, recognise similarities and have some insight into problem solving. They also recognise individuals, predict their behaviour, and form alliances. However, they have no understanding of intentionality of other animals or the causal relationships between inanimate objects. They do not view the world in terms of hidden 'forces' that are fundamental to human thinking. They do not understand the world in intentional or causal terms. They also neither point, hold up objects, or offer objects. By contrast causal understanding is unique to humans. For humans the weight of a falling rock 'forces' the log to splinter, and one may in looking for food be 'forced' to look under the log. When did it occur, and was human causal understanding the keystone on which it evolved?

What Povinelli (2000) has shown is that while many of the abilities to perceive and move are similar to humans, primates like chimpanzees do not have concepts of variable causes to explain interaction between objects. One might have thought that Wolfgang Kohler's experiments with chimpanzees showed just the opposite. His chimpanzees, some eighty years ago, could sometimes stack boxes on top of each other to get a banana nailed to the ceiling. But Kohler himself claimed that the chimpanzees had no knowledge of the forces involved. For example, they would try to place one box on another along its diagonal edge; and if stones were placed on the ground so that the box toppled over they never removed the stones.

In an experiment by Povinelli's group, apes could choose which one of two rake tools to obtain a food reward. The choice was between dragging the food placed in front of the rake along a solid surface, and dragging it over a large hole into which the food would fall. Only one of six apes was successful and this may have been due to success by chance at the first trial. However the apes do learn by trial and error. They also did badly with an inverted two-prong rake that could not move the food and on tests with flimsy tools. Again when presented with getting a banana by pulling on a rope they could not distinguish between the rope just lying on, or being very close to the banana, and when it was actually tied to the banana. They have no notion of physical connection as distinct from mere contact.

It is not that chimpanzees lack visual imagination or are unable to learn quite complex tasks by trial and error, but they do not reason about things. They have, for example, no concept of force, and even worse, no concept of causality. They do appreciate that contact is necessary in using a tool to get food, but will focus only on the contact and not the force it can generate on the desired object. A hook at the end of the stick is not perceived as being the way to get the reward. Tomasello (1999) illustrates the differences in chimpanzee and human thinking with the claim that an ape seeing the wind blowing so that it shakes the branch and the fruit falls, would never learn from this to shake the branch to get the fruit.

Learning to do a task does not require understanding. Weak causal knowledge is the result of associative learning – one event is frequently followed by another one. Usually many repetitions are necessary as in learning by a rat to press a lever for the reward of food. By contrast, strong causal knowledge is based on interpretation and may relate to events widely separated in time or space: damage to the car brake later leads to an accident. The former does not require a belief in cause and effect whereas the latter does.

In a series of key experiments (Povinelli 2000) primates were set the task of using a stick to push food out of a clear tube. In one case the tools are of various sizes, some being too short, too thick, or too flexible. An understanding of basic forces should enable an individual to choose the right tool. Apes can do it but only after much trial and error. In another test there was a small trap under part of the tube and to get the food the subject needed to push the food from the end of the tube that avoided the trap. Chimpanzees failed to do better than just chance over seventy trials. Then, eventually when the animals had learned to do it, the tube was rotated through 180 degrees and so the trap was not on top and had no effect on getting the food. But they continued to push the food away from the trap. By contrast two- to three-year old children understood what to do from the earliest trials. However the chimpanzee Kanzi, a banobo ape, showed remarkable skills. He learned to create and use stone tools to gain access to food. He could make stone flakes and evaluate them after observing a human striking two rocks together. On his own he created flakes by throwing one rock onto another on the ground, suggesting that he may indeed have had some primitive concept of force.

It is not clear whether apes poking sticks into termite mounds and so extracting them is by imitation or learned by trial and error. There is some evidence that wild chimpanzees use sticks and stones as weapons against other males or other apes like baboons or humans. Also monkeys and chimpanzees place thick skinned or armoured fruits on an anvil of stone and smash them open with another stone or a heavy branch. But there is no evidence in the wild of them modifying the stones. They do nevertheless leave their 'hammer' behind near the fruit trees and return to use them the following day. A female chimpanzee has been seen to climb fruit trees with long sharp thorns by ripping off the bark from a tree and using pieces as sandals to protect her feet. At a height where there is much fruit she takes some bark to use as a comfortable seat. The nut cracking technique of the Tai chimpanzee requires about ten years of practice to master. There is good evidence that chimpanzees can recognise themselves when they look in a mirror – they pull faces, and pick at their teeth and ears, they explore themselves. This may help them with tool use, as it distinguishes their action from that of the tool. This could have been an early step on the pathway to causal belief.

In its simplest form a tool is used for some very basic essential purpose such as to acquire food, fend off a predator, or fend off a competitor (Schick & Toth 1993). Natural tool as used by apes are sticks or stones but a tool modified intentionally is an artifact and chimpanzees do show some evidence for this by trimming twigs and crows can choose the right stick to get food from a trap. Note too the mud wasp, which holds a tiny pebble in its jaws to tamp down mud in nest building; finches in the Galapagos use a cactus spine to probe for termites; the Egyptian vulture drops rocks on to ostrich eggs to break them; others use stones to crack open clams. But most impressive is the tool selectivity of the New Caledonian crow in getting food out of a pipe (Chappell & Kacelnik 2002).

Child development

Causal belief is now regarded by developmental psychologists as a developmental primitive – it is a fundamental feature of children's development and behaviour (Corrigan & Denton 1996; Baillargeon et al. 1996). An explanatory drive is at the core of a child's development and is as important as the drive for sex or food. We want to understand what is happening in the world around us. This drive consumes children in their first three years. Piaget's (2001) studies on children led him to the conclusion that at an early stage in the development of children they had what he called feelings of participation which were accompanied by magical beliefs. The sun follows the child and the child's movement makes the sun move, and the wind can obey one. Who, they wonder, is in fact pushing the wind? Do the clouds make the wind? Indeed he thought that explanation of movement is the central point to which all the child's ideas about the world converge. Moreover, at an early age, the child endows nearly all bodies with a certain ability to move spontaneously. Later in development, physical causality is invoked. Influential as these ideas have been, the more recent evidence offers rather little support for them. Piaget held that development of understanding in infants was a result of infants' active manipulations and explorations of objects as they construed reality through converging lines of sensory and motor information. However, there is now much evidence that infants have some understanding about causality at a time before they have had experience of such manipulations.

Arm movements made by newborn babies are usually dismissed as unintentional, purposeless, or reflexive (van der Meer et al. 1995). Spontaneous arm-waving movements were recorded while newborns lay supine facing to one side. They were allowed to see only the arm they were facing, only the opposite arm on a video monitor, or neither arm. Small forces pulled on their wrists in the direction of the toes. The babies opposed the perturbing force so as to keep an arm up and moving normally, but only when they could see the arm, either directly or on the video monitor. The findings indicate that newborns can purposely control their arm movements in the face of external forces and that development of visual control of arm movement is underway soon after birth. One source of the concept of force comes from the infants' own actions. The actual experience of producing a movement must play a key role. Pulling a string attached to a mobile at six months is under their control.

Newborn babies purposely move their hand to the extent that they will counteract external forces applied to their wrists so as to keep the hand in their field of view. In addition, newborns move their arms more when they can see them. These results are in agreement with earlier findings on pre-reaching and hand-mouth coordination in newborn babies and counter the view that neonatal arm movements are purposeless, unintentional, and reflexive and can simply be described as excited thrashing of the limbs. Instead, while watching their moving arms, newborn babies acquire important information about themselves and the world they move in – information babies need for later successful reaching and grasping beginning at around four to five months.

By before three months, infants expect a stationary object to be displaced when hit by a moving object and by five months know how far it should move. They learn the key principles and are aware that the size of an object affects whether it can pass through a gap before they realize that it also affects the size of a container it can fit in or the size of a bulge under a cloth signals the size of the object underneath.

Agents are perceived by children as objects having causal properties with a renewable source of energy or force (Leslie 1996). They act in pursuit of a goal, and their behaviour is determined by their cognitive properties. Force is a primitive mechanical notion – not the same as the scientific concept of force. The basic idea is that when bodies move they possess force and this can, on impact, be transmitted to other objects which can receive or resist. It is a bit like transitive verbs in language. Infants of six months understand that a ball hitting another causes it to move. They also understand by 28 weeks the difference between a hand moving a doll when there was and was not contact.

There is a gap of some eight months in the developing infant's ability to go from understanding that an object can be retrieved by pulling on the cloth on which it is resting to retrieving the object with a stick; the former is at around ten months. At this early stage they do not use a stick with a hook-like end to get the toy unless it is already placed within the hook. By 18 months they will use a 'tool' as a rake to pull a toy out of reach towards them. Think how hard this is for apes. By three and four they can provide explanations for simple mechanical devices and how a system of balls rolling down a system of tubes will behave. They have moved from believing that two objects must have a point of contact between them, to using their knowledge to put the tool in contact with the object.

Leslie (1984) has proposed that infants just a few months old already perceive of the world as being composed of cohesive solid bodies that keep much the same form when stationary or moving. In addition they have a special system in their brains – a module perhaps – for mapping the energy of these objects, some measure of their mechanical properties which can be likened to the concept of force. This concept gradually develops and is constantly present at two to three years. At this age, children know that a moving object – a ball – can make another move on impact. It is this concept of mechanics which may be the key brain property that originally evolved in the early humans for as I repeatedly argue, it was essential for making complex tools.

Babies, one year old, already point at things – something no ape, child or adult, ever does (Gopnik et al. 1999). They do this to get a toy before they can talk. It means that they know that what they see some other person can also see. Babies learn that their own movements can cause motion. If a ribbon is tied to the baby's foot and the other end to a mobile, they rapidly learn to kick and so make the mobile turn; a week later they will remember how to do it. By 18 months they will use a 'tool' as a rake to pull a toy out of reach towards them. Think how hard this is for apes. By three and four they can provide explanations for simple mechanical devices and how a system of balls rolling down a system of tubes will behave.

A nice example of babies' concept of cause and effect is provided by their using a new way to execute a task having seen an adult do it; they do not simply imitate. If 14 month old infants see an adult illuminate a light box by bending over and touching it with the head they will light the box one week later. However, they will more often use their head if in the original demonstration the demonstrator's hands were free, but if they were occupied – holding a blanket – then they use their hands more often. Thus rather than just imitating they were inferring that when the hands were free and not used, this must provide some advantage.

Autistic children have difficulty in understanding other people's minds but with the genetically determined Williams disorder, it is incomprehension of the physical world that is so disabling. This is a nice example of how our genes control development of the brain so that we do come to understand physical causality.

By three years, children can distinguish between physical objects and an imagined one (Wellman 1992). They know you cannot touch an imagined piece of cake. Beliefs describe both a mental state and the state of the world – they attempt to capture something real. Fantasy is not belief. Three year olds had little difficulty in predicting a character's action in accordance with that character's beliefs. So in the story where Sam is looking for his puppy, which may be under the porch or in the garage, Sam thinks his puppy is not in the garage, so where will he look? Contrary to Piaget's emphasis on magical thinking children rarely resort to it but they do acknowledge magical outcomes as a special class of phenomena (Harris 2000). This usually occurs when faced with puzzling processes. They also accept magical transformations in fairy tales.

Two and three year olds can tell lies and this means that they need to understand the difference between what the child and someone else believes. They need to understand belief. But they are terrible liars because they do not yet understand what it takes to make someone have a false belief. 'I did not cross the street by myself' the three year old shouts from the other side.

Children can provide nice examples of how they distort their own observations. They will cook their observations in order to maintain consistency with beliefs. Karmiloff-Smith (1992) has shown that if you take a heavy lead weight and put it on the sponge then on the table, the children say they can see the table went down then came back again. Experiments about balancing rods that are asymmetrical show there's a certain age in which children cannot balance it, because they think the way to balance things is to put the balancing point at the centre of the rod. But if they try with their eyes closed they have no difficulty whatsoever. They have a theory and are not interested in the evidence.

Across all languages when children begin to talk the most common topics are presence of people or objects, exchange of possessions, movement of people and objects, the activity and intentions of people. Almost all of these involve either intentional or causal events – causality is implicit in verbs. Later their stories will be full of causal and intentional links. By the age of four they understand that other people not only have intentions but beliefs which may or may not be expressed but which will affect how they behave. And later can say "Does she think that I like X?" In all languages the word causality plays an important structuring role – causality is a fundamental aspect of human cognition. Even "You broke the glass" is causative. Sign systems created by deaf children of hearing parents in American and Chinese culture shared a striking number of structural similarities and are considered to be innate. Much of children's causative beliefs reflect the culture in which they grow up. How does this reflect in their beliefs about physical causes? But even American children believe that rocks are pointed so that animals will not sit on them and break them.

It is only from four years that children have a proper concept of quantity, including numbers. There are lots of studies going back to Piaget about the difficulty children have at a certain age with what he calls conservation. If a certain volume of liquid is put into a long thin glass and exactly the same amount of liquid into a short fat glass, at a certain age they will say the tall thin glass contained more liquid. Common sense in a way. It takes them quite a long time to realise it doesn't matter into what glass it is poured.

The relationship between perception and physical cause is not simple. Five year olds understand that fan A cannot blow out a candle because of a shield, and when after five seconds fan B is turned on and the shield moved in front of it, it is fan A that blows out the candle. Only by nine to ten do children understand mechanical mechanisms.

Questions asked by preschool children provide insights into how they think about cause and effect (Callanan & Oakes 1992). Even before three years toddlers talk about causes with surprising sophistication. The earliest questions relate to the social rather than the physical world. Quite often questions arise in situations where their expectations were violated or unexpected. Typical among questions are those that ask 'how' – how do they make statues? 'why' – why does it rain sometimes? 'what if' – what if someone's head were cut off? 'what for' – what is this stick (the gear shift) for? 'How'-questions increased between three and five years as did interest in biological phenomena, whereas interest in physical phenomena decreased. Typical questions are: ‘why can we see the stars?’; ‘how do people die?’. With respect to social interactions (Dunn 2000) a three year old child grasps the causal basis of its own action and then develops understanding of others. They initially explain people’s behaviour in terms of their feelings and desires.

When asked where babies come from, some three to four year olds see it as a geographical question – you get them from hospitals, or buy one. Others think of it in terms of making the baby – the mother swallowing something and it is made in her tummy (Bibace & Walsh 1980). A quite widespread belief is that illness is a punishment for wrongdoing and that they are to blame for their illness, but there are also beliefs about germs and food being causes. The beliefs fit with Piagetian stage – pre-logical, concrete logical, formal logical. The first is associated with illness having an external cause – the sun gives one a cold, trees too; God gives one measles. At later stages contamination is a characteristic belief.

Tools

The fundamental difference between humans and other primates is that they use tools and have technology. It was technology that drove human evolution as it offered wonderful new ways of getting benefits from the environment. For tool use a concept of cause and effect, a belief in forces, was essential. Julian Huxley was absolutely right when in 1941 he said: “There is no essential difference between man’s conscious use of a chipped flint as an implement and his design of the most elaborate machine […]”

The earliest Homo appeared about 1.8 mya with a brain size of 600 cc – 200 cc more than an ape. Size gradually increased to that seen in Neanderthals 100,000 ya. Sapiens emerges as recently as 35,000 ya. The human hand differs from apes as it has a longer thumb, less curved finger bones. It is capable of both a power grip and a precision one – it can be used to wield a club and thread a needle. It is also important to recognise that it is not just the shape that matters but the ability of the brain to control complex movements by the hands. Human manipulative skills are much greater than those of apes and this is genetically determined because it is an intrinsic property of the brain. These skills are essential for technology.

Toolmaking ancestors had to be competent field geologists in recognizing which rocks were suitable for toolmaking. Some 2 million years ago humans had acquired the not inconsiderable skill to make stone tools. Even for a modern human it requires several hours to master making such tools. A carefully controlled sharp glancing blow is required to initiate a fracture in making the tool. How could the earliest stone tool technologies have evolved? One possibility is that early humans using stones in a manner similar to chimpanzees to crack nuts with a stone, would have smashed the stone by mistake and been impressed by the sharpness of such fragments. Perhaps they cut their hand by mistake. This could have opened the possibility of using the flakes themselves as tools for cutting. Early humans were probably more involved in scavenging than in actual hunting. Perhaps they used stones to chase away hunters and dogs that had killed a wildebeest and then their tools to cut up the body. Butchery is an important skill. Tools were also used for digging to get at underground food such as roots, tubers, and corns. Tools would also have been essential for working the skins of animals. These would be used for clothing, blankets, water containers and carrying devices. The earliest evidence for such uses dates back about 300,000 years.

Around 1.5 million years ago, larger and more standardised tools were made – the so-called Acheulan named after a site in France. There was over the next million years a gradual shift from large hand axes and cleavers to smaller tools made of flakes. There is also evidence that some 50,000 years ago they were hafted, that is fitted onto a stick or handle. This is a major advance because I wish to argue that one cannot make such a tool – joining quite different pieces together – without having the concept of cause and effect. One would have to understand that the two pieces serve different purposes and imagine how the tool could be used. One could not discover such a composite tool by chance. It was the beginning of the technological revolution that actually makes us human and then drove human evolution. It thus should come as no surprise that it was at this stage humans mastered fire which itself was so valuable for cooking and warmth. Again the idea of cause and effect was an essential prerequisite.

Over the last 40,000 years, bone, antler and ivory were fashioned as tools, particularly for making pointed tools as in spears and harpoons. About 20,000 years ago, bows and arrows make their appearance together with needles and sewing. Early hominids transported materials, food and stones over distances even over ten kilometres – chimpanzees do not do so (Schick & Toth 1993). Our ancestors were conserving large quantities of meat and the stone tools were used to cut up carcasses. To achieve the symmetry and form of the hand axe a concept of cause and effect was certainly there. Great care has to be taken in the initial selection of the stone and detaching the flakes. Planning ahead is essential, and they also needed an understanding of the environment they lived in, both animals and plants. They thus most likely used anthropomorphic thinking to predict how animals would behave – this is true of modern hunters.

Casual ethnographic observation supports the generalisation that fruit collection is easily learned, extraction skills require more time to develop, and hunting is the most difficult foraging behaviour. It is clear that human hunting differs qualitatively from hunting by other animals. Unlike most animals, which either sit and wait to ambush prey or use stealth and pursuit techniques, human hunters use a wealth of information to make context-specific decisions, both during the search phase of hunting and then after prey is encountered. They propose that hunting, as practised by humans, but not necessarily by other predators, is exceedingly difficult to learn and requires many years of experience. Observations of hunters in size different groups suggest that it is not marksmanship, but the knowledge of prey behaviour and remote signs of that behaviour such as tracks and vocalizations that are the most difficult features of human hunting. All this requires causal beliefs.

Which served as the prime mover in the evolution of the human brain – technology or social behaviour (Gibson & Ingold 1993; Wynn 1996)? And what were the adaptive advantages that lead to the evolution of the brain to have causal beliefs? What is the relationship between language, tool use and causal beliefs? There may have been a mutual positive feedback between all three. As long ago as 1927 de Laguna doubted if complex tool-making which requires planning could have occurred without language. Language, which is at the heart of our beliefs, is characterised by three features – reference, displacement and productivity. The first language may have consisted of manual signs imitating the operations of tool use – vocal expression may have come later. But as always there is a striking lack of thinking about cause as a key mechanism. Natural selection for one of the advantages of language, toolmaking and intelligence might have served to haul along the others. It is striking that tool use and language both appear in children around 18 months. All three involve what Calvin (1993) has referred to as stringing things together. Could this also refer to causal thinking? He examines the idea that throwing evolved to capture prey. It provided action at a distance and improved accuracy and distance would have been adaptive evolutionary steps. There could have been a transition from sticks to stones to a fast hand axe which might spin and inflict serious damage. Aphasia and apraxia may be related. Aphasics have difficulties in finding and using words, with apraxia it may be difficult to carry out purposeful movement.

Throwing required improved control of arm movements for accuracy and throwing for hunting, became linked to pointing, a key early gesture. Then pointing could have become associated with vocal grunts. Moreover, movements of the arm could distinguish predator from prey. Language may have had its origins in motor control. Evolution cannot invent something quite new but can only tinker with what is already there. As has been argued, the neurological basis of motor control has very similar features to the syntax of language. Just consider how the same muscles – 'words' – can be activated in an astonishing variety of movements – 'sentences' (Lieberman 2000).

But what were the changes in the brain that enabled all this great advance to occur? Human manipulative skills are not much greater than apes but the difference lies in how these are used. Apes can trace writing but they do not use motor skills in the same way as humans and this is genetically determined because it is an intrinsic property of the brain. The key difference lies in not just the increase in brain size but in the way the brain is organised in relation to motor control. There has to be both analysis and reflection as to what to do and then the ability to do it, and this involves new cognitive processes. This is associated with the significant enlargement of the associative areas of the frontal neocortex.

Religion

Once belief in cause evolved in relation to tools then it was inevitable that explanations for events that affected human life should be sought. Health and death were at the core. It was fear that produced the gods. Explanation is to cognition as orgasm is to reproduction: it is an intensely pleasurable experience that marks the successful completion of a natural drive. Uncertainty about important events can create severe anxiety. Given the extraordinary ability of the human mind to make sense out of things, it was quite natural to make sense out of things that have no sense at all.

There is no society that does not have some paranormal beliefs – and these relate to behaviours completely at variance with what science understands about the nature of the world. This may reflect a claim that "[…] a full apprehension of man's condition would drive him insane". Beliefs relate to health will be treated separately as will religion which is a very special case. Tylor asserted that magic was based on the general human propensity to associate ideas – magic was an erroneous application of these ideas. Moreover as Schumaker (1990) remarked "When the ratio of what is known to that which needs to be known approaches zero, we are inclined to concoct 'false knowledge'".

Uncertainty is unacceptable and religion provides a major source of explanations. Religion is the commitment to culturally postulated super human beings or super human objects. When humans made their very early attempts to explain events that mattered to them, it was natural that they should have assumed that some sort of human agency was the cause; the one force of which they were certain was that created by humans themselves. It is thus inevitable that the Gods should have some, often many, human characteristics. This also had another advantage, for if the Gods had some sort of human form they could be appeased. This gave our ancestors two adaptive advantages: uncertainty, and thus anxiety, was removed, and there was an animate agent that might be appeased in some way. Might it not be that those with this disposition of thought survived better than those who did not have such beliefs, and that it thus became genetically determined?

Levy-Bruhl, the anthropologist, puts the key idea very clearly when he states that "no essential difference has been established between primitive mentality and our own. There is a mystical mentality more marked among primitive societies than our own, but present in every human mind. A sense of an invisible power and a reality other than our normal reality […]". And it is an advantage of mystical beliefs that the less one understands the more one can explain.

Key religious beliefs build on but also violate our ordinary causal ideas. In many religions there are special beings that hear and receive messages and are also, for example, able to read our minds, pass through solid barriers, and to be immortal. A shaman burns tobacco leaves in front of a row of statuettes and asks them to go and cure a friend whose mind is being held hostage by invisible spirits; a witch can hit a person with invisible darts and so poison their blood; an animal is sacrificed in a particular way to appease dead people (Boyer 2001). These are typical of a wide variety of religious beliefs. What is it about religious beliefs that characterises them and gives them a special quality? Boyer thinks that the answer is to be found in the way the mind works. He does not accept explanations that religion explains puzzling experiences, the origin of things, why there is evil, suffering and death, or allays anxiety. Boyer's suggestion is that the information contained in a sentence describing a religious belief will contain a kind of contradiction because they contain counter-intuitive information. For example ghosts have many of the features of persons but have no material body; gods are persons with extraordinary powers; statues are inanimate but can hear one's prayers. And the Christian God has special cognitive properties – no event in the world can escape his attention. God will hear your prayers wherever you are. These beliefs may be considered similar to others like Santa Claus or fairies. But the difference, and it is fundamental, is that while they may be interesting or amusing they do not have an important effect on people's lives. They do not really matter. That is the distinction between the supernatural and religious beliefs.

Similar views have been expressed by the historian Robin Briggs (1996) in relation to his study of craft in the l7th century. Very few people are content to accept that blind chance plays a large part in their lives; they seek reasons and logical connections even when these do not really exist. The human mind, far from being infinitely malleable, tends to impose certain inbuilt patterns on experience. The presence of strikingly similar witchcraft beliefs in most known societies raises the relationship between witchcraft and human universals. Are, he asks, human beings born with a specific inherited mechanism for detecting witches?

Religious concepts are used by people when there is a need for them. They are used to account for a particular occurrence like someone's death or an accident or a drought. For example, the Kwaio in the Solomon Islands believe that good crops show that the ancestors are happy with the way they are behaving. While the ancestors play a key role in determining their fortune they are very vague as to where the ancestors live or how they exert their influence. This is common – just how religious agents perform their good and bad works is rarely a matter for reflection or interest. Again, the Fang in the Cameroons attribute accidents to witchcraft – falling from a tree or a canoe overturning. But who the witches are and how they operate is left as a mystery.

Death is accounted for in some or other way in all religions. Death needs an explanation and religion can provide it. We go to heaven or hell, our shadows persist, we become ancestors. Or, as one friend said to me when I went through a period worrying about dying "It is the next great adventure". Most explanations are comforting but not all, just contemplate hell.

Freud developed a psychoanalytic theory of religion based on the Oedipus complex – the struggle between father and son. He later developed it as follows: "Religion would thus be the universal obsessional neurosis of humanity; like the obsessional neurosis of children, it arose out of the Oedipus complex, out of the relation to the father […] religion brings with it obsessional restrictions, exactly as an individual obsessional neurosis does, on the other hand it comprises a system of wishful illusions together with a disavowed of reality, such as we find nowhere else but […] in a state of blissful hallucinatory confusion". A description that in some ways could be applied to psychoanalysis itself.

William James claimed that "how to gain, how to keep, how to recover happiness is in fact for most men at all times the secret motive of all they do". How do their beliefs help or hinder in this plausible scenario? Religion does help because it promotes optimism and hope. It also provides believers with a sense of purpose and meaning in life.

Believing that God is in control does mean that people believe that they have themselves no control. The evidence is that they have do have control over their lives and God and prayer provide an important set of tools. They also believe less in chance governing their lives. There is good evidence for a positive correlation between being religious and being happy. This may in part be due to the religious assigning to God the cause in matters relating to health and death. Prayer is very important because the individual believes that he or she really can influence what will happen. Such people believe they are empowered to directly communicate with the source of all control and change.

Religion remains very much a part of everyday life in probably the majority of the world's population, although its influence has declined in industrialized countries. Yet even in the United States, only around 3 % of the public describe themselves as agnostic or atheist.

There are claims that link spiritual and religious experience to the activity of a specific region of the brain. A variety of brain imaging techniques have been used. One model proposes that activation of the autonomic nervous system – the one which is not directly under our control and which controls our heart rate and blood flow, for example – acts on regions of the brain responsible for mental experience such as the temporal lobes. These lobes are thought to modulate feelings and emotions. Evidence for a role of the temporal lobes in religious experience comes from epilepsy located in these lobes and their association with sudden religious conversions. It is suggested that the visions of St. Teresa may have been associated with temporal lobe epilepsy. There has been some suggestion that the lack of cerebral asymmetry somehow encourages what has been called "magical ideation".

Although the studies should be regarded as tentative, the evidence is that there is an inverse relationship between pain intensity and religious beliefs and religious attendance (Koenig et al. 2001). This is consistent with the findings that those within a religious community have better mental health, possible due to social support. There is also evidence that religious activities reduce psychological stress and promote greater well-being and optimism and so help to reduce the bodily effects of stress like that on the heart. Religious beliefs and behaviours are inversely related to several of the risk factors for heart disease. Lower blood pressure, for example, has a positive association. The death rate among Mormons, from heart disease, is about 30 % lower than the general American.

Religion does help patients with illnesses that range from heart disease to AIDS. Many believed that God helped and that there would be life after death. There is a Gallup poll which found that almost 80 % of Americans receive comfort and support from their religious beliefs. By contrast 80 % of Swedes had no degree of religiosity. It is for Americans that religion helps with coping with stress. Similarly, religious belief reduces the risk of depression and speeds recovery. In relation to death the evidence that religion can relieve anxiety is not all that persuasive, unfortunately.

Health

Most religions teach that suffering is to be expected and could even be a valuable experience. Belief in its meaning is essential – if the meaning of suffering is clear it is easier to bear. This is fundamental and one of the primary aims of beliefs – uncertainty about causes and events that affect our lives is intolerable. Biblical medicine of the Old Testament is entirely supernatural and religious. Early Christians following Jesus believed that sickness whether or not caused by sin, could be healed by prayer. Even in the West between 200 and 1,700 almost all mental disorders are understood in terms of demonic possession. Pain and suffering is seen, in Judaism, as part of the fate of mankind and can be punishment for sin. For Muslims there is a similar view and it can be thought of as a means of instruction on how to behave. Both religions instruct their followers to fight pain as it is not part of God's paradise. Similar views are held by Christians. The presence of pain on earth was God's wishing to heal swellings of pride, to provide punishment for sin, and to give a reminder of mortality. One can see what a valuable explanation it provided to the more or less helpless individual suffering from severe pain.

Early Chinese medicine believed that life is controlled by spirits and demons and that the ancestral spirits need pacifying in order to avoid disease. Classical Indian medicine is Ayurvedic, which is based on three bodily humours not unlike those of Galen, and seven bodily constituents including blood and semen. In early Mesopotamia disease was diagnosed on the basis of the liver of sacrificed animals, the liver being the seat of life. The hand of God was everywhere as well as spirits, sorcery and malice. Illness was also an omen. For the early Egyptians magic was key and amulets and chants were widely used together with a variety of medicines.

With the Greeks we have for the first time a completely different approach, as it is from them that all science comes. Hippocratic medicine is specifically based on natural causes and is totally independent of the supernatural. The received idea of, for example, a divine origin for epilepsy is totally unacceptable. "Men regard its nature and cause as divine from ignorance and wonder, and this notion is kept up by their inability to comprehend it." What a wonderful quote from 'On Sacred Disease' (c 410 BC). There is not a hint in Hippocratic medicine of the Gods being able to cure a disease. At last there was an appeal to reason. Humans were governed by the same laws as those that governed the physical world. From this came Galen's four humours which were so dominant for the next two thousand years.

Bloodletting occurred for nearly 2,000 years; because people had this belief of the four humours and somehow if you let the blood out everything would be better. It killed millions of people. It was only in the 19th century in France that a double blind clinical trial was done for the first time and showed that blood letting did not work.

Turning to current practices world-wide there is significantly only a small range of theories about physical illness. Almost all theories interpret illness as an injury and so assume that it involves some form of aggression, and not an accident. The illness is inflicted by some human or superhuman agency. Looking at 1,300 different cultures 139 were examined in detail and supernatural beliefs were found to fall in three classes: mystical, in which illness is the automatic consequence or some act; animistic, the cause is some supernatural being; and magical, the cause being a malicious spell. These explanations are very different from theories of natural causation which see the illness as a normal activity gone wrong such as due to infestation by worms. The Western view is that nature is physical and a reductionist approach is common, though seen by many as dehumanizing. But alternative medicine, with its emphasis on 'wholeness' has become increasingly attractive and is now widely used.

The Zande belief in witchcraft as Evans-Pritchard (1976) made clear, in no way indicates that they do not believe in physical causes and effects in much the same way as we do. Belief in death from natural causes and belief in death from witchcraft are not mutually exclusive; rather they supplement one another, the one explaining what the other can not. They accept a mystical explanation of the causes of misfortune, sickness and death but turn to other explanations when social forces and laws require them. Thus if a child becomes ill the cause, not witchcraft, could be that the parents had broken a taboo like having sex before the child was weaned. Again incest could result in leprosy in the offspring. Witchcraft will be invoked to explain why breach of a taboo has not been punished.

It is about health that the Zande most often consult their oracles. Even Zande in good health will consult an oracle at the beginning of each month about their health. A family of a sick relative will consult the oracle to find out who is bewitching the ill person. The means by which the oracle determines who the witch is can be complex and may involve poisoning fowls and using a rubbing board. Once the witch is identified there is a further complex social procedure for trying, in public, to persuade the witch to stop her operation. In addition, every illness has special medicines for treating it.

A key aspect of belief in relation to health is the placebo effect (Evans 2002), the power of the mind in relation to health. One incident in World War II illustrates this. Henry Beecher, an American anaesthetist working at the front line, ran out of morphine. A nurse injected a soldier with severe injuries, with salt water, and the patient settled down and felt very little pain, just as if he had been given morphine. From further work in 1955, Beecher claimed that placebos were capable of producing gross physical change. Many of the studies were flawed as there was no proper control group – those who received no treatment at all and who could improve without treatment. Indeed there are those who have examined the trials carefully and concluded placebo is no more than a myth. The trials must include no treatment to compare with the placebo. Yet there is very good and reliable evidence that all sorts of pain – headaches, post-operative pain and even a sore knee, could be relieved with a sugar pill placebo. In one trial with ultrasound for post-operative pain following tooth extraction, neither doctors nor patients knew when the machine was on. Compared with those who had no treatment, all treated with 'ultrasound' did better. There is also positive evidence for a placebo effect with angina – some patients had their arteries exposed but not treated and yet they improved as much as those who received actual surgical intervention. And in the case of drug treatment for depression there is also strong evidence for a placebo effect. It may be that placebos only are effective in those disorders that involve an acute phase response in which the immune system can play a role. With Parkinson's disease a placebo, like a drug, increased dopamine levels in the brain.

Unintentional communication between doctor and patient can influence the placebo response. Patients who had undergone tooth extraction were given a pain reliever, a drug that increased the pain, and a placebo – just saline. They were however divided into two groups, one with all three randomly assigned, while in another the pain reliever was not included. While the doctors did not know who was getting a particular treatment they knew which group they were in. Those on the placebo in the first group had much greater pain relief than the other – clearly the doctor's expectations affected them in some subtle way.

The other, and unpleasant, side to the placebo effect is termed the nocebo. Nocebo involves getting ill or having unpleasant symptoms because of the expectation that this will happen. For example 80 % of hospital patients given sugar as an emetic vomited and asthmatics have had an attack caused by neutral inhalant which they were told would cause one, and cured by the same inhalant when told that it would help them. Medical student's disease is well known – many students begin to get the symptoms of the disease they are studying. It is also the case that depressed patients have a greater probability of heart disease because, perhaps, of their negative expectations with respect to their health. The most dramatic example is voodoo death which has been reported in diverse cultures in Africa, South America and Australia. Its success depends upon the victim knowing the spell, ritual curse, has been cast. Somatisation could be a related phenomenon.

A very large number of people use alternative and unorthodox therapies when they are ill. There are some 50,000 practitioners of alternative medicine, or complementary medicine which is a more favoured term, in the UK. About one third of the population make use of their services. Why are they so popular when most of them are at total variance with physics, chemistry and biology, as well as orthodox medical practice? Many general practitioners even provide complementary for their patients. A common feature of many of these practices is that they believe in some kind of special energy. They have taken a scientific term and used it in a way that seems to be totally inappropriate; but because the word is from science it gives it a spurious validity.

Paranormal

"When we say that someone shows common sense we mean to suggest more than that he is just using his eyes and ears, but is, as we say, keeping them open, using them judiciously, intelligently, perceptively, reflectively, or trying to, and he is capable of coping with everyday problems in an everyday way with some effectiveness." (Geertz 1993). It is when ordinary expectations fail to hold, when the Zande man-in-the-field is confronted with anomalies or contradictions, that the cry of witchcraft goes up. Supernatural agents can be very different – there can be one supreme God or many spirits or/and ancestors. And as Evans-Pritchard made so clear, many of the magical beliefs of the Zande in Sudan were sensible. They knew that termites could cause a mud house to collapse and injure the inhabitants – but what witchcraft could explain is why that house at that time and with those people inside. It is the particular event that is so important. Again, a young man running through the forest trips and hurts himself. Yes, he knows he did not look properly at the ground, but why not – witchcraft.

Telepathy and extra-sensory perception are believed in by many people but the evidence is simply absent and in contradiction with basic science (Alcock 1995). Some 30 % of Americans believe in ghosts and as many as one in ten has claimed to have seen, or had contact with a ghost. These experiences include not just ghostly apparitions but unusual smells, and the strong sense of someone or something being present. Wiseman (2002) investigated two locations that have a reputation for being haunted. Subjects had no prior knowledge as to which areas were classified as haunted, and those which were not. They did indeed have more unusual experiences in the so-called haunted areas. But this does not implicate ghosts as the variance in the magnetic field and lighting levels are much more likely to be the cause.

Lay theories about the cases of events are rarely explicit and practically never formal (Furnham 1988). If asked to provide an explanation lay people can do so but rarely in an explicit or formal manner. More often they do not know that their explanations have come from a particular set of beliefs and they are rarely if ever presented formally. They often confuse cause and effect and generally underestimate the importance of external factors and most often see people as the causes of events. The function of beliefs is probably to establish the cause and effect relationship between phenomena, which in turn enables one to apportion blame, praise or responsibility. In an attempt to make sense of the social and physical world, to see it as stable, orderly, predictable and understandable, people develop theories or explanations for phenomenon important in their lives. Three suggested functions and parts of lay theories are control, esteem and public approval. Common sense explanations often start with the specific but do not always correctly or appropriately generalise. Like other human drives, the explanatory drive comes equipped with certain emotions: a deeply disturbing dissatisfaction when you cannot make sense of things and a distinct pleasure when you can.

The primary aim of human achievement is not accuracy but the avoidance of paralyzing uncertainty. There is good evidence that people can hold two beliefs at the same time which contradict one another. And there is what Furnham (1988) calls the Barnum effect. That is that there is a sucker born every minute; the Barnum effect is that we accept vague statements as being specific for us whereas they apply to everybody. It is likely that graphology and astrology make use of this principle. Thoughts about the unbelievable may be both natural and adaptive and also genetically determined.

False beliefs

False beliefs reflecting neurological damage or mental illness are more common than one might hope. False beliefs can also be generated by the suggestions used in hypnosis.

Brain damage can result in confabulation – that is finding explanations for our experiences and conditions which have little relation to what has actually happened. Confabulation is probably closer to the way we normally think than we may like to believe. We want a story, a plausible explanation. A man with brain damage is in hospital. When asked by the doctor where he thinks he is, he replies he is at work. But, says the doctor, who are all these people in the ward. My employees, is the reply. But they are in bed. Yes, he says, we like them to be comfortable. Some patients have brain damage resulting in poor memory and that can be associated with confabulation. They recall incidents after hearing a story that had not occurred in the story. One patient believed he was a Russian chess master though he could neither play chess nor speak Russian. His explanation was that he had been hypnotised to forget that he could speak Russian.

There are a number of neurological illnesses that result in false beliefs of a very puzzling nature (Ramachandran & Blakeslee 1998). Anostignosia patients usually have had a stroke that affected the right hemisphere of their brain and so their left side is paralysed. They deny that they are paralysed. For example, an elderly woman, who can neither walk nor use her left hand, will say that she can do both. When asked to clap her hands she makes the movement with her right hand and says that she is indeed clapping. This example of confabulation is typical. Again other patients when asked to point with their right hand say they cannot because of arthritic pain, or 'I've never been very ambidextrous'. As Ramachandran says, to listen to patient deny ownership of her own arm and at the same time to admit it is attached to her shoulder is, for the neurologist, perplexing in the extreme.

Patients often recover and then stop denying they are paralysed. When questioned as to why they had a false belief some deny that they had such a belief whereas others may say that their mind knew it but would not accept it. Another puzzle arises from the observations that irrigating the left ear of a patient can temporarily make them accept that their arm is paralysed.

The Capgras delusion is another example of a neurological condition giving rise to false beliefs. When the patient sees someone he knows very well, a wife or parent, or child, he claims that the person looks like, for example, his spouse, but it is not really his wife and may be an alien impostor. In other respects the patient may be largely normal. One explanation is that when he recognises his wife, the normal emotional response is absent, but this explanation has been shown to have difficulties with other observations. More generally it reflects a dissociation between recognition and familiarity. A related but different disorder is prostpagnosia in which the patient cannot recognise the identity of faces. Yet physiological studies show that the patient does respond to a familiar face even though he or she fails to recognise the face.

False beliefs are characteristic of mental illnesses that include both schizophrenia and depression. These affect around 5 % of the population. False beliefs are common in schizophrenic patients. They may hear a voice telling them that they cannot do what they want to do or telling them to kill God. Sometimes they think another person is speaking for them or that they are victimised and someone is trying to hypnotise and kill them. There are other forces controlling the patient's actions. Often it is difficult to distinguish between false beliefs and false perceptions, but as William James recognised, part of what we perceive comes through our senses while another part is constructed in our mind.

The delusion of being controlled by an outside agent could be due to the uncoupling of intention to move from that action itself. Some patients have been shown to be unable to monitor their own movements without visual cues. This fits with the theory of motor control in which in order to monitor our actions, it is necessary to monitor the sensory consequences of those actions. The programme for generating movement also generates the predicted sensory consequences, but if something goes wrong there could be a mismatch and could lead to a patient being unaware of disabilities as described by Ramachandran.

Delusions of motor control is one class of symptoms in schizophrenia – the patient feels that his own actions are being created not by himself but by some outside force (Frith et al. 2000) or that emotions are being made by outside forces. It is quite different from the so-called anarchic hand which is the result of brain damage in which the patient recognises that he/she is performing unintended actions but there is no belief in alien forces. It is not possible to compute a unique sequence of motor commands that will produce a required movement – the inverse model, but given the sequence the consequences can be computed exactly – the forward model. Patients with motor control delusions have something wrong with the generation of the forward model. Thus delusions of control arise because of a failure to form a representation of the predicted consequences of an action. The abnormal experience of control of movement is the result of a disconnection between frontal brain regions where actions are initiated and parietal regions where the current and predicted states of limbs are represented – there is overactivity in these regions for reasons which are not known.

Depression provides a good example of pathological false beliefs (Wolpert 2001). It was the psychoanalyst Aaron Beck who realised that it was the conscious thoughts of his depressed patients that really mattered. Instead of the psychoanalytical assumption that it is unconscious thoughts maintaining the depression, Beck recognised the fundamental importance of automatic negative thinking in his patients. All beliefs are negative and may have little relation to reality. In the inner world of the depressive the self is perceived to be ineffective and inadequate, whereas the outside world is seen as presenting insuperable obstacles; moreover there is the belief that the depression will continue forever and that the patient will never get better. They draw negative conclusions without any evidence to support them: "I failed once, and this means I will never be successful", reaching major conclusions on the basis of a single event: "John says he does not love me, nobody cares for me". Underlying all these negative thoughts are a set of false beliefs and it is the aim of cognitive therapy for depression to uncover and correct these beliefs.

Hypnosis can give rise to false beliefs. Hypnosis is not that well understood but suggestibility is a key feature. It can unquestionably affect physiological aspects of our bodies as in the classical experiments using the tuberculosis test. In this test a small amount of the test substance is placed on the subject's skin on the arm. If the subject is resistant to tuberculosis then a small red swelling develops due to the body's immune response. A person with this positive response was hypnotised and told that there would be no response when his right arm was injected but his left would respond. And then there was a red swelling on the left arm and not the right. But examination of the right arm region showed that the cells responsible for the response had indeed accumulated but the hypnotic suggestion had prevented changes in the blood supply. There is also very good evidence that hypnosis can result in reduction in pain (Wall 2000).

There are two aspects to hypnosis – one is 'trance' and the other is 'suggestion'. Trance simply refers to the state of focussed attention, disattention to extraneous stimuli and absorption in (usually self-focussed) thoughts, ideas, images etc. – which hypnotic induction procedures are designed to produce. All the phenomena of hypnosis – the altered experiences, involuntary actions, amnesias, are produced by suggestion.

Hypnosis can also give rise to a delusion, which can be defined as a belief that goes against all the evidence and others do not share. Under hypnosis the subject experiences the conviction that the world is as suggested by the hypnotist even though it does not conform with reality. It is certainly possible to use suggestion with hypnotised subjects to change their beliefs about themselves and about the world – at least on a temporary basis and in some instances more permanently. When confronted with evidence that their belief is false they provide what is for them an explanation rather like confabulation.

To investigate this process subjects were hypnotised to believe they were of the opposite sex. They were then asked what they would say if a doctor entered the room and challenged that belief. They were also asked to look at a video of themselves and how they could reconcile that image with their believed sexual identity (Noble & McConkey 1995). Highly hypnotisable subjects experienced a change in sex and one commented afterward: “It was so real it was disgusting”. When confronted with an imagined doctor they argued that the doctor was simply wrong, possibly a quack. They also denied that the person seen on the video was them – it was a person who had nothing to do with what was going on.

There are also some classic studies which show that providing subjects with misinformation in the form of a vivid ‘reliving’ of a fictional past event in hypnosis (in this case hearing gunshots in the night) can create a clear belief that these events had really happened. The belief in this case was resistant to explanations of the experimental (and fictitious) nature of the hypnotic experiences. Oakley has been carrying out some semi-systematic observations on the creation of ‘alien abduction’ experiences using hypnotic procedures – his purpose in doing them was to support the skeptical view that these are essentially believed – in imaginings which can be elicited quite readily in even moderately susceptible subjects with no prior history of alien abduction claims. The experiences produced, however, can be quite powerful and compelling and if they were presented in a less sceptical context they could be construed by some subjects as evidence of their own (forgotten or repressed) actual experiences of being abducted by alien beings – with consequent changes in their beliefs on the subject. Individuals who were watching the demonstrations had their beliefs in the reality of alien abduction confirmed and strengthened by what they saw. They were convinced that they had happened by chance on a subject who actually had been abducted but had forgotten the experience until they were hypnotised.

These are predominantly examples of belief being changed as a result of experiences created in hypnotic contexts. However there are doubts if attempts at directly suggesting a change in fundamentally held beliefs – such as political beliefs – would be successful, and hypnotic subjects seem to retain a capacity to resist unacceptable thoughts and ideas if they are presented in a confrontational way.

Science

Belief in science is special. It is a quite special way of thinking and it is the best way of understanding how the world works. It is a communal enterprise with the individual scientist ultimately being irrelevant as all scientists contribute to a common body of knowledge, although the topics range from physics to the mind. There is no one scientific method other than to be internally consistent and to have explanations that fit with the real world. There are many styles of doing science from theory to experiment to careful observation. Does science provide beliefs that are fundamentally true? – in general the answer is yes, though evidence can always make those truths subject to change. It is implausible in the extreme that DNA does not code for proteins, or that water is not H_2O. If the history of science were to be rerun it would be different but the conclusions the same. Science is independent of cultural beliefs. I believe in the Big Bang since I think I could understand the evidence if I took off, say five years, to study the physics. One can be very sure that over 90 % of chemistry is correct and always will be, and so is the vast majority of physics.

I want to emphasise one aspect that I think is very relevant, the unnatural nature of science (Wolpert 1993). Science is unnatural because the world just happens to be built in a way that does not fit with common sense, that is with our everyday expectations and beliefs. I would go so far as to say that if an idea fits with common sense then scientifically it will almost certainly be wrong. To any sensible person it is clear that the sun goes round the earth and most of us accept that it is the other way round more by authority than a proper understanding. Again, we all believe that the moon causes the tides but the correct explanation is rather complex. Despite our experience of moving objects since birth and Newton's discovery of the laws of motion several hundred years ago, it goes against all common sense that force causes acceleration and not movement.

No matter where one looks in science its ideas confound common sense. It is not even easy to think of how ice cools one's drink in the correct way – cold does not flow from the ice to the liquid. And things get much worse when one enters physics, chemistry and biology. In the world of subatomic particles, quantum mechanics, black holes and big bang, everyday analogies completely break down. Part of the problem is that the language of science is mathematics, which can be very alienating.

Common sense thus does not lead to science. Doing science requires a special self-awareness and it is often necessary to resist common sense since an unfamiliar quantitative rigour is required. Indeed one can live one's life rather well knowing no science at all since most of it has little direct relevance to day-to-day events. Sherlock Holmes' response to Watson's criticism of his ignorance of science was: "What the devil is it to me if you say we go round the sun? If we went round the moon it would not make a pennyworth of difference to me." Of course people like Holmes are excluding themselves both from the greatest intellectual achievement of our age.

Science is not the same as technology. It may help to illuminate the relation between science and technology by looking at their history. While much of modern technology is based on science, this link is of recent origin since science had virtually no impact on technology until the 19th century. Technology alters nature – things are made. Technology includes the ancient arts of agriculture and metal-making as well as the great Renaissance buildings and the machines and engines of the Industrial Revolution. The steam engine owed almost nothing to science – it probably could have been built by the Greeks. While the final product of science is an idea or information, that of technology is a product, something that is used. It is possible to have very complex technology without any scientific understanding at all, but there must be the basic understanding of cause and effect.

The relationship between science and technology is not symmetrical, since technology had an enormous impact on science which could not have advanced without it. And since science had no real use it is something of a puzzle as to why it should have prospered or have even been invented. Humans needed technology but not science. For science we must thank the Greeks.

It is part of the special nature of science that unlike either technology or religion it had a single origin. This is a somewhat controversial view but I believe it is one that can be justified. All science as we know it had its beginnings in Greece. It was with the Greeks of Ionia that it is possible to identify the first attempt to explain the world in concrete terms as distinct from mystical ones, a belief that there were general laws that could be discovered, and a conviction that rational argument was essential. Science is not a natural mode of thought as the world is not built on the expectations that we gain from our everyday experiences. They stood back from nature and tried to understand it for its own sake – as the historian Sir Geoffrey Lloyd has suggested they may even be thought of as having invented the idea of nature. Understanding was to be its own reward.

This is beautifully illustrated by the first record of a scientific theory, that of Thales in about the year 300 of that ancient millennium. Thales of Miletos suggested that everything was made of water in different forms. Water could change its form from solid to liquid and back again, and water was essential for life; a fantastical suggestion, against all common sense, but clearly science that could be tested. The possibility of objective and critical thinking about nature had begun and most important open debate – Anaximander strongly disputed Thales' claim about water and proposed air as the key substance. While giving Thales the honour of being the first scientist we must also recognise that he was almost certainly aware of the achievements in mathematics, particularly that of the Egyptians and the Babylonians. Yet it was Thales who first made formal mathematical statements such as: a circle is bisected by its diameter, and if two straight lines intersect the opposite angles are equal. He laid the foundations for geometry and Euclid.

The Greeks had a society in which there was vigorous debate and discussion of evidence. It was also the first society where an individual author explicitly distances himself from the received tradition and criticises it, and even claims originality for himself. The admiration of one's peers is one of the major rewards of science and in Greece it became possible for the first time when authors adopted the first person singular. Perhaps all this had its origin in the demand for recognition by the Greek poets and the Greek tradition in examining evidence in the context of law and politics. The success of science depends on our having inherited that openness in science and the right to challenge authority.

Aristotle was the dominant influence but because he often based his ideas on a common sense view of the world his science was almost always wrong. However his promotion of logic lead to the achievements of both Euclid in geometry and Archimedes in mechanics. It is only with Aristotle that the idea of logical contradiction appears for the first time.

The Chinese, while brilliant engineers, made a minimal contribution to science. Albert Einstein, on receiving a letter from a correspondent asking why it was that science only arose once and in Greece, and then only persisted in the West, replied: "Dear sir, The development of Western science has been based on two great achievements, the invention of the formal logical system (in Euclidean geometry) by the Greek philosophers, and the discovery of the possibility of finding out causal relationships by systematic experiment (at the Renaissance). In my opinion one need not be astonished that the Chinese sages did not make these steps. The astonishing thing is that these discoveries were made at all."

My hero is Archimedes who followed in the tradition of Aristotle and Euclid by stating postulates and then deducing the logical and formal consequences. In mechanics he invented the concept of the centre of gravity. He created hydrostatics, just consider the achievement of his second postulate: "Let it be granted that bodies which are forced upwards in a fluid are forced upwards along the perpendicular to the surface which passes through their centre of gravity". From such postulates he shows that the loss of weight of a body in a fluid is equal to the weight of water displaced and went on to discover specific gravity of substances. For those who insist that scientific knowledge is transitory and continually replaced his work is an elegant counter-example. He is the first true mathematical physicist and applied mathematician. No one made any progress in his area for another one and a half thousand years. No wonder Galileo called him "divine". It remains a puzzle as to why Archimedes' approach took so long to become generally adopted.

Science is special and its beliefs of a special nature. Yet many scientists are deeply religious. We may have to accept that there are some aspects of the world – like physics itself, that requires us to believe that we may never have all the answers. Lucretius should have been referring to science when he so perceptively remarked: "Happy the man who knows the causes of things".

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