ARRANGEMENTS IN SCIENCE AND MIND

A PHILOSOPHICAL AND SCIENTIFIC EXPLORATION

Richard Davies Gill

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For L, C, and L.

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CHAPTER 1

The embarkation

1.1 Human knowledge as a piece

Human knowledge must be of a piece. That is not to say that a particular person knows everything, but that all the different strands and elements of knowledge and experience must be related to each other, rather like a large net in which some parts are sufficiently removed from much more distant parts to allow them to be considered individually. A germane analogy is provided by the different places in the mainland of England: all English men and women know something about some parts of the country, but no one person knows everything about all the different places. All roads, except cul-de-sacs, can lead to London, so that in travelling to the capital, the starting point does not matter. A person might know her own village intimately and almost nothing of the wider world, but could still travel to London should she wish. Although it is no longer possible to hope to have an all-inclusive knowledge of the arts and sciences as might have been possible in the past, it would seem reasonable to expect that an understanding of their main features and relationships should be attainable. The analogy of travelling to London and the idea of the ultimate indivisibility of knowledge suggest that an exploration of knowledge can start anywhere, and travel as convenient from idea to idea, or from concept to concept. This is not how expositions of the arts and sciences are usually presented: some sort of linear or historical account is made, resulting in gradually developing conclusions, or in layered constructions that form a hierarchy. In part, these methodologies are a consequence of the necessity to present things in the form of a structured written account. The most obvious starting point is science, as it is the part of human knowledge that is most secure, but this choice does not imply that there has to be some sort of logical path to the rest of knowledge: we will just consider it as a part of the great net of human interests and see where an exploration might lead.

It is natural for all individuals to try to understand themselves and their surrounding world, and although trying to understand the relationships between all things is certainly desperately difficult, it is impossible not to try to grasp the main landmarks. Such an undertaking has its perplexities partly because of the sheer volume of very specialised areas of knowledge. It is also very hard, if not almost impossible, to escape from one's own conceptual strait-jacket to reach knowledge that is not hopelessly tainted by one's particular background. Image a coach party going from a small town on a day's outing. The butcher, the baker, and the candlestick-maker will all return with different but not incompatible impressions of their trip. Perhaps the butcher will see plump lambs grazing and ready for eating, and the baker might be more interested in fields of wheat ripe for the harvest. Similarly, the mathematician, the scientist, the artist and the philosopher will all give different accounts depending on their life's content and experience. There are still difficult problems to be solved in the sciences and great creative possibilities in the arts, but understanding the mind must be the greatest challenge. The purpose of this book is to try to advance the understanding of its nature.

1.2 Minds and experiences

Our minds are both the most familiar thing and the most mysterious. Many attempts, largely unconvincing or unsuccessful, have been made to relate our minds to the rest of the universe, and to provide a plausible, believable account of their workings. All who have pondered on the nature of the world have at some time become interested in and intrigued by the many enigmas and obstacles that are encountered. This was clearly expressed by the English biologist when he wrote: 'How it is that anything so remarkable as a state of consciousness comes about as a result of irritating nervous tissue, is just as unaccountable as the appearance of the Djinn, when Aladdin rubbed his lamp.' This encapsulates the conceptual difficulty that we face. How can it be possible that the interactions of our physical bodies produce our experiences, such as the sight of a coloured flower, or meeting other humans? The British philosopher Colin McGinn (b. 1950) has wondered how evolution could have converted the water of biological tissue into the wine of consciousness. The Australian philosopher David Chalmers (b. 1966) has written extensively about the nature and problems of consciousness and drawn attention to what has become known as the hard problem of consciousness, which is the problem of explaining how and why we have experiences and sensations, and their nature. He takes the view that many aspects of our mental workings will become explicable as neuroscience advances, but that there will remain a residue of problems related to subjectivity and the apparent impossibility of explaining how our phenomenal experiences can possibly arise from the physical world.

It is remarkable that millennia of philosophy and centuries of science have not produced a believable and acceptable concept of the mind, its workings, and its relation to the world. Even worse, despite exceptional and sustained efforts, there seems to be no clear way that a route can be developed towards a proper understanding, either of the conceptual ideas required, or of an adequate definition of the nature of the difficulties that are faced. No other area of human enquiry faces these sorts of problems. The mind is also unique in that everyone has direct access to their own thoughts: the puzzles raised are not obscure issues, known only to arcane specialists working in esoteric laboratories or dusty libraries. Few have not at some time contemplated the difficulties in relation to their own mind and wondered at its mysteries, even though they may have no sustained interest in the history and development of philosophy or science, or may have eventually dismissed the problems as intractable, or even irrelevant. The ways in which the concepts about the mind have been perceived have changed over the centuries from animistic beliefs in vital spirits to complex philosophical and neurological considerations about the nature of consciousness and self-consciousness. There are no generally accepted views, the difficulties of understanding are poorly formulated, and there is no agreement on the nature of the explanation needed.

Ideally, one would like to be able to view the intellectual horizon without interruption. Although a person cannot hope to understand everything in detail, she would like to have some sort of general understanding of the whole of human activity and thought. This might seem to be absurdly overambitious. However, although it may be almost impossible to have an Olympian view of the world, it is clear that it is not difficult to understand the principles of many forms of human activity, even if the details are unknown. For example, I am fairly ignorant of chemistry and abstract mathematics, but that does not mean that I am puzzled or mystified by the thought of what might go on in a chemistry laboratory or a university course on mathematics. The reason is that I believe that, with suitable training and perseverance, I could have become a chemist or a mathematician of some kind, and could have acquired the necessary detailed knowledge. This would no doubt change my way of understanding the universe in many ways, but not greatly alter my overall conceptual understanding of the everyday world or my own mental processes. This argument can be applied to the activities of the butcher and her friends. Perhaps this sounds overly arrogant, but it is simply an observation that it is possible to have some reasonable but simple understanding of the activities of others without knowing any of the details.

To explain succinctly the experiences and workings of the mind is no easy task, partly because of the enormous variety of mental activities, but more particularly because of conceptual inadequacies. If asked, we could all produce a list of what we regarded as essential mental activities, though these would vary from person to person. Humans have very diverse experiences of the world, and this affects their mental activity. Much mental territory is well known to us all: the effects of our senses, emotions, deductive thinking, flights of imagination, trying to understand the unfamiliar. The list is extensive and multifarious. Some of our most vivid experiences are visual as through our eyes we have direct experiences of the people and world around us. We can see bright colours and marvel at the beauty of a sunset. Our vision is three-dimensional, and we can recall memories of visual impressions from the past, not in their exact form, but as remembered features. Talking and reading provide entirely different windows on the world. The written thoughts of authors from long ago can be immediately recreated in our minds. The worlds of Homer, Dante, Shakespeare, and Proust can come alive in our minds. Our ears allow us to listen to the music of the great composers of the past. For many, the experience of listening to music and the emotional response created are a major source of inspiration and joy in their lives. Music can speak directly to our emotions in a way that is not possible with words. We can listen to the voices of our family and friends which convey their thoughts to us.

The ancient Greeks recognised that the five senses of hearing, touch, sight, smell, and taste together provide our direct knowledge of the world. There are further senses such as the awareness of temperature, balance and pain. Altogether they are essential for our well-being and proper mental functioning. This has been proved in sensory deprivation experiments which have shown that volunteer subjects totally isolated from any environment eventually become disoriented and experience mental distress. Unfortunately, in recent years some Western governments, particularly that of the USA, have exploited these effects to mistreat and torture Muslim prisoners, under a warped and perverse concept of freedom and justice.

There is a strong philosophical tradition that asserts that everything we know about the external world is derived through our senses. This cannot be the whole picture as we know about many things from second-hand sources, learned from those around us and our educators. Also, our instincts, determined from our genetic make-up, contain important knowledge about how to survive in the world. Some of our behaviour is totally instinctive such as that of a newborn baby who can suckle and attract her mother's attention. We can give a reasoned account of some behaviour, but we are unable to explain the springs of all our actions properly. Sexual activity is an example *par excellence*.

The world of our senses is only part of the picture because, in addition, we have private internal experiences, and memories; those, together with our perceptions, make our individual world. Through acts of imagination, we can create possible futures or new fictional worlds to enjoy. These, if we are able, we can share with others as novels, science fiction, or other artistic creations. Our internal world is totally familiar, and, for many, our inner world of thoughts is of equal importance as the external world, and without it, we are nothing. These thoughts are tied together by memory, experience, and creative processes. Our thoughts can range from the trivial that accompany everyday activities to great pinnacles of intellectual and artistic endeavour.

1.3 Awareness and consciousness

A distinction needs to be made between awareness or consciousness and self-consciousness. I can be aware of something but not self-conscious of it. If I go for a drive in my car, I am at all times aware of driving the car, changing gear, breaking the speed limit, and so on, but I cannot say that I am self-conscious about driving. Often when driving, my thoughts will stray to other more interesting things, and the driving will be an automatic activity, interrupted only by surprises or unexpected events. Self-consciousness arises when I start to think about myself: that is when 'I' becomes the subject of my thoughts, and this seems to be where confusion sets in, particularly if I try to think about my thoughts and experiences at the present instant. Thoughts of the past or constructions of the future offer no particular puzzlement, at least in the sense that I am concentrating my mind on something specific that is not my present self.

Thought processes are of an enormous variety and complexity, and to compartmentalise them is a great oversimplification. Much mental activity is not reported as it is of an insignificant or repetitive nature, unlikely to interest another. However, these activities are a part of the complete picture and can be used to illustrate the variety of mental activity that arises when I am engaged in simple tasks. For example, when I get dressed in the morning I am aware of the various activities: I have to find clean socks, trousers, shoes, and other items, but while engaged in these activities I am generally not thinking much about what I am doing; my mind is concentrating on other things, perhaps the events of the coming day. I am simply just getting dressed on automatic, but at the same time aware of all my activities. If questioned minutes later, I could give a reasonable account of the types of socks and shoes I have chosen, but I would not describe any of the activity as self-conscious. I can also go back in time and think about what was going on in my mind when getting dressed, and I can, to some extent, recreate the feeling of this earlier time. I could make an account of possible mental events related to getting dressed. First look for clothes, decide what is appropriate for the day's activity, and then dress. I can ponder on the nature of thoughts while doing this and think about what could be said about this, and about past thoughts on the subject. I could recall these memories while listening to the birds singing outside and starting to think about how it is possible for me to think at all, before remembering that the lawns need cutting, and being distracted by the preparation of breakfast and the arrival of the newspapers.

Most mental activities have a subject matter that is not quite situated at the present moment, and thought processes are by necessity distributed in time. If I try to think about what I am thinking of at an exact instant of time, I enter a state of uncomprehending confusion. I can think about myself and my activities, both mental and in the world, but not about my own mental activities at the same instant of time. Thoughts about thoughts seem to pose a peculiar difficulty. If they could be formulated, further thoughts about thoughts could be considered, setting up an infinite and ultimately meaningless regression. If a thought occupies a substantial portion of a person's mental capacity, as reflected in neural activity, there is never going to be the capacity for even a part of the regression. When we think, with our minds not in a vacant state, our thoughts are about something, either something directly perceived or some construction from our inner resources. Macbeth remarked, 'Is this a dagger which I see before me' and although he expressed some doubts about the possibility, he did not regress into the meaningless territory of thinking about thinking. As a thought experiment, I can imagine how another person, in this case Macbeth, might think about the dagger and the many subsidiary thoughts that might occur. Am I dreaming? Is it sharp? For what shall I use it? However, I cannot imagine how Macbeth might start thinking about his thoughts about his present dagger thoughts, which would only have the thought of the thought of the dagger as the object in his mind and unconnected with other mental states. Nor can I imagine the succession of his thoughts if he tries to construct thoughts about thoughts, and it is equally difficult for me to entertain thoughts about thoughts. Beyond some point, these would seem to be devoid of any additional content even though it is possible to imagine a procession of different thoughts and mental images that might have appeared in rapid succession in his mind. As a different example, I can imagine a person thinking about her dinner, but I cannot imagine the same person thinking about thinking about her present thought of thinking about dinner. In contrast, I can imagine a person formulating a similar but different thought, such as, 'This time yesterday I was thinking about my dinner (but today I am not hungry).' It seems not to be possible to think about what one is thinking at the same time as contemplating the thought. A possible chain could be set up by a group of people arranged in a circle, each thinking that the person in front is thinking about the thoughts of the person in front. In this case, a regression is not set up but just a circular pattern of similar thoughts. There seems to be a barrier here to our thought processes and attempts to surmount it lead to either meaningless or incomprehensible ideas. The difficulty seems to be that if one particular thought fills one's mind, then there is somehow no room to think thoughts about thoughts at the same instant; or, to put this in a more familiar form: we cannot think about more than one thing at a single instant of time. For complex objects, we conceptualise them and think of the concept instead. For example, Macbeth, Lear, and the rest can come under the concept of characters in the plays of William Shakespeare (1564-1616). However, this process cannot continue forever: higher up the chain there can be the concepts of all written works, but there is not much further to go, and we cannot keep adding more and more concepts of concepts. All these difficulties emerge when we try to think about our conscious experiences, and they impose restrictions on our possible thoughts.

The easiest way to try to expose the difficulty of thoughts about thoughts seems to be to objectify them and, instead of considering oneself, to consider, as a speculation, what another person is doing when she tries to think her own thoughts about thoughts. Imagine someone thinking about her pet dog. All sorts of dog-related thoughts and images would appear about Fido. Suppose that she starts to think about the thoughts themselves, that is, about the particular nature of her thoughts. For example, the new thought could be, 'I am now thinking about my present thought that Fido needs his dinner.' This would seem to be devoid of content, but if allowed as a possibility then a further thought about a thought would be possible, again setting up an infinite regression that would occupy more and more of her mind's resources with ultimately meaningless content. This shows that this activity is senseless. It is possible to have a succession of thoughts on a particular matter, but to think about the present thought at the same instant as it appears seems unimaginable.

Thoughts take time to formulate and experience, and therefore the role of time in the mind is quite different from scientific time, in which there is only the past, the present instant, and the future. Our thoughts are spread in time, with closer and more distant thoughts and experiences influencing the present experience and thoughts. At the theatre, our experience of the performance is quite different when we see the whole play rather than just an excerpt or the last few words of the final act. Without our memories and our recognition of familiar things past and present, and our ability to construct the future, all experiences become devoid of content, as seems to happen to those who suffer from senile dementia. Meaning comes to our experience because of the contrast and interaction between our present direct experience, our repertoire of experiences and our mental constructions of the future. Our position in time is essential to our sense of being a person, and our store of memories uniquely distinguishes us from others. Our conscious experience is not a thing of an instant but an unfolding of our thoughts and senses against the background of our essential nature which in turn is conditioned by our construction as members of the human race, and our emotional and intellectual journey through life.

When we start trying to think about ourselves and our own minds, many difficulties arise. There are different classes of confusion and bewilderment that need to be separated. Of many things we are ignorant, but we are not perplexed by all of these. For example, I may not know the time of the first train to London tomorrow, but I am not puzzled by this lack. It is when I come to think about myself that major difficulties arise. Even here many thoughts about the past and future glide by in quiet observation, but when I start to think about myself and my mind at this particular instant in time a fog of frustration descends and only disperses when my mind moves on to more usual, better-formulated thoughts. This book is intended to try to lift the fog and to provide a rational account of our minds and their relationship to each other and to the universe. This will need a radical change in how we think about ourselves, the world, and our place in it.

1.4 The philosophers

Mankind has divided and classified the world since the beginning of time. This is still embedded in our language: day and night; friend and foe; sweet and sour. As concepts these must have preceded any written language and are still part of our thinking. The importance of the use of language cannot be overstated, as it is one of the essentials of the human condition. Without language we are just animals. On an evolutionary timescale, the development of language has taken place rather recently and has been accompanied by increased brain size and physiological changes that have aided speech. The original development of language necessarily preceded any records, and its development and accompanying cultural changes can only be inferred from archaeological methods applied to the physical remains of ancient cultures, and from later written records, but it is doubtful if this sort of speculation has any real value. Much of the very earliest writing that survives from Egypt and the Middle East was of a purely utilitarian nature: to note transactions; to extol the virtues and achievements of the king; and to record religious practices.

The concept of the mind or the soul has existed since ancient times. Early ideas often involved animism, vital spirits, and other insubstantial objects needed to explain the cycle of life and death, the progression of the seasons, and the motion of the sun. In primitive non-literate cultures, human beings, animals, and in some cases inanimate objects have been thought to possess a life-giving spirit which was believed to impart essential properties to its bearers. Appeasing malevolent evil spirits was an important part of some ancient cultures. Generally, these ideas are no longer accepted, although the concepts live on to a degree in everyday conversation, for example in talking of 'the spirit of the place' when describing a visit to an exotic or evocative location, or to a person who is the 'life and soul' of a party.

For some, religion is still important. In classical Greek times, large numbers of gods, led by Zeus, were thought to exist and to affect or control the affairs of humans. Religious beliefs grew in all societies, and a common theme from the ancient Egyptians to the Christians and others was the desire to escape from the apparent inevitability of death. Elaborate theologies accompanied by exotic rituals explained how the individual could transcend the mortal realm and achieve the afterlife. In those times of almost universal ignorance of the working of the universe, it is easy to understand how these traditions were established and accepted uncritically, particularly by those who led simple lives devoted to struggling to keep themselves and their families alive.

Some of these ideas persist into the present and form an important part of the beliefs of those with religious faith. The sources of religious knowledge have often come from revelations to individuals, supposedly directly from divine sources, or from particular individuals who claim to have acquired a more intimate connection with the gods. These revelations were then passed on by priestly clans who often used their specialised knowledge as a source of power over the superstitious masses. In a completely rational world the old religious ideas should have withered away, but not everyone is swayed by rational argument, and some are gullible or easily misled, so these ideas have persisted. In this book, we shall assume that these ancient religious beliefs have no place in trying to understand ourselves or the universe.

Thales

Some early fragmentary written accounts of how humans viewed the world have survived from ancient Greece. According to Aristotle (384-322 BC), Thales of Miletus, (c. 624-546 BC), was one of the founders of philosophy and science. He made contributions to geometry and astronomy but is known to us through later accounts. He thought that the earth rested on water like a piece of wood, and that water was the material principle of the world. He had the idea that, underlying all the continually changing things in the world, there must be something from which they come into being and into which they eventually decay. The substance remains but its properties change. Although we cannot accept the idea of water as a universal substance, Thales' philosophy was an important first step in trying to gain a unified understanding of the world. His idea that the world is ultimately composed of a single substance was established by reasoning, but there would seem to be no compelling necessity why the world could not be composed of any number of elementary objects. The naturally occurring chemical elements, or the six varieties of quarks, became popular candidates at later dates. At first sight, with no preconceived ideas, it would be natural to think that the world is just composed of a collection of disparate items that grow or are made, and decay or are destroyed. Examples include cows and sheep, tables and chairs, mothers and daughters, or sons and lovers. The early philosophers had the desire to look beyond mere surface appearances to try to discover some underlying fundamental certainties, starting a philosophical and scientific tradition that has continued in an unbroken chain until today.

Pythagoras

The ideas of Pythagoras (c. 570-495 BC), famous for his geometrical theorem, are known from secondary sources. He was born on the island of Samos, and eventually settled in Croton in southern Italy where he attracted a number of followers who formed philosophical schools that followed his teachings. He founded a religion based on what seem to be arbitrary rules. Adherents to the religion should not sacrifice a white cockerel; pleasures of all sorts are bad; the heart should not be eaten, and many other prohibitions. Traditionally Pythagoreans were thought to be forbidden from eating beans, but some later commentators have claimed that the banned beans were testicles. Their greatest and far-reaching innovation was their idea was that the world is ruled by numbers. They knew that musical intervals were determined by integers, and believed that numbers were the elements of everything that exists. This discovery has had long and successful consequences, and it underpins much of modern science, particularly in quantum mechanics where integers play an essential role.

Heraclitus and Parmenides

Change and movement perplexed the earliest philosophers to such an extent that two entirely opposed ideas were put forward. Heraclitus, a native of Ephesus (c. 500 BC), thought that things changed continuously and that this was an important principle of the world. His work was thought of as difficult by later Greek philosophers who called him Heraclitus the Obscure. For him, fire was the element from which all other things originated and all things changed under its influence. He believed that the sun is renewed every day, and that you cannot step into the same river twice as fresh water is being supplied continuously. In contrast, Parmenides, active in the 5th century BC and a native of Elea on the Italian coast, believed that everything is changeless. His philosophy was presented in a poem, *On*

Nature, which survives only in fragmentary form. He wrote that nothing could come into existence as, if it does, it must have come from something that already existed, but this is logically not possible as it would then already have been in existence. To convince sceptics, he presented several different arguments and said that the apparent world of change was just a deceitful show. His views are probably not too convincing to the modern mind, but some aspects of his ideas have influenced later philosophers.

Empedocles

More is known about Empedocles (c. 492-432 BC) who lived in the then Greek town of Acragas in southern Sicily. He wrote several works in verse, some of which have survived, most importantly *On Nature* and *Purifications*. He believed that things in the world were formed by the action of love or strife on the fundamental elements of 'fire and water and earth and the boundless height of air'. He believed that there is constant change and decay of things created with different proportions of these elements. From a modern perspective, there are parts of his system with which we can identify, although now we would identify his elements with the different phases of matter: flames, liquids, solids and gases.

Democritus

The first ideas about the atomic nature of matter were developed by Leucippus. Little is known about him and he is remembered almost entirely because of his influence over his famous pupil, Democritus (c. 460-370BC), who was born in Abdera in the north of Greece. He travelled widely, including to Egypt and Persia, before returning to his home town. He was the author of many books, mainly lost, on a wide range of subjects including ethics, natural science, and mathematics. His original writings on atomism do not survive, and his views are known only from secondary sources, notably Aristotle. He thought that things consist of substances that are so small that they escape our notice. They have different forms, shapes and sizes; from these all visible objects are produced. The atoms move about in an empty void and intertwine and entangle with each other for a certain time until a stronger necessity shakes them apart. Some of these atoms have scales, some hooks, some are concave or convex, and they have innumerable other features. Quite why he came to these conclusions is not so clear. His ideas were later criticised by Aristotle for ignoring the question of the motion of the atoms. In his day, there was certainly no evidence in favour of his views, although he was perhaps influenced by the idea that knowledge about the world could be obtained entirely by logical arguments, in the same way that arithmetical and geometrical truths had been established. It was more than two thousand years later that the modern atomic theory was developed, and this has served to greatly enhance the standing of the first atomists. Some of Democritus's other views have stood the test of time less well. For example, he recommended that one should pay careful attention to the cawing of rooks, the crowing of cocks, pigs rooting among rubbish, and to treat these as signs of wind and rain.

Plato

Plato (429-347 BC) and his illustrious pupil Aristotle were the greatest and most influential of the Greek philosophers, and a substantial body of their work has survived. They both flourished in Plato's Academy in Athens, and in his later life Aristotle started his own school, the Lyceum. Both made major advances on their predecessors and became the dominant authorities in Western philosophy and science until the developments of the Renaissance and later periods. It is impossible to exaggerate their importance, either as philosophers of the first rank or in terms of the extent of their subsequent influence. Few details are known of Plato's life: he was born in Athens into an influential aristocratic family; he probably travelled in his earlier years before returning to Athens to establish his Academy. His extensive writings, which have survived almost in their entirety, and been transmitted to us by Muslim scholars, were deeply influenced by his contact with the older Socrates, and are almost all cast in the form of dialogues. Plato wrote with great style on an immense variety of subjects including politics, metaphysics, ethics, and the theory of knowledge. He is probably the most important philosopher of all time. Although Plato did not write systematic works, as became the later practice, his philosophy has many interlocking themes that appear in several of his dialogues. In particular, his theory of knowledge and of forms, together with his writings on the soul, have many interacting ideas and concepts.

There is a huge literature about Plato. Here, a snapshot of Plato's concepts will have to suffice so they can be seen as a backcloth to modern attempts to gain a better understanding of the workings of the mind. He made many far-reaching innovations in philosophy, particularly with his theory of forms. He was concerned with the relationship between particular examples of things, say a horse, and the general, or universal, idea of a horse. There are many horses, but there is only one idea of a horse, and this he identifies with the form of all horses. His theory is discussed at length at the end of *Republic*, although earlier passages contain many references to the form of justice, the form of beauty, and many other forms. A contrast is presented between the painter of a bed, the carpenter who makes the bed, and the idea of a bed that is made by God. The artist is dismissed as an imitator and, because the carpenter has not created the idea of a bed, it is left to God to be the originator of the timeless and perfect bed to which all other beds aspire. This argument allows the introduction of forms that are independent of ourselves, and that are somehow models for our imperfect world, not just for beds, but for all other objects and concepts. For Plato, the universal was what really existed and gave things in the world their essential nature. One effect of this is to create a world of ideal forms at the expense of the everyday world, which is seen as having less importance or permanence. These ideas were largely rejected by Aristotle, but have continued to be influential. Many contemporary professors of mathematics believe that their numbers exist in a Platonic world.

Plato's views on the sources of knowledge and the relationship of the soul to the body may be found in *Phaedo*. This book presents a dialogue set in the last few days of Socrates' life after he had been condemned to death by poison by the Athenian court. It also presents the arguments put forward by Socrates for the belief in the survival of the soul after death. These arguments do not amount to a proof but are given as sufficiently persuasive reasons to believe in the afterlife. Plato's views on immortality were taken over by the Christians and became an important part of their beliefs. The distinction between soul and body is everywhere entrenched in the dialogue between Socrates and his followers, and the concept of the soul is clearly established as an entity separate from the body.

Plato was puzzled about our sources of knowledge, and his solution is presented in a dialogue between Socrates, Simmias, and Cebes. Socrates starts by stating that the sight of a thing can cause the recollection of something similar, and then goes on to consider the idea of equality of a stick with another stick. Exact equality of sticks or other objects cannot be found in the world, and he goes on to argue that there must be an idea of equality that is independent of particular objects. Because there are no examples of exact equality that can be experienced, the concept must have come from elsewhere. It must be likewise for other ideas such as beauty, good, or justice. These concepts must therefore have been acquired before we were born. The argument continues with the idea that, although we had all this knowledge at birth, it has been forgotten, but it can reappear in later life through learning, which he regarded as the recovery of lost knowledge. Having established the point, Socrates goes on to argue that the pre-birth knowledge must have been possessed by our souls. While accepting the argument so far, Simmias and Cebes are unconvinced by the further idea that the soul can survive death, but Socrates continues to insist that he has presented a compelling argument for the independence of our souls from our bodies, the existence of our souls before birth, and their continuation after death.

The flavour of the style of argument can be seen from the extract: 'and if we acquired this knowledge before we were born, and were born having it, then we also knew before we were born and at the instant of birth not only equal or the greater or the less, but all other ideas; for we are not speaking only of equality absolute, but of beauty, goodness, justice, holiness, and all which we stamp with the name of essence in the dialectical process, when we ask and answer questions'.

However, Cebes remains unconvinced that the existence of the soul before birth implies that it will continue after death. Socrates replies that he has already given the arguments for the continuation of the soul, but continues with further arguments that contrast the soul with that of the body, and he concludes that their differences are so great that the existence of the soul cannot be dependent on that of the body. Simmias and Cebes are eventually satisfied. The nature of the argument can be appreciated from a further quotation: 'the soul is in the very likeness of the divine, and immortal, and intelligible, and uniform, and indissoluble, and unchangeable; and the body is in the very likeness of the human, and mortal, and unintelligible, and multiform, and dissoluble, and changeable.'

I cannot imagine that the idea of knowledge before birth would appeal to anyone today, but Plato had more to say about the nature of knowledge, to which we shall return in a later chapter. However, the argument that the enormous differences between the body and the soul imply their complete separation has continued to influence philosophical ideas and discussions to this day.

Aristotle

Aristotle had different interests from Plato and wrote extensive influential works on physics, astronomy, logic, and animals. He was assiduous in classifying both things and concepts and has provided valuable knowledge about earlier philosophers. His output was enormous, and many of his works were based on extensive collections of facts about the world around him. Inevitably, some of these were eventually found to be incorrect, but sometimes not until two millennia had passed. Famously, he declared that women have fewer teeth than men. This has tended to discredit him unfairly and has sometimes obscured the genius of his originality. In most scientific subjects, there was a complete poverty of concepts that prevented his ideas from being much more than speculation, but he set the scene for future generations. Again, great tracts of time passed before correct scientific concepts became formulated. However, his influence is still present, and he is the favourite philosopher of the Roman Catholic Church.

Aristotle was interested in the overall structure of human knowledge, and he classified different activities into botany, chemistry, and other subjects in the theoretical sciences; politics and ethics in the practical sciences; and art and other pursuits in the productive sciences. He was extremely interested in the nature of things in the universe and the processes of change. In *Physics*, after explaining the views of earlier philosophers, he goes on to distinguish between things that have their causes in nature and things that have other causes. In the first category, he places animals, plants, and the four elements and, in the second, things that have been made, such as beds or coats which have no innate tendency to change or decay. He remarks that some believe that the elements represent the entire reality, and claim that all other things are mere affectations, states, or dispositions: the elements do not change, but some things come into being and decay. He identifies nature with both form and matter but thinks that form has a better claim to be called nature. He illustrates his distinction between matter and form by the example of a sculpture. The block of marble is the matter and the shape carved is the form. The completed work is then the fusion of the two. One cannot exist without the other.

The question of the nature of the real objects of the world is addressed in *The Metaphysics*. This book is introduced with the delightful sentence that 'All men by nature desire to know', but later parts of the work become quite obscure. The concept of substance is of great importance: its definition is given explicitly, and many examples are provided. Aristotle inquires about the definition of the primary substance. This could be matter, form or shape or a composite of these, although he rapidly dismisses the last of these as it is a derivative of the first two. His starting position is that the substance of a thing is something that has qualities. The distinguishing feature is that qualities cannot exist without the underlying substance. The example given is of the casting of a sphere from bronze or the imprint of a signet ring in wax. The bronze and the wax are both matter and the sphere and the ring the respective forms. In this case, form could be identified with shape, but it should be understood to have a much wider meaning. Initially, Aristotle seems unable to conclude that substance is matter and considers form or the composite to be more likely candidates. This leads him to the introduction of the idea of essence as the defining feature of substance. The essence is the feature that both defines the substance and explains its properties. This may all sound rather confusing, and it has given rise to endless discussion.

In *De Anima*, Aristotle starts by defining the soul as the first principle of living things and remarks that it is one of the hardest things about which to gain any conviction. Two approaches to possible definitions of the soul are made by analogy with a house that can, on the one hand, be thought of as composed of bricks and beams or, on the other, as the form of these for the provision of shelter. He again summarises the views of his predecessors and criticises the idea that the soul is what produces motion or that it is identical with the mind. For Aristotle, the soul is a substance that is the form of a natural body that has the potential to be alive. The soul as a substance has various faculties, such as nutrition, sense perception, intellect, and desire. He has the interesting view that perception is the acquisition by a person of the form but not the matter of the object perceived.

Aristotle continually looks for the cause of motion. He starts with arguments that convince him that all motion must originate from a source that itself does move. The first mover is eternal, and he thinks that he ought to suppose that there is only one of these. He is puzzled by the motion of animals and suggests that they move as a result of things that enter their bodies. He develops the concept of things moving to their natural place, and about natural and unnatural movement, so that fire and air naturally move upward and, in contrast, water and earth move down. The stars undergo circular movement as their natural motion. At the time that these ideas about motion were developed they were an advance on what had preceded them, but it is unfortunate that they were uncritically accepted and became rigid parts of the Western intellectual tradition. They were a considerable bar to further progress until they were comprehensively overthrown by the Renaissance scientists and their successors.

Thomas Aquinas

Philosophy in Europe was greatly influenced by the works of Plato and Aristotle who came to be regarded as the ultimate authorities in matters both philosophical and scientific. In science and logic, this became an impediment to further progress. The rise and spread of Christianity had a further dominant effect on how man thought, and some members of the religious orders also became well-known philosophers. One of their preoccupations was to try to reconcile the philosophy of ancient Greece with Christian beliefs and principles. This activity reached its pinnacle in the work of Thomas Aquinas (1225-74) who was born in Italy, between Rome and Naples. He became a Dominican friar, produced an astonishing number of written works, and gave lectures in many parts of Europe including Cologne, Paris, and Naples. His most well-known work, *Summa Contra Gentiles*, was written to help convert the Moors in Spain to Christianity.

Summa Contra Gentiles is concerned with the nature of God and tries to establish five proofs for His existence. The first argument, taken from Aristotle, uses the concept of the unmoved mover: something must have originally started the universe in motion, and that must be God. The second argument, similar to the first, is of efficient causes. All things have causes, and this leads to an infinite regression unless there is a first cause that can be identified with God. Third, many things have the possibility of either existing or not existing. Aquinas argues that not everything can be like that, and a thing that necessarily exists by itself is called God. Fourth, we find things in the world with varying degrees of perfection, and this must originate in a Divine being of complete perfection. Lastly, he notes that many things, both living and non-living, have a purpose and this purpose must be provided by something outside of themselves. Some of these proofs, although not now generally accepted as valid, continue to appeal to some today. However, those of a religious disposition, including followers of Aquinas, hold their views because of their unshakeable faith, supported by revelation, and do not need to be convinced by philosophical arguments or demonstrations. For the ignorant, the uneducated, or the very young, these sorts of proofs are not accessible, but the conclusions might be believed.

During the Renaissance, the whole of ancient Greek and medieval philosophy and science was overturned by the rise and development of new ideas and concepts. This was the beginning of the transition to the modern world and the rationality of the eighteenth century that is often eclipsed today. For many in Western cultures, the rule of ignorance, magic, superstition and religion gradually came to an end, but for others, these ancient vestiges have continued and, unfortunately, still influence and sometimes blight lives. The effects are visible in the many conflicts and wars still being fought because of religious intolerance.

Descartes

René Descartes (1596-1650) was born in France and educated at the Jesuit college of La Fleche. He is regarded as the founder of modern philosophy and also made important innovations in mathematics. His education included instruction in medieval philosophy which included Aristotle's ideas about substantial forms. He rejected the idea that there could be substances attached to matter to make 'a true substance, or self-subsistent thing'. After further study, he joined the army of the Prince of Orange and later that of the Duke of Bavaria. When he was returning from the coronation of Emperor Ferdinand II, he spent a whole day alone in a stove-heated room and emerged having thought out the foundations of his future philosophy, which also included unifying the many sciences using mathematical principles.

In his first work, published in 1637, *Discourse on the Method*, he explains that the great variety of different opinions he has heard on all matters has led him to try to establish the truth by applying a method of universal doubt to all received wisdom. He starts by rejecting all ideas that are not completely clear and distinct in his mind. He found that although he could doubt the existence of objects in the external world, he could not doubt his own existence. This led directly to his famous dictum: 'cogito ergo sum' – I think, therefore I am. The *Discourse* continues with proofs of the existence of God, his views on the nature of the human soul, and his views on science. Four years later, in 1641, Descartes published his greatest and most famous work, the *Meditations on First Philosophy*, which systematises and expands many of his earlier arguments. He again applies the method of universal doubt to all things and considers all the uncertainties of things perceived by the senses. He worries that all he sees and knows about the world might be false, that he is being deceived by a malevolent demon, and that the world of his senses is just a dream. This also casts doubt on the existence of all other minds. The only escape route from his dilemma is the proof of the existence of an all-perfect God who is not a deceiver. He argues that although he, Descartes, is an imperfect being, his ideas of perfection must have come from somewhere other than himself or another imperfect being. Therefore the idea must have come from a perfect being, and He, God, must exist. He further argues that if he had created himself, he would have made himself perfect. As he is not perfect, he argues that he was created by another perfect Being. He goes on to consider the properties of the perfect Being and cannot imagine that among His many perfections is not that of existence. Although he can imagine the existence of other non-existent things, such as winged horses, he is entirely unable to conceive of God not existing. His God then guarantees the existence of the material world that he has so greatly doubted.

Descartes goes on to consider the separateness of the soul and the body, and this defines his dualist philosophy, which still stalks us today. He claimed that we are made of two entirely different substances: a thinking substance, or the mind, and an extended substance called the body, or matter, and which exists in space. The mind is unextended and indivisible, but matter is divisible. As mind and matter are so entirely different, it is difficult to understand how they can possibly influence each other, as seems to be required by common sense. Descartes's own answer to this difficulty was to propose that they interact via the pineal gland in the centre of the brain. He chose this part of the brain because it is a single rather than a paired organ, such as the eyes, ears or hands. Descartes's world is thus defined as the dual substances of mind and matter, with God as a Supreme Being. His ideas about the respective roles of the mental and the physical have dominated the last three and a half centuries of philosophy. His distinction between mind and matter is firmly embedded in everyday life and is an established part of our culture.

Some of the difficulties of his concepts of mind versus matter were exposed in his correspondence with Elisabeth, Princess Palatine of Bohemia (1618-80) who questioned how the mind could cause changes in such a different substance. In a letter to Descartes in 1643, she wrote that she could not see why 'we should be persuaded that a body can be pushed by some immaterial thing'. It is fair to comment that Descartes never produced an adequate answer.

George Berkeley

Since the seventeenth century, much effort has been devoted by philosophers and others to trying to reconcile the two sides of Descartes's dualism. Several extreme positions have been proposed as an alternative. These solve the interactive difficulty of dualism but introduce new problems. Some radical solutions deny the existence of mind or matter, in order to establish a monist position in which there is only one fundamental entity. Idealists, most notably the Irishman Bishop Berkeley (1685-1752), deny the existence of matter, whereas materialists think that matter is the only ultimate object.

As a young man in his twenties, George Berkeley wrote the influential *Principles of Human Knowledge* and the *Dialogues between Hylas and Philonous*. In his later years, he tried, unsuccessfully, to establish a missionary college in Bermuda funded by the British government. Later he became the Bishop of Cloyne and wrote a book extolling the virtues of tar-water. His philosophy starts from his observation that all objects of knowledge are ideas in his own mind. From this starting point, he finds it clear and obvious that nothing in heaven and earth can exist without a mind to perceive it. Others have not found this as plausible, for it suffers from the obvious difficulty that material objects will have an intermittent jerky existence according to whether or not they are being perceived. He had an unshakeable belief in a God who has an infinite, all-seeing mind, whose perception of objects in the world then rescues them from an otherwise strange discontinuous existence. One advantage of his philosophy is that it renders meaningless any speculation about the distinction between mind and matter as the latter is dependent on the former. Another difficulty is that, without God, the world would not have existed before life started in the universe. Berkeley's ideas were derided on common-sense grounds, and he had to devote some of his energy to defend his philosophy.

In conversation with Dr Samuel Johnson (1708–84), Boswell said that he was satisfied that the Bishop's doctrine was not true but that he could not refute it. Johnson replied by kicking a large stone with his foot and exclaiming, 'I refute it thus.' This has remained the common view of Berkeley's idealistic philosophy – ingenious but impossible to accept or believe. His philosophy removes Descartes's difficulty of trying to explain how mind and matter interact, but it falls apart if one is not prepared to allow for the existence of God. However, other versions of idealism were later developed, and this strand of philosophy has continued to exert a powerful influence.

The rise of science and behaviourism

Over the last few centuries, one of the most dominant influences on philosophy, and almost all other areas of life, has undoubtedly been the rise and success of science and engineering. For philosophers, science has been seen as important both for the extensions that it has provided on our perspective of the world and for providing a methodology that can be used to investigate problems traditionally considered as outside the scope of the sciences. Generally, the sciences are concerned with trying to understand things and events in the world from a detached point of view. Things are seen and studied in isolation from the scientist, and the aim is to try to produce a simplified but accurate account of what is observed, and to predict the future. This approach, while leaving out many things that are important in our lives, has been enormously successful, and has been responsible for producing the complex technical, and still developing world, inhabited by the more wealthy members of the human race.

In the early part of the twentieth century, the influence of the scientific perspective dominated both the behaviourist and the logical positivist schools of philosophy. Behaviourism started with the work of the American, J. B. Watson (1878-1958), who wanted to turn psychology into a subject modelled on the physical sciences. He thought that the psychology of his time, with its emphasis on the mental states of individuals, could never become established as a proper objective science. He therefore proposed, just before the First World War, that henceforth only behaviour should be studied, as it could be observed and recorded without uncertainty; and that the methods of psychological investigation involving introspection should be abandoned. All talk of unobservable mental states, consciousness, the mind, and its workings were to be banished forever. In particular, he rejected the method of psychoanalysis which had been developed by the Austrian, Sigmund Freud (1856-1939). Watson was greatly influenced by the Russian physiologist Ivan Pavlov's (1849-1936) work on conditioned reflexes. Watson had an enormous influence on the further development of psychology and also philosophy, even though his career was cut short by the scandal of his extramarital affair with a student assistant who became his second wife. His ideas were developed much further by his younger compatriot B. F. Skinner (1904-90), who thought that behaviour was more complicated than could be explained by simple reflex action. Skinner introduced the more extended notion, called operant conditioning, that 'behaviour operates on the environment to generate consequences'. He was dismissive of any ideas that tried to link feelings and motives to behaviour, regarding all mental events as superfluous in predicting behaviour because they occurred as an associated effect of a particular behaviour pattern. However, despite his efforts, the study of consciousness and internal mental states has not disappeared from the agenda of interesting problems. Behaviourism has now been eclipsed and is thought of as only partially successful.

One of the effects of behaviourism was to remove mental events from philosophical consideration for many decades. This is particularly apparent in Gilbert Ryle's (1900-76) hugely influential book, *The Concept of Mind*, published in England in 1949. In this book, Ryle takes great exception to what he calls the official doctrine, derived from Descartes, of the nature of the mind. This he takes as the view, shared by philosophers and laymen, that we are all composed of a body and a separate mind. He regards this idea as absurd, and his book is devoted to proving this and to elucidating the conceptual confusion that exists about all things mental. He castigates the official doctrine by labelling it the 'dogma of the ghost in the machine' and also rejects idealism and materialism on the grounds that these philosophies make a category error when they try to explain the physical in terms of the mental and vice versa. He particularly objects to attempts to analyse mental processes by assuming that the mind is a separate entity from the body, and gives several examples of category errors in other spheres of life in order to illustrate the nature of the mind/body error. He considers a foreigner who visits Oxford in England for the first time and is shown around a number of colleges, libraries, museums, laboratories, and administrative offices. She then asks, 'But where is the University? I have seen where students study, work, and live, but you have not shown me the University.' It is then explained that the University is not another institution on a par with all that she has already seen, but rather is the way in which all that she has seen is organised. She is mistaken in thinking that the University is something separate and additional to its parts. The category errors committed when talking of mind and body are of a much more subtle variety and are elucidated in his book.

According to Ryle, there are no acts of a specifically mental sort independent of behaviour that is conducted in the public arena. He thinks that accounts of the workings of the mind are a conceptualised way of explaining the actions of the body. All thoughts, feelings, and sensations do not belong to a mental world separated from the physical world. Behavioural actions are explained by dispositions to behave in particular ways and are not to be explained by occult goings-on in an inaccessible arena. He analyses and discusses different forms of human behaviour from this perspective, and, as we progress through the work, some of us gradually become convinced that perhaps we should not be puzzled by the mind. Maybe all the difficulties of understanding are just slack and illogical habits of thought by those who have been conditioned from an early age by Descartes's myth.

Ryle acknowledged that philosophy had been profoundly affected by the behaviourists' rejection of the two worlds concept. However, he thought that that theory was too mechanistic and simplistic to provide a reliable concept of mind. Ryles's influence has waned in the intervening decades, and his explanations of traditionally mental events in terms of dispositions to behave are not now regarded as sufficient to capture the richness of internal experiences. Nor did he completely elucidate the exact nature of the error committed by Descartes and subsequently propagated by others. Perhaps the most interesting critique comes from those who ask what the famous statue *Le Penseur* by the French sculptor Auguste Rodin (1840-1917) is actually doing as he sits in his thoughtful pose. It is difficult to imagine that he is in a dispositional state rather than just thinking of matters unknown. Rodin has written that at first he thought that the subject should be Dante thinking of the subject of his poem, but his plan changed and he 'conceived another thinker, a naked man, seated on a rock, his fist against his teeth, he dreams. The fertile thought slowly elaborates itself within his brain. He is no longer a dreamer, he is a creator'. Here artistic imagination outstrips philosophy in its depth and complexity.

Recent philosophy

The philosophy of mind since Ryle's time has become a more active area of research stimulated, particularly in the United States, by the enormous growth in institutes of higher education. It is more difficult to determine which of the new ideas proposed in this recent period will have lasting value, but there are several strands of thought and schools of philosophy that stand out which will now be mentioned briefly. In addition, interesting contributions to the subject have been made by philosophical outsiders who have considered the mind from the perspective of their own subjects, chiefly neuroscience, biology, and quantum physics. Perhaps the greatest single change over this period has been the recognition that there is a real problem to be addressed and that mental events and consciousness cannot simply be ignored because they do not fit comfortably into outlooks strongly influenced by the physical sciences, with their objective standpoint and emphasis on hard facts, observable phenomena, and mechanistic explanations.

The arrival of digital computers and the mathematical developments that preceded their introduction led to the idea that our minds might work on similar principles and are little more than sophisticated computational devices based on systems constructed mainly of hydrocarbons rather than silicon chips. In some ways, this is the continuation of a long tradition which has always grasped the latest intellectual discovery in geometry, mechanics, chemistry, and other sciences, and extended it beyond its proper boundaries to try to provide a comprehensive picture of humans. From the 1950s onwards, many influential ideas have come from those working in the sciences of computing and artificial intelligence. Initially, there were very high expectations that, as computers became more powerful, many mental activities, other than mathematical manipulations, could be done in an indistinguishable way by a computer. This led immediately to the idea that what goes on in a computer is identical in many respects to what happens in a person's mind when it engages in the same activity. It was a short step from here to asserting that machines could also be conscious. This idea was dealt a mortal blow by the American philosopher J. R. Searle (b. 1932) in what has become known as the Chinese room argument. It goes as follows. Imagine a person who understands only English sitting alone in a closed room and provided with a set of instructions that explain how to manipulate Chinese characters so that sensible answers can be constructed to any question written in Chinese. Questions are posted in Chinese from outside the room, and the person inside finds a suitable answer according to the rules and returns a reply. If the rules are sufficiently well-formulated, those outside the room will conclude, incorrectly, that they are dealing with someone who understands Chinese. Searle compares this with a computer that can answer questions in Chinese using the same set of rules, and considers the claims of the artificial intelligence community that the computer understands the Chinese language. In both cases, what is taking place is the manipulation of symbols, and no understanding of the meaning of the symbols has been achieved. Understanding is therefore something separate from the manipulation of symbols and is something that no computer is able to possess. It is difficult to continue to believe that a computer has some sort of mind in the face of this and similar arguments.

Despite the best efforts of scientists, artists, philosophers, and religious leaders to render the world more comprehensible, it is undeniable that it remains a mysterious place, starting with our own minds. In our efforts to understand the human situation, a constant theme has been to try to explain the mysteries by the introduction of new concepts and beliefs that are justified by their explanatory power rather than their intellectual foundation. These often provide the psychological and emotional nourishment that most of us need to fortify ourselves for life's journey, with its tribulations and vicissitudes, but while this may lead us to accept these ideas, it may also partially blind us to their inadequate foundations. Examples abound: the ancient Greeks and Egyptians had a panoply of gods with elaborate relations with each other, this world and the afterlife that they inhabited. These concepts continue as bodies of myth and belief in religions that are still followed today. In philosophy, similar concepts appear, especially in Plato through his theory of forms and his continual reference to the gods. One might be tempted to dismiss all of this as ancient superstition, except that some of the great philosophers of the last few hundred years, who are still influential, also use these devices. Science is not immune to the introduction of extensive new concepts in order to explain something quite simple. The idea of vast numbers of parallel but unseen universes has recently crept into scientific thought, and one interpretation of quantum mechanics requires that the world is continually splitting into many separate worlds.

Generally, in any field of inquiry, it cannot really be a reasonable strategy to introduce hidden and unknown elements in order to explain something that is not understood, unless they also lead to greatly increased overall understanding.

1.5 Possible advancement

The weight of past concepts and speculations makes it difficult to know either how to make progress in understanding the mind or even where to start. What sort of solutions might we hope to find, and where should we look? There seem to be many diverse possibilities, some of which are listed below.

Complexity

Maybe any proper understanding of the mind is just extremely complicated so that we cannot easily grasp it. There are examples of mathematical problems that are quite easy to state but have extremely long and obscure solutions. The French lawyer and mathematician, Pierre de Fermat (1601-65), claimed to have found a proof, referred to as his 'Last Theorem', that a particular set of equations could not have integer numbers as solutions. The equations are quite simple, but it was not until 1995, more than 350 years later, that the English mathematician Andrew John Wiles (b. 1953) finally found a proof that ran to over a hundred pages of advanced mathematics. There cannot be many who can understand this, and most have to accept it on trust.

The map-colouring problem is also easy to state: what is the smallest number of colours needed to mark out the different countries on a map so that neighbouring countries are always differently coloured? The answer of four can easily be found by trial and error, but it took over a hundred years for the appearance of a proof which depends heavily on the use of computers to perform many elaborate steps and is difficult for us to comprehend.

Suppose that there is a way of understanding the mind but it is so extensive that, with our limited mental capacity, we could never even read about it and certainly could not understand it. If we read a book a day, in a lifetime, we could ever only read 20,000 to 30,000 books. If an adequate explanation filled 50,000 books, we would never be able to read them all, much less understand their content.

Neuroscience

Although huge progress has been made in neuroscience since the early twentieth century, there are aspects of the operation of the brain that are still imperfectly understood. There is bound to be further progress in this field, which might lead to a proper understanding of our minds. Observing the mechanisms at work may suggest new but presently unknown concepts. In recent years, non-invasive methods, particularly imaging techniques, have been developed to study activity in various parts of the brain, but the view obtained is still external to the person under study.

Antiquated concepts

Perhaps we have been saddled with inaccurate antiquated concepts that we should abandon, and we should start from scratch. Maybe the whole vocabulary of minds, bodies, religion and much of philosophy should just be dumped, and we should rid our thoughts of all the old ideas. This would certainly feel liberating, at least at first, and would give us an opportunity to create a new world for ourselves. Thoughts along these lines have been developed by the American wife-and-husband, Patricia (b. 1943) and Paul Churchland (b. 1942), who championed the philosophy of eliminative materialism. They regard our common sense and everyday concepts as folk psychology which is a wholly inadequate and outmoded attempt to understand the world and ourselves. They believe and argue that this psychology has little or no explanatory power and should be abandoned. Its concepts will never be explicable in terms of the scientific concepts that they regard as paramount and that, they believe, will one day provide a complete picture of the mind.

Quantum mechanics

Some aspects of the theory of quantum mechanics have encouraged the belief that it plays an essential but little understood role in the mind. The unique role of the observer in the theory and the existence of entangled states have been both discussed extensively since the 1930s. More recently it has been suggested by the English physicist Roger Penrose (b. 1931) and the US anaesthesiologist Stuart Hameroff (b. 1947) that certain quantum events in microtubules in the brain lead to conscious experiences. These are still live unresolved issues.

New philosophy or science

Maybe more philosophy will produce an acceptable and believable concept of the mind. A refined and better understanding of our existing concepts might be constructed. There is certainly no shortage of philosophers now compared to the past, and so it would be reasonable to hope for progress.

The laws of science are certainly incomplete, so perhaps there are some overlooked aspects of the laws that do not make any difference to the consideration of fairly simple objects or to gross overall properties, but which become important when considering an object as complicated as the mind. It is always possible that some completely new and unanticipated discoveries will completely transform our way of understanding our minds and our relationship with the world. This is not a very helpful comment as, if true, it would encourage us to sit back and wait for further developments, maybe for generations. Most would hope for much more immediate progress.

Attempts have made since the 1990s to establish a science of consciousness. This aims to bring the expertise of different academic disciplines together to try to establish a coherent view of the basis of consciousness. So far, no consensus has been established, but these are early days. Those involved include computer scientists, neuroscientists, psychologists, psychiatrists, chemists, quantum physicists, parapsychologists, philosophers, and those engaged in religious and other similar studies. One clear aim of this group is to solve the 'hard problem' of consciousness, that is, how the physical processes of the fundamental sciences can produce conscious experiences in the brain.

The early developments of digital computers led to considerable speculation that they could act as a plausible model of our minds. The electrical circuits were regarded as analogous to neurons, and our thought processes as analogous to the computer programs or software. Despite a great initial flurry of activity, this idea is now in decline.

Perhaps we just do not have the right tools and new ones – whether linguistic, scientific, conceptual, or other – need to be developed.

Dualism is really true

Perhaps dualism is really true after all. Maybe there are vital spirits that are in the world but can be detached from material bodies. The distinguished Australian neuroscientist and Nobel Prize winner John Eccles (1903-97) developed a form of dualism, and thought that 'we are spiritual beings with souls existing in a spiritual world as well as material beings with bodies and brains existing in a material world'.

Lack of capabilities

Perhaps the most pessimistic idea of all comes from the English philosopher, Colin McGinn, who proposes that the human mind is constructed in such a way that it cannot formulate the concepts that are needed to comprehend itself. It may be like asking one of our ancient ancestors from the Stone Age to explain the intricacies of the theory of relativity or how jet engines work. Clearly they could not. However, Stone Age humans could no doubt be educated, but McGinn is saying that, in relation to understanding our minds, this forever remains an impossibility for any of us. This is a deeply depressing thought, and if we accept it, we should just fold our tents and disappear over this particular intellectual horizon immediately.

Intractability

Maybe the problem of understanding our minds is simply intractable. That is, one could understand in principle how an understanding of the mind might be achieved but be unable to perform the necessary steps. The travelling salesman problem is a good example of a mathematically intractable problem. The salesman has a list of shops that he has to visit and wishes to know the shortest route that he should take to visit them all. This is quite simple to figure out if he has few shops on his list, as the distance travelled for each possible route can be calculated. However, the volume of computation needed increases sharply as the number of shops increases, eventually making it impossible to find the shortest route he should take, even with the most powerful computer. However, salesmen travel about each day either ignorant of or untroubled by this apparent difficulty.

Panpsychism

Ancient and primitive man believed they, and all other things in the world, including sticks and stones, possessed a soul or spirit. More recently it has been suggested that even the simplest object has some definite but insignificant mental properties that are overlooked, but become apparent when these simple objects are aggregated into much more complicated things such as people or animals. These ideas linger on in the philosophy of panpsychism as an explanatory principle. This is the idea that, in some sense, elements of mind are everywhere, but come to a of pinnacle in ourselves. This idea is perhaps hard to refute completely, but it is equally difficult to convince the sceptical mind of its truth, and the newly introduced elements lie outside of science.

Inadequacies

Perhaps our language is simply inadequate to express the concepts that are needed to understand our minds. By analogy, science could not have been developed without new mathematics. For example, German born Albert Einstein (1879-1955) needed non-Euclidean geometry and tensor algebra to establish his theory of general relativity.

1.6 Concepts, good and bad

Positions of extreme scepticism are often very difficult to dismiss satisfactorily, as also are strongly held beliefs that have no rational foundation. If a person refuses to believe that the world has any existence outside their own mind, it is quite difficult to produce logically compelling arguments to convince them. There is a curious mental illness, Capgras syndrome, in which the sufferer believes that everyone that she meets is a replica of the original person. It is difficult to dislodge this belief. It is also very difficult to find proof that a mythical creature such as the Loch Ness monster, or any imaginary creature, does not exist. What is accepted as a valid proof varies considerably from subject to subject: in logic and mathematics only the most irrefutable arguments are accepted, whereas at the other end of the scale, say in medicine or biological science, evidence-based common sense arguments are generally acceptable.

Any investigation will have a starting point that is supported by assumptions, both explicit and implicit. It is very difficult to escape, or even properly understand, those assumptions that are deeply embedded in our language and culture. However, it is necessary to try to give a list of our assumptions and beliefs as a point of departure for this book.

Independence of the world

The world exists independently from my own mind, and other minds exist and operate in ways generally similar to my own. I cannot prove this, as I cannot occupy another's mind in the way that I could occupy her house or car. However, strong support for this assumption must surely come from the identical way that all humans are produced; that is by birth from a human female following sexual intercourse. We are all made the same way and so it is reasonable to assume we must all have the same major features, rather in the way that all new Ford cars leaving the same factory are the same, but with different colours and accessories.

Science is correct

Science, within its known defined boundaries, is assumed to be essentially correct. This does not mean that the present body of knowledge is immune from future correction but that these will not make previous ideas completely redundant.

Minds need bodies

There is no survival of the soul or mind as a separate entity following death. They depend on a corporeal body for their creation and continued existence. If parts of the brain become destroyed by accident, illness or the ravages of old age, this is accompanied by a diminution of their owner as a person. Further, vital spirits, gods, God or any other insubstantial objects have no independent existence.

No privileged knowledge

Priests, witchdoctors, shamans, and religious figures have no privileged forms of knowledge unavailable to the masses. Crystal power is a figment of the imagination, as are all the other similar totally conjectural beliefs involving pyramids, paganism, tarot cards, and tea-leaf reading. All superstitions, especially astrology, are meaningless, worthless practices. It is not possible to obtain any true knowledge by revelation, either from a sacred text or as directly revealed from on high.

1.7 Starting point

Any concepts about the mind must involve all human experience and therefore must not be formed by extensions or expansions of specialised knowledge beyond their scope. Although the destination is to have a complete view of the mind, there is no obvious starting point. To continue where others have left off either in philosophy, neuroscience, computer science or psychology is unattractive. This is because of the very nature of the difficulties: some new directions are required, not just a recycling in novel ways of the old categories and concepts. Some other starting point is therefore needed. In some senses, it does not matter where to start as it seems that human knowledge must ultimately be of one piece: there cannot be isolated areas with no connection with other areas. This must be true even though not obvious as knowledge is often much compartmentalised. Analogies can be found from travelling, as mentioned earlier in this chapter. The starting point does not affect the destination.

Further, any new approach, even if it seems novel, must be generally consistent with what was previously known in the sense that it can offer an entirely new perspective, but it must also be able to shed light on the nature of the previous erroneous ways of thinking. The realisation that the earth circles the sun provides a perfect example of this: at a stroke both a correct way of conceptualising the universe and an understanding of the old error was found.

The division between mind and matter is still deeply entrenched, and a philosophically active interest both of those who want dualism to form their world view, despite its many difficulties, and those committed to the view that everything is ultimately physical. Others are determined to escape into some form of monism in which everything is an example of a single thing. This second group are usually materialists of some hue, and their efforts often diminish or eliminate the role of the mind in their overall conception of the world. Rather curiously, the two sides of the mind-matter divide get unequal attention from philosophers. A search of the internet shows that the number of hits from 'the philosophy of mind' outnumbers those from 'the philosophy of matter' by more than a hundred to one. This is a very large disparity, and it implies that matter is so well understood that there is little or nothing to say about it beyond the discussions of the scientists. This, then, shall be where we start to try to gain a foothold into trying to understand the mind.

1.8 Summary

Understanding the mind is an intractable but intriguing problem with a long history. Much has been written, but no universally accepted views are established. A new starting point is needed.

CHAPTER 2
What exists

2.1 What is matter?

To the ancients, ignorant of the invisible substructures, many things must have been inexplicable. It is only in the last few centuries that this substructure has been revealed, and material objects have been stripped of their many mysterious veils. Matter can be considered either by common sense or from a specialised scientific or philosophical stance. We all have a view of one sort or another: matter is wood and stones, tables and chairs, cars, aeroplanes and computers. Most people would include at least some living things: viruses, trees, and lowly life forms. Animals and humans are generally also regarded as made from matter. Philosophers now tend to refer to matter as whatever can be studied by the methods of the physical sciences, and they regard physics as the most fundamental of these. This definition has both the advantage that it does not need to be changed when new discoveries are made at the forefront of a rapidly changing subject and, in addition, those who adopt this definition can retain an Olympian detachment from a detailed knowledge about the physical sciences. It is generally assumed that physics is of paramount importance and that the other sciences are dependent on the bedrock of certainty that it provides. There are many things in the world that would seem to fall outside the philosopher's definition. Not far from here there are derelict buildings and slightly further afield a rubbish tip. Both of these objects have a somewhat but not entirely random structure, and it seems unlikely that they can be usefully studied by scientific methods; certainly, no passing scientists appear to have become interested in their structure so far. The philosophic definition is far too inexact and vague and does not provide the necessary distinction that it tries to make. It must, therefore, be recognised that there are many objects that fall outside the definition, but that would ordinarily be considered as examples of matter. These objects cannot be thought of as obeying any laws of science, but neither do they disobey them.

A more extreme definition is that matter is what obeys the laws of physics. Clearly, tables and chairs have no equations of their own, and their existence as matter has to be related in some way to the more fundamental equations of matter. It is difficult to see that their uses as opposed to their structure, come within any scientific ambit. There are numerous other examples of matter that are not properly encapsulated by this definition.

The details of all the sciences are necessarily complex and have changed considerably over the last two centuries as new facts and relationships have been found, and new theorems have been proposed. In much earlier times matter was conceived by philosophers in exercises of speculation. The conception of matter has changed from the atomic speculations of the ancient Greeks through many stages of increasing exactitude to the recent speculative ideas of string theorists.

The German philosopher Carl Hempel (1905-87) raised an interesting objection to the idea of using physics as the basis of philosophical discussion. Because there will be new discoveries in the physical science, it must be incomplete and cannot form a reliable basis for metaphysics, but alternatively, a metaphysics cannot be based on a completed science as we do not know at present what that will be. This problem has never been properly resolved, but perhaps, like the sciences, metaphysics must change and develop in line with what is known.

There are two important questions that can be asked about any piece of matter. What is it made of and where has it come from? The first of these is the traditional question that has interested man since the start of philosophical activity. The second has been posed as a religious question but has been answered only quite recently by scientific explanations about the origins of the different chemical elements and the origin of the universe. The answer to both questions lies outside everyday experience and involves either a journey to the very small, or backwards in time to the 'Big Bang' at the start of the universe, 14 billion years ago, when the vast emptiness of space, and all it now contains, occupied an unimaginably small volume.

2.2 The seven circles: from the living to strings

A brief excursion will now be made into current ideas about the structure of matter that underlie visible experience. Some order can be brought to bear on the very different ideas by comparing the structure of matter with a descent into the Inferno in the first part of the *Divine Comedy* by the Florentine Dante Alighieri (c. 1265-1321).

The journey starts in our everyday world of familiar objects – tables and chairs, people and animals. The descent continues into a microscopic world, invisible to our senses, and as the depths of the Inferno are approached the objects encountered become smaller and more exotic, but to produce them requires increasingly more energy or a hotter furnace, reminiscent of Dante's burning cities and boiling blood. In our universe, these extreme conditions are found only in the very early universe, in exploding stars, and in particle accelerator laboratories such as that at CERN in Switzerland. At the deeper levels of the Inferno, a huge zoo of new particles is found with strange properties that have been encountered only recently. On descending further, the more exotic quarks appear and, at yet deeper levels, the dimensions of the Inferno suddenly increase from the four of space and time that are so familiar to 10 or maybe 11, and peculiar strings appear that are the ultimate constituents of everything at the higher levels through which we have descended. Let us start the descent.

The first circle: living cells

In the first circle, invisible to the naked eye, are all the cells of which living creatures are made. These were discovered in the seventeenth century following the invention of the microscope, but it was only much later, in the nineteenth century, that they became recognised as the basic building blocks of all higher forms of life, and the origin of the next generation. Each cell is like a small factory. Inside it, complex chemical reactions are orchestrated, and it interacts in multiple ways with neighbouring cells and with its environment. Cells are destroyed by heat which breaks them up into parts.

The second circle: molecules

In the second circle, at a smaller scale and a deeper level, complex molecules are found including the very important deoxyribonucleic acid (DNA), which contains all the instructions for the development of life. Large protein molecules are found together with much simpler molecules, many of them carbohydrates. Dante had the poet Virgil to accompany him, but for our journey, there is no guide; our journey into the unknown has been put together piecemeal quite recently by an army of intellectually curious academics.

The third circle: atoms and the chemists

This part of the journey was started just over 200 years ago. The alchemists were succeeded by the chemists who placed the mysteries of chemical composition and change within a rational framework. Our modern concepts of the atomic structure of matter started with the work of John Dalton (1766-1844). He was born into a modest Quaker family in the north of England and became interested in meteorology and chemistry, on which he made meticulous notes. He never married and worked for some years as a school teacher. His researches on the chemical reactions of gases showed that different substances combined in fixed proportions. From this, he deduced that each element must be composed of tiny identical particles called atoms. The molecules of different chemical compounds are formed when these atoms combine in fixed proportions. In chemical reactions, the atoms are unchanged, but can combine into different molecules. Dalton worked out a table of the relative atomic weights of the elements, and his work was the scientific starting point for modern ideas about the structure of matter, bringing to an end millennia of speculation.

After Dalton, the science of matter developed enormously, supported by evidence based on experimental findings, and unimpeded by fanciful conjecture. However, the acceptance of the reality of the atoms was quite slow. Advances in the mechanical theories of the behaviour of gases gave estimates of their very small sizes and led towards their general recognition. Atoms are extremely small: 10 million of them would be needed, side by side, to cross a pinhead. Further evidence of them comes from Brownian motion in which very small, but visible, particles suspended in a liquid can be seen under a microscope to dance about with a random motion. In the early years of the twentieth century, Albert Einstein showed that this was a direct consequence of collisions between the small particles and the very much smaller molecules of the liquid. Any lingering doubts about the reality of atoms have been dispelled in the last few decades, by direct images of individual atoms.

Let us pause a moment and consider the journey that has taken us down to the third circle. Immediately below the world of our bodies and our immediate senses, in the first circle, are the ever active, but invisible cells from which we are made. In the second circle are the complex molecules that can change by chemical reactions. Many processes take place in these two circles at ambient temperatures, such as the digestion of food or the coagulation of blood. Many complex and irreversible changes are seen, for example, in the cooking of food, the breaking of eggs, the setting of glues, or death. At higher temperatures living cells are destroyed and chemical reactions of atoms and molecules can take place as in the smelting of ores in a furnace or in their destruction in the garden bonfire.

The first direct evidence for the substructure of the atoms was not found until the early part of the twentieth century as a result of work in Manchester, England, by the New Zealander Ernest Rutherford (1871-1937) and his collaborators. In bombarding a thin film of gold with alpha particles from radioactive decay, they discovered that some of the alpha particles were deflected through very large angles. This could only be explained if the atom consisted of a collection of electrons surrounding a tiny central nucleus. Inspired by these results, Niels Bohr (1885-1962) from Copenhagen, Denmark, developed a theoretical model of the atom that also provided an exact explanation of many of the regularities that had been observed, over previous decades, in the light emitted by hot gases. Bohr's work, greatly developed and extended by himself and others, has withstood the test of time and still provides a further departure point for the understanding of matter. These men were the first to descend into the fourth circle where the nucleus is found and which has properties quite different from the higher circles. The dangers of nuclear weapons are found here, and Dante's warning should be heeded by those inclined to explore: 'Abandon all hope, you who enter.'

Rather than continuing by giving a history of the development of ideas about the atom, we will give a brief account of the structure of matter at the atomic level here. The main facts are uncontroversial and accepted by everyone. All atoms are extremely small, and even the thinnest sheet of gold leaf is 10,000 atoms thick. There are 92 different naturally occurring atoms ranging from hydrogen to uranium, the smallest to the largest. Every atom consists of a cloud of electrons moving at high speeds, surrounding a smaller, but much heavier, nucleus that is only a hundred-thousandth of the radius of the electron cloud. Each element is defined by the number of its electrons. The atoms are held together by attractive electrical forces, with the electrons negatively charged and the nucleus with an exactly equal but opposite positive charge. The electrons circulate around the nucleus in some ways like planets moving around a star. The analogy is not too exact as, unlike planets, the electrons move in all directions and not just in a single plane, and are more similar to a swarm of bees. Overall the atoms are electrically neutral, are extremely stable, and, with a few exceptions in our environment, have remained unchanged over billions of years. The chemical properties of the atoms are determined by their outermost electrons, some of which are easily removed mechanically. This was known by the ancient Greeks who discovered that amber rubbed with fur becomes electrically charged and attracts small objects. A similar effect occurs when a person becomes electrically charged as a result of walking on a carpet made from artificial materials and receives an electric shock.

Of the different atoms, hydrogen is the simplest with only one electron that circulates around a nucleus of a single proton. Nearly all the mass of the atom is contained in its nucleus as its constituents are more than a thousand times heavier than the electron. The electron circulates around the nucleus at high velocity, and left to itself it will remain like this forever. Heavier atoms have more complex nuclei with both neutrons and protons, and correspondingly more electrons. A neutron is electrically neutral and slightly heavier than a proton. Neutrons do not occur by themselves as they decay in a quarter of an hour into a proton and other products. The carbon atom has six electrons and a nucleus that contains six protons and six neutrons.

All other atoms are built up in this way, and this relatively simple structure, which is understood with great certainty, is the basis of matter in our world. Atoms can combine with each other to produce molecules. Some of these are quite small, such as the water molecule, H_2O, but others, as found in the biological materials, are very complex: a single molecule of haemoglobin in the blood is made of many thousands of atoms. All the complicated structures of the world are made of atoms, which is perhaps surprising as they seem such simple objects. These structures are sufficient to explain, from a scientific perspective, many features of our world, and our understanding of them has resulted in the development of the many technological developments on which we now depend.

It would be conceptually both neat and convenient if atoms were the most elementary objects in our world. This would give a final answer to the child who continually asks ‘why’ when her previous question has been answered. However, deeper and ever deeper circles have been found, and perhaps a final destination is in sight.

The fourth circle: the nucleus

Delving into the structure of the nucleus of the atom is a further descent into the Inferno: there are further levels with different natures, each with a character of its own. This world is entirely unlike anything we have directly experienced and can be understood only by adapting, distorting, extending or altering the concepts developed for the world we know from everyday experience. Also, like the Inferno, the deeper we descend, the more energy is needed, or equivalently the hotter it becomes. Before starting the further descent, we must say something about how this can be done and why gradually increasing energies are needed to investigate the structure of matter.

Atoms of the elements were for a time regarded as indestructible building blocks from which everything is made, and this is true in our normal environment. This simple idea changed forever as a result of Rutherford's report in 1919 that he had artificially transmuted one element into another. He bombarded nitrogen with alpha particles of high energy and showed that the nitrogen was converted into oxygen. At last, the alchemist's dream had been realised, and subsequently it even became possible to convert lead into gold. Following Rutherford's methods, James Chadwick (1891-1974) discovered the neutron in Cambridge, England, in 1932 by bombarding beryllium with alpha particles. Chadwick showed that nuclear reactions had taken place which produced unknown uncharged particles, which he christened neutrons. The existence of these as constituents of the nucleus had been suspected for some time.

Rather more sinister was the later discovery, in Germany, of the fission of uranium into fragments with a massive release of energy. And in Cambridge, England, the fusion of the deuterium isotope of hydrogen into helium was demonstrated, also with considerable energy release. After these discoveries, no time was wasted before bombs of unimaginable destructive power were developed in the United States. Unfortunately, these have been used twice against civilian populations in southern Japan. The same nuclear reactions can, alternatively, be used for peaceful purposes to provide heat to generate electricity.

Atoms such as carbon have 12 times the mass of a hydrogen atom, which consists of a single electron and a proton. As it was known that carbon has six electrons circulating its nucleus, which contains six protons of opposite charge, the problem was where the extra mass came from. The neutron provided the answer: the carbon nucleus must be composed of six protons and six neutrons. Neutrons and protons are the building blocks of all nuclei and are held together by so-called strong forces. These forces operate only at extremely small distances and have no analogue in the everyday world.

In the fourth circle, the structure of the nucleus can be revealed by bombarding it with protons or other particles. This needs accelerators to produce particles with huge energies, about 100 million times greater than the energy of atoms at room temperature. This is a staggeringly large difference, and almost equally surprising is the extremely small sizes of the nuclei, typically 100 thousand times smaller than the atoms that contain them. They are so small that a grain of sand made of nuclei would weigh a million tons. The beams of particles from the early accelerators were enormously successful both in causing nuclear transformations from one element to another and also enabling the investigation of the complex structure of the nuclei. They have, with a few exceptions, extraordinary stability on Earth, and this underlies the unchanging nature of many things in the world.

The fifth circle: the particle zoo

Encouraged by successes in investigating the nucleus, even larger accelerators were built. These became very complex and were operated by very large teams of scientists and technicians. Since the 1950s, scientists have been bombarding matter with particles of ever-greater energies, up to 100 million million times more than the energy of atoms at room temperature. This was the entrance into the fifth circle of the Inferno where huge numbers of exotic, previously unknown, particles were produced. They were classified into families by their similarities.

At these exceptional energies, a whole zoo of unfamiliar particles appears including mesons, new leptons, strange particles, charmed particles, antiparticles, and bosons. Thousands of these particles have been discovered, and matter at these energies and small sizes is rich in unfamiliar properties and is more complicated than the simpler world of the atom. The more matter is examined, the more perplexing it is. The apparently relatively inert stuff that surrounds us has a complex and fascinating interior.

In a typical investigation, hydrogen is bombarded by energetic protons and showers of unfamiliar particles are produced. This does not mean that these particles were somehow inside the hydrogen nucleus waiting to be released: they are created by converting some of the energy of the protons into new matter. The great showers of new particles are therefore entities in their own right, not to be thought of as constituents of the proton. This is possible as a result of Albert Einstein's discovery that energy, E, and matter of mass, m, are equivalent and related by his famous equation, $E=mc^2$. Because the velocity of light, c, is so large, a huge amount of energy is needed to produce a small quantity of matter.

The technical details of how this is accomplished are complex, and much advanced engineering is required. Accelerators are now enormous and occupy circular underground tunnels many kilometres in diameter in which the particles circulate, guided by magnets in an evacuated tube. As they circulate, the particles receive small but regular increases in energy, which gradually build up to the very high energies required before they are allowed to react with matter. The largest of these is the Large Hadron Collider (LHC) at CERN in Geneva, which has been operating since 2008. Observing these new particles is a gargantuan technological feat. It is ironic that the observation of such tiny particles requires equipment of enormous size. The ATLAS detector at CERN is 22 metres high and 44 metres long, containing millions of silicon microchip detectors and immersed in a large toroidal superconducting magnet.

The discovery of the inhabitants of the zoo revealed the far greater complexity of what had appeared to be the simple structure of atoms and their nuclei. Since the late 1950s, more of the 'elementary' particles were discovered every year. Even the world at large became interested and impressed, and some early discoveries, such as that of the omega minus particle in the early 1960s, were reported in the newspapers. Much more recently, the public has become excited about the discovery of the Higgs boson.

The sixth circle: quarks

So many new particles were discovered that none of them could be considered elementary in any sense. Order was brought to the developing conceptual chaos by the American scientist Murray Gell-Mann (1920-2019), who proposed that the existence of all the different particles could be explained if each was made of a much smaller number of particles that he called quarks. These are quite unlike anything previously seen and occupy the deeper sixth circle of the Inferno. A striking difference of quarks is that they have an electrical charge that is either one-third or two-thirds that of the proton or the electron. As all previously known particles have a charge of one or zero, they can only be made of combinations of quarks. For example, a proton and neutron are made of three quarks, and the somewhat lighter mesons are made of two quarks. The quarks also have properties that have no direct analogues in the everyday world, but to distinguish them for descriptive purposes, these different properties have been given names. The quarks come in six different flavours: up, down, charm, strange, top, and bottom. Another remarkable fact is that they have never been seen, but it has been realised that they made a brief appearance in the first moments of the creation of the universe. There is no doubt among the experts that they exist as the substructure of the 'elementary' particles, and there is experimental evidence that they are small point-like particles. There are also plausible reasons for their non-appearance. Is this then the end of the journey, or is there further to go? Developments from this point seem to have diverged, and elaborate speculative theoretical structures have been constructed to describe the ultimate structure of matter. So-called theories of everything are being sought, but some will be disappointed to know that 'everything' in this context is restricted to the specialised interests of scientists and astronomers.

The seventh circle: strings

Again it would be simpler if we could stop here, but there is a deeper circle. This descent can be made only in the mind, as it is well beyond direct experience. These greatest depths are far removed, and far beyond the abilities of any scientists to explore by direct experiment. We humans are too large, too slow, too cold, and have the wrong number of dimensions to venture there ourselves. The lowest depth is protected by a thick, dense fog that can be penetrated only by those with advanced mathematical knowledge.

All objects and particles interact as a result of four different forces. There are gravitational and electrical forces, which are familiar to all, and the strong and weak forces that operate only at the very small distances of the nucleus. The strong forces hold the nucleus together, and the weak forces are responsible for radioactive beta decay. For many years all these forces were regarded as separate, but in the 1960s several theoretical physicists managed, from considerations of symmetry, to combine the weak and electrical forces into a single electroweak theory. As a major advance in the progress towards a final theory, this breakthrough won the Nobel Prize for physics in 1979 and, together with the theory of quarks and strong forces, set the stage for further developments. The new theory became the Standard Model of the zoo and provided the theoretical underpinning for a huge body of experimental data.

In a separate development, in the late 1960s a start was made on the construction of string theory. This describes all the most fundamental particles of matter as strings which have different properties according to how they vibrate, rather like the different strings on a cello. Some strings are loops, while others are open-ended. They are extremely small, and there is no direct evidence that they exist. This has attracted criticism from those who think it is an unwelcome move away from science as an empirical activity, based on observation of the world. One of the predictions of string theory was that a completely unknown particle should exist, but it was quickly realised that this particle was the graviton, which was responsible for the gravitational attraction first studied by Newton. This realisation caused huge intellectual excitement: at last a theory of everything seemed a real possibility, and the three forces mentioned above could be joined by the gravitational forces. This is still a developing area, however, and while encouraging results have been obtained there have so far been no final answers on the ultimate structure of matter. A considerable difficulty is that string theories come in a very large number of different possible forms.

Strings are very peculiar objects. They are unimaginably small, 10^{20} times smaller than an atomic nucleus, and, unlike our world of the four dimensions of space and time, they exist in 10 or 11 dimensions. It has been suggested that they might be the final constituents of matter, the irreducible atoms of the ancient Greeks, but this may not be the ultimate frontier. It is extremely difficult to imagine an object that exists in 11 dimensions, but apparently, these extra dimensions are somehow curled up inside the particles and are therefore invisible. As an analogy, think of a tangled ball of string in the real world. Viewed from afar it looks like a point-like single object in three space dimensions, but to understand it fully we must know its internal structure.

Our descent into the Inferno stops here. There are no final answers yet, and the nature of this deepest seventh circle is, for most of us, additionally shrouded by dense layers of mathematical reasoning. The downward journey ends with an all-enveloping fog of ignorance that no one has yet penetrated. This world is not some distant land but is all around us. We exist in blissful ignorance of its presence. All these extra dimensions and the subatomic particles are right under our noses and are an ever-present and permanent, but invisible, part of everyday objects.

2.3 The creation of matter

There are various bits of matter in front of me now and it would be interesting to know their origin. The answer in many respects is quite trivial. The spectacles came from the optician and the books from the bookshop. However, this is not the question I am asking. What I want to know is the ultimate source of these material objects. If I keep going back and continue to ask, time and again, 'Where did that come from?', I will need to journey back in time, eventually to the start of the universe, in order to understand its origin and development.

One of the most important first steps in understanding the structure of the universe on the largest scale was made by the American Edwin Hubble (1889-1953), who worked at the Mount Wilson Observatory in Los Angeles. Using both the 60-inch and the 100-inch Hooker reflector telescopes, he established that the fuzzy nebulae that had been seen with smaller telescopes were galaxies of huge numbers of stars. His estimates of their distances from Earth showed that they are well outside our own galaxy, the Milky Way. The velocities of these distant galaxies were determined from the Doppler shift of their radiation. This led to Hubble's greatest and best-known discovery, that the universe is expanding, and that all galaxies in the universe are moving away from each other, with the more distant ones moving fastest. This picture of the structure of the universe, refined over the years, has provided the foundation of all subsequent cosmological work. One immediate consequence of Hubble's work is the supposition that all the galaxies and stars must have been in one place in the past at the very start of the universe, which was subsequently christened the Big Bang. This suggestion was first made shortly after Hubble's discoveries, but the detailed structure of the Big Bang has only recently been investigated. Its existence was brilliantly confirmed in 1965 when universal black-body radiation was discovered, which could only be explained as a remnant of the original very hot universe that existed when the universe was small and young, some 14 billion years ago. All matter must have had its origin at this time and place.

Now, after enormous expansion, the universe is a largely empty place. Our galaxy is part of a local group of galaxies, and on a larger scale, there are clusters and super-clusters of even more galaxies with great empty voids between them. There is an unimaginable number of galaxies, and even more stars in the known universe. The universe contained only hydrogen and helium early on, but it now contains a great variety of other elements including iron and gold. As they were not made in the very early universe, they must have been made later.

So where did the various constituents of the earth come from? This story is quite complicated but starts with the creation of the first galaxies from the primeval hydrogen and helium. In these galaxies, stars were formed that shone brightly and illuminated the universe. In the nineteenth century, it was thought that all stars radiated as a result of the energy they had received when they formed by contraction under the force of gravity. However, this source of energy would have become rapidly exhausted, and our sun would have long since ceased to shine. After the discovery of nuclear reactions in the early twentieth century, it was realised that such reactions provide a source of energy and at the same time build up the elements. In the hot centre of our sun nuclear reactions occur that transform hydrogen into helium with a release of energy. The process takes place quite slowly, and this allows our sun to continue shining for billions of years.

Stars eventually exhaust their fuel and become unstable, with explosive results that can sometimes be seen by the naked eye. A notable example was the supernova that was seen by Chinese astronomers in 1054. It was so bright that it could be seen during the daytime for several weeks, but fortunately, this event took place a long way from Earth. The remains of this explosion can be still seen as the Crab nebula, which contains both remnants from the solar interior and heavier elements that were created in the explosion.

These remnants will eventually combine to form new generations of stars and planets. It was from similar long past events that most of the elements of the earth and in our sun were created. The history of all the matter on my desk can now be told. It came from the very early universe, followed by galaxy formation, and then by the formation of our sun and earth from the debris of exploding stars. Incredible though it may seem, you and I are made from this debris.

However, the tale is incomplete without some consideration of the nature of the very early universe when it was small, dense, and very hot. We can go back in time by imagining a film of the universe running backwards. The first thing we would notice is that it is shrinking. After a while, there are no stars, just clouds of gases, dominated by hydrogen and helium atoms. As the universe becomes smaller and hotter, the atoms break up into their nuclei and electrons. When it gets hotter new classes of reactions take place, producing some of the zoo of subnuclear particles mentioned earlier. At even earlier times, at unimaginably high temperatures, a quark soup brewed. Eventually, the gravitational forces become comparable to all other forces, and strings appear in their extra dimensions. All the known physical laws break down. This state is the start of both space and time, and questions about what went before have no apparent meaning. At this very early stage, the universe is incredibly small, and it is difficult to imagine that everyday objects really had their ultimate origin there. The very early universe is not fully understood and, while very considerable strides have been made, it continues to be a subject of active research.

2.4 Arrangements are fundamental

Are there any philosophical issues that arise from our circuitous journey into the nature of matter? Or are the philosophers right to treat its whole complex history and structure with lofty disdain? Put another way, what is it that all examples of matter have in common?

It is difficult to produce a concise answer that will encompass pots and pans, molecules and subatomic particles, and you and me. An important feature is the appearance of hierarchies. In scientific language: molecules are made of atoms; atoms of electrons and nuclei; the particle zoo of quarks, and so on. Each higher object has an existence and properties of its own that are dependent on the lower elements as a substrate on which it rides. This seems a proper representation of the science, even if it is very generalised.

A very simple example of a piece of matter is the helium atom, which is composed of two electrons, two protons, and two neutrons. However, this is not the only way these building blocks can be arranged. They can be arranged in different ways as two heavy hydrogen atoms, each consisting of one electron and a nucleus made of a proton and a neutron, or just split up into their separate parts. The atoms are dependent on the existence of their building blocks, but their nature is dependent on their arrangement. The blocks do not determine the structure, as the same blocks can be arranged in different ways. Further, when thinking of the atoms, we do not continually remind ourselves of their constituents but regard them as things that exist in their own right, and this was the universal view before the discovery of their substructure. Balloonists do not consider their helium supply as a collection of particles with a particular atomic and nuclear structure, but simply as a handy gas that keeps them aloft. The successful balloonist needs to know nothing of any deeper structures. It would be useful if this could be stated in a more formal way that would also allow a similar sort of description to be applied to both larger objects such as molecules and smaller ones such as protons. A specific object must be seen as an arrangement in its own right, and while it is dependent on its substructure in the sense that it would not exist if that was taken away, the arrangement has an independent existence of its own. The arrangement *is* the object, and in everyday life, only very complex arrangements are encountered.

Therefore it is proposed that the statement '*A* is made of *Y*' be replaced by '*A* is a particular arrangement of *Y*'. This then makes it clear that the *A* items are not simply just the *Y* items, as the *Y*s can be arranged in different ways, and that to define the *A*s additional elements are needed: this we refer to as their *arrangement*. *A* is then a hybrid of the idea of an arrangement and the constituents *Y*, which themselves are also arrangements. The *A*s are not just the *Y*s but are something else, even though they cannot exist without the *Y*s. This definition of an arrangement is recursive so that a great hierarchy can be set up, as the *Y*s are arrangements of other arrangements. The unifying idea is that all things are arrangements in some great hierarchy. The hierarchy does not go on down forever to smaller and more obscure objects but stops eventually in a fog of ignorance in 10 or 11 dimensions. A possible scheme is: a person is an arrangement of cells; cells are arrangements of molecules; molecules are arrangements of atoms; atoms are arrangements of electrons and nuclei; nuclei are arrangements of elementary particles; elementary particles are arrangements of quarks (which have never been seen), and quarks are arrangements of strings in many extra dimensions surrounded by an enveloping fog of ignorance. An important feature of these hierarchies is that the lower levels do not fully determine the higher levels: an understanding of quarks will tell us nothing about molecular structure, but without quarks, there can be no molecules. In conclusion, all things of which we know are arrangements of some sort.

It is difficult to object to this scheme on scientific grounds even though there are many unanswered questions at the most fundamental levels. It is possible that the theories of everything that are being actively sought will fit into the proposed conceptual scheme, but it is equally possible that fundamental theoretical ideas become so abstract and mathematical that they cannot be properly understood in terms of analogies to the familiar world of our senses. We will have to wait and see how this all turns out. There have been many false dawns in science when it was believed that there was little further to discover. It is quite possible that scientific thinking in the future will be quite different from anything we envision today.

It could be objected that all this is mere hair-splitting and adds absolutely nothing to what is known. This may be true for some of the examples given, but we will now argue that this different way of considering objects provides a way of uniting all the disparate items labelled 'matter', and will eventually have many other interesting features. Though equations are anathema to many, it is useful to restate '*A* is a particular arrangement of *Y*' as

$$A=A_pY$$

If the helium atom is identified with *A*, then *Y* represents the two electrons and the four other particles. The way in which they are put together is contained in A_p. In this way, objects that we previously called matter can be thought of as arrangements. The term 'matter' can then be either removed from our vocabulary or thought of as synonymous with an arrangement. Physics and science become investigations of what sorts of arrangements can exist and their properties. The advantage of this scheme is that widely different objects can be seen as exemplars of arrangements. Thus, atoms can be seen to have a commonality with considerably more complex objects, such as motor cars and aeroplanes. There would seem to be no objection to extending the concept to objects of considerably greater complexity, such as humans and their activities. If this could not be done, a dividing line would have to be drawn at some arbitrary point between us and objects that clearly are arrangements. This would seem to be both undesirable, unjustified, and unnecessary.

For many purposes, it is not necessary to try to understand the ultimate composition of a particular arrangement. If *A* is an arrangement of a set of arrangements *X, Y, Z*... not much is added to an understanding of *A* by knowing all the detailed ultimate composition of the elements of the set. Though it is necessary that the arrangements *X, Y, Z*... persist in time during the existence of *A*.

Returning to the real world, we can say that a house is an arrangement of bricks, timber, and glass, or that a motor car is an arrangement of its components. When constructed, both of these have properties of their own, which are not determined by their components but dependent on the arrangement of their construction. For example, I can say that my spectacles are an arrangement of glass and plastic, that cells are arrangements of molecules that, in turn, are arrangements of atoms. Going to smaller objects, the scientist might want to say that a proton appears to be an arrangement of quarks and that these are arrangements related to strings. There are some difficulties with this from two sources. First, when we think of an atom as an arrangement of other particles, part of this idea is related to what we know about atoms. We understand how they are made by assembling them or discover their structure by pulling them apart. When it comes to the quark structure of a proton, neither of these is possible, as individually free quarks are not encountered. Therefore we need to shift our meaning a bit and state that a proton, or another member of the particle zoo, *appears* to be an arrangement of quarks. To go further down into the seventh circle requires further conceptual contortions, but we know too little at present to perform the necessary mental gymnastics. Perhaps we should leave this with the statement that many particles are arrangements in four dimensions of quarks which are arrangements of strings that exist in many more dimensions. These latter sorts of arrangements are quite different to those needed to consider the atoms. However, the effects of strings only become apparent at very short times and minute distances, so except for these extreme regions, the concept of an arrangement is a valid one. Maybe in the future, it can be generalised satisfactorily, but for the moment all we can say is that in the seventh circle the concept of an arrangement fades away in a general fog of ignorance, and the journey certainly has to end there for the moment. From a philosophical point of view, the conceptual drift and final fog are unsatisfactory, even though the idea of an arrangement seems to be a valid one over almost the entire universe, past and present. Indeed, if the very early universe and very short times and distances are excluded, it would appear that the concept of an arrangement applies to everything else.

One of the great attractions of the idea of an arrangement is that complex objects can have their structure exposed recursively. For example, a motor car can be thought of as a particular arrangement of its major components: its engine, bodywork, wheels, and other parts. Then the arrangements of the parts can be further considered, down to blocks of steel being prepared for the rolling mill, and eventually, if we wish to make the journey, down into the depths of the Inferno to atomic structure and beyond. However, in order to understand the structure of a particular arrangement, it is not necessary to undertake a complete journey down to the seventh circle. For example, an understanding of tables and chairs requires a knowledge of the material from which they are made, but nothing is added to our understanding of a table if we are told that it is ultimately constructed of quarks.

2.5 Arrangements of complex objects

Knowledge of the constituent arrangements gives no information about how a particular arrangement might be constructed. Consider a girl playing with her building bricks. An uninterested adult might remark that that anything she constructs is just something made out of her bricks, but there is more to be said about her constructions. It is not the bricks that determine the result of her efforts but the way in which they have been chosen and arranged. Perhaps she makes an elephant from the bricks, but she could have made a giraffe instead. Therefore, the elephant should be regarded as the arrangement of the bricks and as something over and above, and more than, the bricks, also arrangements. This way of thinking about matter has the great advantage of being able to be generalised both to more complex objects than building bricks.

In some levels of the Inferno, knowledge of one circle implies the nature of the circle above. However, this is not generally true at the upper levels of the Inferno, as a particular selection at one level does not determine a particular arrangement at higher levels, just as a pile of bricks and timber do not imply a particular design of house, office, or skyscraper.

When referring to the structure of particles in the subatomic world scientists typically speak of a particle or atom as being made of other objects. At the subatomic level, this is often a sufficient description: if we know its substructure, the properties of an object are also known or at least are implied. A particular selection of quarks arranged together will produce a particular elementary particle of the zoo; or an electron and a proton can be arranged together to produce a hydrogen atom. Great varieties of different arrangements cannot be made from a few of the fundamental arrangements, and these arrangements can be determined from their constituents. For very complicated objects, knowledge of the constituents is not sufficient to determine their properties, and further information, from outside the physical sciences, is needed in order to complete the description of the object. This is because a small number of objects can be arranged in a huge number of different ways, and the number of arrangements of the constituents of a large object, although not infinite in the mathematical sense, is so huge that it may as well be considered infinite for all practical purposes. The idea that a complex object is a sort of arrangement would be acceptable to many, but the new idea that is being put forward here, in addition, is that the traditional objects of the physical sciences must also be regarded as arrangements, with the proviso that the concept of an arrangement gradually changes as we consider smaller and more exotic particles, and that the chain of arrangements terminates in a fog of ignorance that, at present, we cannot penetrate. This view of what exists is sufficiently general to encompass anything that we might encounter and provides a conceptual bridge between the relatively narrow interests of the hard physical sciences and wider human activities. The physical sciences have often been regarded as the pinnacle of human truth, on which everything rests, and this has encouraged some to arrogance, and to despise or denigrate other activities. Ernest Rutherford is reported to have remarked that 'All science is either physics or stamp collecting'. More recently, there have been growing claims that a scientific world-view can encompass all of life and human activity. The English scientist Stephen Hawking (1942-2018) thinks that he is close to understanding the mind of God, but others take a less sanguine view, believing that the complex human world cannot be fitted into a simple mathematical or scientific idea extended well beyond its valid domain.

Arrangements in time

One of the consequences of defining all things as arrangements is the implied relationships in time. If an arrangement is made of other arrangements, this implies that the original arrangements existed prior to the new arrangement, or at least have been created simultaneously with the new arrangement. This gives a time ordering to all arrangements. In addition, the original arrangements must persist in time for any arrangement of them to continue. Hence, in the universe at large, galaxies precede stars, planets precede life, and the development of animals precedes humans. Our parents precede us, just as we, in turn, precede the next generations.

Arrangements made with a set of children's building blocks are reversible, but not all actions are reversible. Exceptionally, the building blocks of some Egyptian temples have been disassembled and reused to build new temples or other monuments. So, for this example, the structure of the arrangement can be considered in terms of both its method of construction and its disassembly. A film of the assembly of a temple, if run backwards, would look the same as a film of its demolition.

This cannot, however, happen with most arrangements. In making an omelette, eggs are broken, butter is melted in a frying pan, the eggs are whisked, and then cooked to produce the omelette. This whole process has a time sequence to it and cannot be reversed. We simply cannot make eggs from an omelette or put the egg back into its shell. Most processes are of this irreversible nature, and many new arrangements can be viewed only by the way in which they are created.

Nature of arrangements

There is also the question of exactly what can be identified as an arrangement. Tables and chairs are clear examples, but there are other arrangements that have a random construction or arbitrariness in their identification. Again consider a pile of rubbish. This is not an arrangement in the sense that it has been deliberately created by someone, as in the case of a chair, but it is a random arrangement of broken bottles and cans, old bits of plastic, and other discarded items. Nevertheless, it is an arrangement and can be deconstructed backwards in time, at least in principle, into the arrangements from which it is made. We say 'in principle', as the history of the rubbish is almost certainly lost.

Now that we are satisfied that everything we have so far regarded as part of the world is an arrangement, we shall consider how this might apply to the realm of the mind. Having described the material world as arrangements, we can ask if all the remaining things about us can be properly and adequately identified as arrangements. For example, it has long been recognised that mental events have many properties that are entirely different from those encountered in the world at large. For the moment, we shall just concentrate on the notion that mental events have a proper existence in the universe as arrangements and that, in contrast to many arrangements, they also have a meaning. Surely all of us have at some time gazed up into the immensity of the night sky and despaired at the meaningless nature of the universe. However, things that go on in our heads are not like that. Many of our thoughts are perhaps not too profound, but they have a meaning. We do not entertain rambling random thoughts that would be unrecognised by others. It is therefore proposed that mental events should be considered as arrangements with meaning, and this is what distinguishes them from arrangements outside our minds. It must be added that there are other sorts of mental events, such as feeling hot or cold, which will also be identified as arrangements. We shall return to these later.

An essential question is how anything with meaning can be established in the first instance. At one time, the earth was a lifeless planet, but now things with meaning proliferate on every corner. How can this have happened? It is clear that something with a meaning has to have a relationship with other things outside itself. It is no use shouting 'fire' in a foreign land where no one understands the word. There is no reason that meaning cannot initially develop by random chance or fortuitous circumstance, and we propose this as a suitable and sufficient mechanism. This might be thought of as a rather poor and unproductive instrument, but its power has been established in another context by the English naturalist Charles Darwin (1809-82), in his great works about the origin and development of living creatures. An example will show the potential of this mechanism. Consider a lowly life form that moves haphazardly but, as a result of a random change in its genetic make-up, it flashes with light every time it eats something. Suppose some of its fellow creatures respond to this, also as a result of random change, by being attracted to these light flashes and moving towards them so that they can join the feast. It is clear that this behaviour produces communication within the species about the location of food. The individuals that respond to the flashes will become well-fed, but their unreceptive fellows will starve. In this way, a small element of meaning is created, and we can imagine that a similar process might apply to our early ancestors, before a spoken language was developed. If your grunt, stimulated by an approaching lion, was recognised by me as the same as my grunt, then we could both get up a tree quickly, leaving our less advanced and unfortunate companions to provide lunch for the lions.

We are proposing that the old matter/mind division be replaced by the idea that everything is an arrangement, but that mental events have the additional property of having meaning. This removes at a stroke any difficulties we might have in allowing the realm of the mental into our thinking. The separation of mind and matter into two completely different substances, first proposed by Descartes, simply disappears if everything is an arrangement. The philosophy of dualism can be replaced by what philosophers call monism, in which mind and matter can be reunited as they are both arrangements, though greatly different ones. The concept of an arrangement is sufficiently broad to encompass very widely differing objects, such as both sorts of golf clubs: those that are used to hit golf balls, and the organisations of members with rules about correct behaviour and other important matters. The concept should also appeal to those philosophers of a materialist bent who are sceptical of things of the mind that they regard as '*just* arrangements of matter'. It is the 'just' with which we would quarrel and the implication that matter is something quite different from an arrangement.

Huge complexity of arrangements

Even a few objects can be arranged in a bewildering variety of ways, as can be illustrated by considering a tiled floor. No trip to Venice is complete without a visit to the basilica in St Mark's Square. In addition to the magnificent architectural delights, the murals, paintings, and mosaics, there are floors made of small stone tiles of different colours and shapes. After admiring the sheer variety of patterns that appear, one might wonder if the unknown craftsmen who laid the floors exhausted the possibilities of their craft. This is a question that can be answered from a scientific point of view. There is certainly nothing about those tiles that have lain on the floor for so many centuries that disobeys any of the scientific laws.

Consider a very small area of tiling that could be covered with 100 tiles. Suppose the tiles come in 10 different colours. The tiling can proceed quickly. The first tile is chosen from one of the 10 colours, the second, and then the rest until the work is done. How many distinct patterns can be created? The answer is simple: the first tile can be chosen in 10 ways, the first two in 100 ways, the first three in 1,000 ways, and the whole 100 tiles can be chosen in 10^{100} ways. This is a huge number, which is greater than the number of atoms in the entire universe. It is quite surprising that such a very large number of different arrangements can be made. I have no idea how many tiles cover the basilica floor, but it must run into millions. The number of possible ways of tiling the basilica floor must be so large as to be beyond contemplation, and we can conclude that it is impossible to know more than a few possible patterns. We can certainly not proceed from knowledge about coloured tiles to deduce what might be found when we visit Venice. An important conclusion can be drawn from this: a deductive approach can never be used to determine what might exist in general, as there are just too many possibilities. Even computers of unimaginable power will be of no help. This argument has many consequences in our ideas about the world, and when contemplating practically anything, it is well to remember that the range of other possibilities, although not infinite in the mathematical sense, is so large that, for practical purposes, it may as well be.

Most objects in the world are much more complex than small areas of flooring, and we cannot ever hope to make any progress in understanding the complete range of possible complex objects. All that can be done is to consider the complex objects that are presented to us, whose number will necessarily be finite. We can know all the rules of assembly of arrangements into new arrangements, but we cannot know what all these new arrangements will be because of their enormous number. So we can know little about the different worlds that could exist. To take a simple example, if the land-masses of the world were all arranged differently, it would profoundly affect all our lives. However, the number of possibilities is too large for us even to consider. It is a mistake to believe that the physical sciences can give any real guidance about the nature of what complex objects might exist. Anyone who feels disinclined to believe this should take a look at the enormous diversity of fossils that have been found in the Burgess Shale Formation in the Yoho National Park in Canada. Both the soft and hard body parts of different life forms that existed in the Cambrian world have been preserved here, and it is impossible not to be impressed by their sheer variety. Many of these strange creatures have no known descendants in the subsequent fossil records or today. Presumably there are many other species that could have existed, and maybe some of these are now alive elsewhere in the universe.

Universal scope

To summarise: we have travelled a long way down into the depths of the microscopic world and back in time to the early universe. The traditional categories of matter have been glimpsed in all their complexity. It is proposed that all objects in the universe are arrangements of varying degrees of complexity and that everything previously considered to be in the category of matter is also an arrangement. It has also been shown that the range of possible arrangements cannot be determined by a deductive approach because of the huge numbers of possibilities. The idea of an arrangement is wonderfully recursive, as any particular arrangement is an arrangement of other arrangements, allowing the consideration of arrangements of any degree of complexity. Although in the sciences different arrangements form distinct hierarchical constructions – such as are found in atoms, molecules, and cells – there is no reason why arrangements have to follow this pattern. In general, a complex object can be an arrangement of any other type of arrangement without regard to its position in a hierarchy.

An immediate consequence of this idea is that things that have previously been considered as separate mental substances are also arrangements. This provides us with a continuity of concept that will embrace both the traditional subject material of the physical sciences and everything else outside these narrow confines, including the concepts of science. Although these concepts are used to further our understanding of the world, they stand apart from the subject matter of science itself. In order to comprehend any sort of object, it will be necessary both to understand and to dissect its arrangement, as well as to appreciate the properties of the arrangement as a whole, and its relation to other arrangements. The distinction between different sorts of arrangements, particularly those of the mental variety, will be discussed in a later chapter.

Once it is accepted that the most fundamental thing in the universe is an arrangement, all other objects and structures can be related back to this basic element. So far arrangements have been presented as essentially static objects (the pyramids, tables, atoms, molecules, and so on). However, it is apparent that the world also contains many things that are in a constant state of change and some of these changing scenarios can be thought of as events, which must be related to the more fundamental arrangements. A simple and adequate definition would be that events consist of the changes and developments in time of an arrangement. This definition would seem to be sufficiently broad to cover all eventualities from the great complex scientific events in the development of the universe to the prosaic and trivial, such as jokes or television programmes. This gives us another strand of allowable objects that are compatible with the laws of science: all things are either (for fairly static objects) arrangements, or (for objects that are under continual change) events. Allowable objects can also be thought of as static arrangements in three spatial dimensions or as events in the four dimensions of space-time.

A related question is how a particular arrangement can be picked out. Any random collection of arrangements can be considered as a new arrangement, but this is generally not helpful. The simplest idea is that particular arrangements have some sort of independent existence, at least for a time so that their identity can be established. Few things are totally independent of their environment, making this is a concept with somewhat hazy edges – but the world is like that. However, the question presupposes that someone or something is determining what it is that is interesting and deserves its status as a separate entity. For the army practice of naming of parts, this process is clear, but it is not so clear for much more complex cultural events such as the development of a language.

Separation of parts

In considering different arrangements that can be made, the discussion has tacitly assumed that the same thing is always under scrutiny and easily identifiable, even for subatomic particles that have only a transitory existence. It also implies a carving up of the world into clearly separate entities. For this to be reasonable, a particular arrangement must have only a weak or slow interaction with other arrangements for its lifetime. This is quite an acceptable idea for tables and chairs or a motor car, and for about living objects that are continually undergoing change, albeit slowly, such as plants or trees. We think of these as changing slowly from one state to the next in the journey from seed to destruction.

The simplest arrangements carry no history: All water molecules are identical, and there are no historical facts attached to them. This is not true for living creatures, as they have a basic structure, encoded in their DNA, that not only contains the instructions that guide their growth but also carries a historical record containing information about their origins. In addition, living objects are sufficiently isolated from their surroundings for them to count as separate arrangements.

Copies

In considering a particular arrangement, it is interesting to consider other arrangements that are related to it. The simplest relation is that of an exact copy. A cloned plant or animal is an example, and all nitrogen atoms are the same, but although most living things are unique, they come in families that are similar to each other.

Representations

However, it is much more interesting to consider the nature of a representation, that is, an arrangement that contains the essential features of another arrangement, but is neither a copy of nor identical to what we might call its parent. If A represents B, there has to be a mechanism, also an arrangement, that is able to determine the nature of the representation. This is clearly a matter of great complication: it has been endlessly debated how a word is able to represent something in the world. Some arrangements cannot be represented by something simpler. An example is a random number. Things that are close to random are difficult to represent.

2.6 Summary

All things, including mind and matter, are arrangements. This concept gradually dissolves in an as yet unknown multidimensional space at short times and distances, and at the birth of the universe. These are places that are impenetrable to humans.

CHAPTER 3

Change

3.1 The ancient Greeks

Ideas of motion and change mystified the earliest Greek philosophers. For Heraclitus the world was in a perpetual state of flux, but for Parmenides, no change was possible, and we are constantly deceived by our senses. These ideas have been a continuing preoccupation of humankind and still hold some attractions, as even today we hope to recognise permanent features of the world while accepting that we are surrounded by the creation of the new and the decay of the old. The ideas of Parmenides, though influential, are not easy to understand. We would now side with Heraclitus, and accept that our world is continually changing, even though some changes can be so slow that nothing happens in a lifetime.

The concepts of motion and change were greatly developed by Aristotle in his writings about physics and the heavens. His views, though largely incorrect, were highly influential for many centuries. In his time, which was lacking in any real scientific knowledge, the movements of animals and the apparent motion of the sun, moon, planets, and stars were deeply mysterious, and these, together with all other changes, called for an explanation. Aristotle believed that it was essential to have an understanding of these phenomena as part of our knowledge of the world, and discusses their causes. In *Physics* and elsewhere, he offers four separate causes. The first is the *material* cause, and to illustrate this, he gives the example that the bronze is the material cause of a statue. The second cause is the *form* of the statue. So the complete statue needs both of these as causes. The third cause is the *primary* cause, and examples he gives include the father as the cause of the child and the artisan as the cause of the statue in the sense that he makes it. This is nearest to the modern conception of a cause. Finally, he identifies the *end or purpose* as a cause. Certain things are caused because they are aimed at a particular end. Going to the supermarket has the purpose of buying food to prevent hunger. Aristotle was also preoccupied with the potential difficulty that when a thing changes, there is also a continuity between the initial and final thing. This idea later produced religious difficulties for those who wished to believe that God had created the world from nothing. He thought that there were essentially two different sorts of motion: terrestrial objects travelling in straight lines, and heavenly things that travelled in circles and continued their motion forever. His views of what would now be regarded as scientific were taken up by the Christian Church and, unfortunately, turned into a rigid system that should not be questioned. The earliest universities also regarded Aristotle as the ultimate source of truth.

In the Renaissance, these views were overthrown, as a result of developments in astronomy and mechanics. The new developments were not just confined to these narrow areas but spread to influence the entire Western intellectual tradition down to the present era, and for this reason, it is necessary to outline the main principles and strands of these new ideas.

3.2 Astronomy

Astronomy had interested and intrigued mankind since the dawn of history. A huge contrast was seen between the unchanging heavens and the constant change and decay seen on Earth. For practical purposes, the regularities seen in the sky were used to reckon the changes of the seasons and to determine religious events. The heavens were divided into different spheres that revolved about the earth, with the fixed stars moving in perfect circles. The sun, the planets, and the moon were also supposed to move around the earth, but the outer planets did not move in simple circles. In order to remedy this, and to retain the idea of circular motion, a theory of epicycles was developed in which a second circular motion was imposed on the motion of a planet circulating the earth. This provided a description of planetary behaviour that accounted for their sometimes retrograde motion across the background of the fixed stars. The whole system was explained in great detail in the *Almagest*, written by Claudius Ptolemy (c. 100-170), who flourished in Alexandria in the second century. Ptolemy's book was the authority on astronomical matters for well over a thousand years and became an important part of orthodox thought. In our present era, when concepts and ideas alter with bewildering speed, it is difficult to comprehend how influential were the ideas handed down as established fact and principle to successive generations.

The first major challenge to the prevailing views came from Nicholas Copernicus (1473-1543) who was born in Poland and later travelled to Italy. Copernicus studied a wide range of subjects, including law and medicine, but became deeply interested in astronomy and the motions of the planets. In his great work, *De Revolutionibus*, he proposed that the old Ptolemaic system be replaced, and suggested instead that the planets revolve around the sun, and that the earth rotates once a day to give apparent motion to the stars. He gave an account of the motion of the planets, but retained the idea of epicycles and obtained agreement between the observed planetary movements and the somewhat inaccurate measurements that were available to him.

Armed with better measurements, and having abandoned epicycles, Johannes Kepler (1571-1630) was able to give a much more accurate account of the motion of the planets. Born in Weil der Stadt, now in Germany, and educated at Tübingen University, Kepler did most of his well-known work in Prague. He found that the planets move around the sun in ellipses, with the sun as a principle focus. He reached this conclusion only after performing calculations of very great length, a task that was considerably eased by his use of the newly published logarithmic tables. Kepler also formulated the three laws on planetary motion that bear his name. The view of the heavens was changed forever by these discoveries.

3.3 Galileo, Newton, and Laplace

Further important changes to the established body of correct knowledge were made in Italy by Galileo Galilei (1564-1642) who created the new science of mechanics, made important discoveries in astronomy, and, most egregiously, had his views condemned by the Inquisition. Before Galileo's time, the motion of terrestrial objects was treated as a matter of philosophical speculation: all motion was thought to be in straight lines, with sudden changes of direction. A stone thrown in the air would travel along a straight path so far and then fall directly to Earth. In particular, Aristotle had held that heavy objects fall to the ground faster than lighter ones, and it is often, but probably erroneously, repeated that Galileo showed this to be untrue by dropping unequal weights from the Leaning Tower of Pisa. Although he reported the result of similar experiments on falling bodies, he also, very much in the older tradition, showed that Aristotle was wrong by means of a thought experiment. He imagined two objects of unequal weight falling together, but joined by a string. If the lighter one fell more slowly, it would make the string taut and slow the heavier object. The composite, of a greater mass than the heavy object, would then fall more slowly, in contradiction of Aristotle's conjecture, which therefore must be wrong.

Galileo's approach to determining the movement of objects was entirely new: he observed their motion, and, most importantly, applied mathematics to his results. He made measurements of the movement of spheres down inclined slopes and showed that the distance travelled increased with the square of the time. He also investigated the motion of a swinging pendulum and found its period of oscillation varied by the square root of its length. He also greatly clarified the concepts of velocity and acceleration. In particular, he formulated the idea that objects in motion would continue to move with the same velocity forever if they were not acted on by external forces. His laws are still regarded as correct today.

Although all of Aristotle's ideas about motion turned out to be incorrect, they were a good first step, as an initial enquiry into both mechanical and many other matters. The real failure was the uncritical adoption of his ideas by subsequent thinkers who turned them into articles of faith. Indeed, Galileo himself did not believe that Aristotle had been an obstinate person but that his authority had been bestowed on him by later followers with closed minds.

Galileo also made important discoveries in astronomy by looking at the heavens with the newly invented telescope for which he ground the lenses himself. Some of his telescopes, together, somewhat bizarrely, with one of his fingers, can be seen in the Galileo Museum in Florence. He observed the moons of Jupiter and found that they were in orbit around that planet, a fact that was at variance with the generally accepted view that heavenly bodies moved around the earth. Galileo saw mountains on the moon and observed that Venus had crescent-shaped phases, like the moon. Both these observations defied the accepted wisdom, and some responded by refusing to look through a telescope to confirm for themselves what he had seen, while others argued that what he had seen was some artefact in the lenses of the newly invented instrument.

Galileo fully accepted all the new discoveries about the planetary system and taught and wrote about the heliocentric ideas. This brought him into serious conflict with the Roman Catholic Church. The immediate cause of this was the publication of his book *Dialogue Concerning the Two Chief World Systems*, in which he explained the two systems of astronomy: the older Earth-centred ideas that were part of Church dogma, and the new ideas of Copernicus in which he believed. The Roman Inquisition banned sales of the book, and Galileo was summoned to Rome to be tried, even though he was an old man and unwell. He admitted a degree of guilt, hoping for a light sentence, but was condemned to life imprisonment. Through the intervention of a sympathetic archbishop, the sentence was commuted, and Galileo spent the rest of his days under a form of house arrest near Florence. Despite the Church's opposition, Galileo's work and that of other astronomers became widely accepted throughout Europe. It marked the start of the division of science from religion that is now almost complete, except perhaps for those who oppose Darwinism on flimsy theological grounds.

The stage was then set for further developments: the structure of the planetary universe was understood, as were the laws of the movements of the planets, and, the laws of mechanics were established. The next decisive step was made by Isaac Newton (1643-1727) in Cambridge in England where, on account of his great brilliance, he was appointed Lucasian Professor of Mathematics at an early age. He carried out extensive investigations on the nature of light, reported in his celebrated book *Optiks*. He developed an early form of calculus called the theory of fluxions, which was essential for his work on gravitation.

In 1665 Newton was forced to return to his home in Woolsthorpe, Lincolnshire, because of an outbreak of the plague. While there he began to consider the motion of the moon and the planets, and the nature of gravitational attraction. According to legend, his discoveries were stimulated by his observation of the falling of an apple from a tree in an orchard. The tree continued to grow into the nineteenth century when it was cut down and its timber preserved for posterity. From Kepler's laws of planetary motion, Newton deduced that the force of gravitational attraction must vary inversely with the square of the distance, and this led him to consider the motion of the moon. He calculated that the moon must fall from a tangential path by 13 feet a minute; he had first calculated, using inaccurate information, that it should fall under the gravitational attraction of the earth by 15 feet. The discrepancy between these figures led him to abandon his ideas for some years until improved estimates of the size of the earth enabled him to reconcile his calculations. Newton regarded this as proof of the correctness of his idea that gravitation on Earth and in the heavens were the same. After various delays and an unseemly dispute with Robert Hooke (1635-1703), his theory of gravitation and his equations of motion were published in 1687 in one of the greatest, but perhaps little read works of science, *Principia Mathematica*.

The success of Newtonian mechanics, refined in its application to planetary motion by the French mathematician and astronomer Pierre Laplace (1749-1827), profoundly affected further scientific progress and many other developments of thought and philosophy. Rational rather than ecclesiastical methods of thought gradually advanced, and the view of the world as obeying a set of universal laws became more widely adopted. These new methods of understanding the world displaced the incorrect ideas that had been perpetuated for centuries by the Church and by medieval scholars. Also, the whole edifice of Aristotelian science was abandoned as it came to be seen as wrong in both method and fact.

Laplace had the greatest confidence both in himself and in the new mechanics: with a complete lack of modesty, he told Napoleon that he had no need to include God as a necessary hypothesis in his works. He also believed that mechanics applied not only to planetary motion but to the universe at large. He wrote:

We ought then to regard the present state of the universe as the effect of its anterior state and the cause of the one which is to follow. Given for one instant an intelligence which could comprehend all the forces by which nature is animated and the respective situation of the beings who compose it - an intelligence sufficiently vast to submit this data to analysis - it would embrace in the same formula the movements of the greatest bodies of the universe and those of the lightest atom; for it, nothing would be uncertain and the future, as the past, would be present in its eyes.

On this view, the world is a giant deterministic system that, once set in motion continues forever in accordance with of the laws of the universe. The intellect that oversees this system is referred to as Laplace's demon. This impressive claim needs to be considered in more detail.

If true, Laplace's claim applies to any completely isolated classical system: once the system is set in motion it continues to move forever in a way that is determined by the Newtonian laws. If the positions and velocities of the planets are known at a particular time, they will be known forever. This is truly impressive, but the everyday objects that surround us do not seem to behave in this predictable manner, so we may question how useful or applicable this approach is. An essential part of these calculations is the requirement to set the initial conditions: only then can the subsequent motions be determined. This may seem easy to achieve for a relatively simple mechanical system but for complex objects it is difficult or impossible. One of the fundamental motivations in scientific explanation is the wish to explain fairly complicated behaviour economically. Laplace's demon does not seem to offer that prospect for many of the objects that might interest us, as it is just too difficult to specify the configuration of a complicated object. Nor does his approach allow us to fully understand the behaviour of relatively simple objects composed of many parts.

Although I do not wish to propose that Laplacian determinism is a correct view of the world of classical mechanics, its claim needs to be taken seriously mainly because of the influence it has had in suggesting that the universe is a deterministic place. This can lead to an abandonment of the ideas that we have of free will and that we are responsible for our actions. So why should we wholeheartedly reject his claim even if it seems to be true for simple mechanical systems? The claim is about the development of the whole universe and does not apply to the consideration of a small local system unless it is completely isolated for everything. Although we can imagine such a system, we can never know anything about it as it is isolated from us. It is often argued that, apart from the problem about the specification of the whole universe noted above, if we know anything about some local thing we must interact with it, and this alters it. Although these effects are sometimes extremely small, they must always exist. Therefore the principle is rejected except for totally isolated systems that can be conceptually conceived but never encountered. This allows us to consider how things change in our part of the universe without the burden of determinism.

In the real world everything is subjected to noise and the effects of heat, and the causes of events are varied depending on how far the search for understanding reaches. We live in a state of ignorance and all our thoughts and decisions are made in a noisy environment on the basis of partial information.

3.4 Complex systems

As an example, consider a set of 50 rods linked at each end to another rod and assume that there are forces of some sort between each pair of rods: these could be provided by springs or elastic bands. Given the initial positions and velocities of all the rods, the laws of mechanics can provide equations that allow all the future movements of this system to be calculated. A difficulty arises in specifying these initial conditions, as there are just so many of them. It is easy enough to investigate the behaviour following one particular initial configuration, but quite impossible, as a practical matter, to investigate the total behavioural possibilities following all possible initial conditions. If the rods are all in a single plane, the initial configuration can be specified by the angle of each rod and the position of one of the rods. If each angle is specified to a not very high precision of about 1 per cent (3.6 degrees), the number of different possible configurations is 10^{100}, which, like the Venetian floor example in Chapter 2, shows the general impossibility of this sort of investigation. The complete behaviour of this composite object cannot, therefore, be investigated in practice; the investigation of a limited subset is all that can be hoped for, given its initial conditions.

This does not mean that the behaviour of a particular system cannot be explored by the application of the laws, but it does mean that the system can have properties that are not amenable to investigation because of the practical difficulty of enumerating all initial conditions and calculating the subsequent behaviour. This sort of argument will apply to any sort of physical theory, and we are left with the conclusion that the physical sciences cannot possibly provide an account of all possible modes of behaviour that might exist for a composite object. The particular development for a given set of starting conditions can be investigated with precision, but the number of possible starting conditions is so large that it is impossible to deduce all the possible behaviours. It should also be emphasised that the laws of physics are never broken and that once a classical system is set in motion, it will continue to develop in accordance with the laws of mechanics. There are no known exceptions to this, and it is the origin of the idea that the laws of science are causally closed, as indeed they are but only for completely isolated systems. However, this cannot provide a way of understanding complex objects, many of which are much more complicated than the system of rods, and will have even more possible configurations. The idea of causal closure must be replaced by the very much weaker idea that complex systems cannot behave in a way that is inconsistent with the laws of science, but this behaviour cannot necessarily be determined. These laws must include much more than the mechanical laws: electrical and magnetic laws, laws of quantum mechanics, and other scientific laws that have been discovered and found to be universally true. In conclusion, the idea of causal closure may be true, but it will never assist in the understanding of a complex object even though that object will never behave in a way that conflicts with the laws of science.

So when we ask what causes a particular change, the answer is clearly that the final state of a system is determined by the development of the initial conditions in accordance with the laws of the universe, but for complex objects the initial conditions are unknown. This is far removed from the Laplacian universe, in which the planets move in their orbits, with their future and past rigidly determined. Fully deterministic processes that are given as examples of closure are usually of a very simple variety, but the idea cannot be generalised to something much more complicated, that is in continual contact with other things in it environment.

Automata

The idea that the universe is a sort of machine controlled by scientific laws took hold of man's imagination in the eighteenth century, and it influenced subsequent generations of philosophers and rationalist men of culture. The Frenchman Julien de La Mettrie (1709-51) wrote an influential book, *Man a Machine*, in which he put forward a version of materialism and attacked the substance dualism of Descartes. In addition, La Mettrie was also influenced by the invention of accurate clocks. It had been common to suppose that humans might operate in a similar way to complex clockworks, and various mechanical automata were made to illustrate the point. Notable examples were made in the 18th century by the Swiss Jaquet-Droz family, who produced not only clocks but, more interestingly, a mechanical figure that could write up to 40 characters, and a draughtsman that could make four different drawings. Automata were created that could play musical instruments, and there were mechanical swans and even, bizarrely, a defecating duck. These all created considerable public interest, and some of the mechanisms developed were later used in the production of artificial limbs and fairground amusements.

In recent decades, the idea of a deterministic mechanism has been revived by those who think that aspects of mental behaviour can be regarded as analogous to the operation of digital computers or computer games.

The end of rationalism

Outside scientific circles, belief in rationalism came to an end in the Romantic period when it became fashionable to think that the emotions could be used as a certain guide for thought and behaviour. The movement was started by the Frenchman Jean-Jacques Rousseau (1712-78) and popularised in his novels. Earlier ideas that strong emotions should be kept under control were abandoned, and their unconstrained expression became admired, together with individualism. In this period, the belief in rationality as a guide to thought and behaviour gradually began to decay. This was also encouraged in England by the man of letters, Samuel Taylor Coleridge (1772-1834), through his poetry, his other writings, and translations from German. Romanticism emphasised the role of individual feelings and the power of the imagination in understanding humans and their relation to the world. Spontaneity in thought and action were valued, and a new view of nature was developed, which valued places that had previously been regarded as wild and hostile, such as the English Lake District. In terms of enlarging the human spirit, the effects of these new ideas were valuable, and they freed us from the sometimes dry and sterile doctrines of rationalism. However, taken to their extreme, they produced some extremely unpleasant individuals. Most damaging was the idea that emotion and the will are a sure guide to thought and action, a view subsequently shared by the German philosopher Friedrich Nietzsche (1844-1900), who wrote in offensive terms about humans he considered his inferiors; and also by the fascists of the twentieth century who visited such destruction on the world. Unfortunately, the Romantic influence is alive and well and sometimes misleads us as to how we should best live our lives, and supports the individualism ever present on social media. More positively, Romanticism liberates us and encourages us to exercise our imagination.

3.5 Electricity and magnetism

For two centuries Newton's laws reigned supreme and became expressed in more advanced mathematics. However, they did not apply to electrical or magnetic effects, which had been known since ancient times. Aristotle reported that Thales ascribed souls to lifeless things, on the evidence that magnets and amber, when rubbed, could move other objects. Millennia later, Hans Ørsted (1777-1851), who lived in Copenhagen, made extensive investigations into the magnetic field produced by an electrical current. Later, the nature of the forces between a magnet and an electric current, and between two separate electrical currents, was discovered in France by André-Marie Ampère (1775-1836), and others. In Bavaria, Georg Ohm (1789-1854) established his law for the conduction of an electrical current along a wire, but the greatest discoveries of all were made by Michael Faraday (1791-1867) working in London. He discovered the effect of induction, that is, the electrical currents in nearby wires affect each other, and a change of current in one wire changes the current in the other. Changes are also caused by the movement of one of the wires. Faraday also developed the idea that lines of electrical or magnetic force exist and, for example, connect the poles of a magnet. All these discoveries led directly to the development of the dynamo and the electric motor.

However, the major advance in understanding electrical and magnetic effects came with the development of a set of equations that bear his name by James Clerk Maxwell (1831-79) who worked in Scotland and Cambridge, England. These equations unified all the diverse effects that had been observed, and are one of the greatest intellectual achievements of the nineteenth century. They have many applications and also determine the behaviour of complex electrical circuits, including those used by digital computers. They clarified the properties of light and predicted the existence of electromagnetic waves, later discovered by the German physicist, Heinrich Hertz (1857-94).

If we attempt to apply Maxwell's equations to complicated interacting systems, we will encounter the same difficulties as mentioned above in connection with Laplace's demon. Again, in order to consider the behaviour of a system, we must investigate its development from a set of initial conditions, and, as we have seen, these are so large in number for systems of only moderate complexity that it is impractical to investigate more than a few of the initial configurations.

3.6 Thermodynamics

Another development in classical science came from the study, stimulated by the operation of the earliest steam engines, of the relationship between heat, work, and energy. An important initial step was made in the late eighteenth century by the American born Benjamin Thompson (1753-1814), later Count Rumford, in the workshops of the military arsenal at Munich. Thompson observed that when the barrels of cannons were being drilled, heat was produced in the metallic chips separated from the cannon by the borer. This led him to conduct controlled experiments on cannon boring and, to everyone's astonishment, he showed that this heat could be used to boil water, which previously could only be achieved by the heat from a fire. Thompson concluded correctly that the heat had been produced by the motion of the drilling tool and hence disproved the previous idea that heat was a form of fluid that flowed from one body to another.

The next major advance was made by the French engineer and physicist, Nicholas Carnot (1796-1832), who became interested in knowing if there was a limit to the work that could be derived from the boiler of a steam engine. Carnot was motivated by the success of English steam engines, developed on a purely empirical basis, for the great benefit of English industry. He found that the maximum work that could be derived from any sort of heat engine depended only on the temperatures of the hot and cold reservoirs between which the engine worked, and did not depend on the nature of the fluid used.

The science of thermodynamics, based on the work of Rumford, Carnot, and others, was given a proper mathematical basis by Rudolf Clausius (1822-88), who was born in Prussia and became a professor at the University of Zurich. Clausius recognised that different sorts of energy, such as heat and the energy of motion, are essentially the same, and propounded the first law of thermodynamics: *the energy in the universe is constant*. This may seem obvious now, but at the time, much clarification was needed of the concepts of energy, heat, and temperature. Clausius elaborated and extended Carnot's work, and formulated the second law in terms of the very important new concept of entropy: *the entropy of the universe tends to a maximum*. In terms of heat engines, the entropy change of a body is the heat exchanged divided by the temperature. This law has the unique property of defining the direction of time, that is, the flow of time from the past into the future. The other fundamental laws of science are independent of the direction of time and contain no preferred direction. This may seem counter-intuitive: in the real world, eggs get broken, cars rust away, and disorder often reigns supreme. In a film of everyday life, it is immediately obvious if it is played in reverse, as is sometimes done for comic effect. However, this is not universally true. For example, a film illustrating the motion of the planets around the sun, or a pendulum, will look the same played in either direction. This property of the increasing disorder of the world seems fundamental in the world that we inhabit; that it is not reflected in the underlying fundamental equations is a considerable difficulty that has not been fully resolved.

Entropy turns out to be a quantity of fundamental importance, not just for steam engines but for many other processes. The second law of thermodynamics prevents the use of all the heat from a body to carry out work without the loss of some heat to a colder body. It also prevents the flow of heat from a cool body to a hotter body without any additional effects. This sort of flow apparently takes place in a refrigerator, but the refrigerator has a compressor that does work on the cooling fluid so that the whole system is not in conflict with the second law.

The third law of thermodynamics was formulated by the German scientist Walther Nernst (1864-1941), based on the realisation that it is impossible to cool anything to a temperature of absolute zero. However much heat is extracted from a body, some always remains. The third law states that: *as a body approaches a temperature of absolute zero it also approaches a state of zero entropy.* This recognises that there is a temperature, corresponding to a state with no internal energy, below which it is impossible to go.

The laws of thermodynamics, together with Maxwell's equations and Newton's laws of motion, are the foundations of what is now referred to as classical science. They apply to everything, and in the latter part of the nineteenth century were thought to be a complete description of the physical world. The variables that appear in the theories can, in principle, be calculated with an arbitrarily high accuracy. However, as already noted, there are limitations in the way in which these theories can be applied to complex systems.

Random motion

The apparent near perfection of classical science was first called into question by the development of statistical mechanics by Maxwell and the Austrian scientist Ludwig Boltzmann (1844-1906). Both developed a new understanding of the behaviour of gases based on the notion that they were composed of small individual atoms that did not interact with each other, except during collisions. The pressure of the gas was determined by the force exerted by the atoms as they bounced off the walls of a containing vessel. As the atoms were so numerous, it was impossible to construct a theory to account for them individually; instead, methods based on probability were used. On average, each atom would behave similarly to any other atom, and so the behaviour and properties of the whole gas could be found. One of Boltzmann's greatest achievements was to relate the behaviour of the atoms to the concept of entropy that had been developed in thermodynamics, and to show that systems always tended to maximum entropy. While this was known from the second law of thermodynamics, Boltzmann connected it with ideas about probability and showed that the states of maximum entropy were also the most probable states. They are also the most disordered states, and so the tendency for systems to develop in the direction of maximum entropy also means that they develop into states of maximum disorder. His ideas attracted strong objections from those who could not accept atoms as anything other than theoretical fictions, and from those who could not be persuaded that a set of atoms interacting mechanically with each other would have to follow laws that contained a definite direction to time. The counter-argument was that the laws of mechanics were symmetric with respect to time, and it would seem to follow that any set of particles would also behave in a way that was symmetric in time. Boltzmann defended his views vigorously from the criticisms of others, but his end was a sad one as, overwhelmed by depression and illness, he hanged himself. Discussion about the directionality of time has continued and is still an interesting issue.

The reasons for systems to become disordered have become well understood in terms of relative probabilities. Imagine a snooker table with no pockets and suppose that there is no friction so that the energy given to one of the 22 balls is never lost. Suppose all but one ball is at rest. The moving ball will collide with the other balls, and they, in turn, will have further collisions, gradually sharing the initial energy between all the balls. Thus things will continue. Each ball will behave similarly to the others, and anyone watching will have witnessed what seems to be an irreversible process. This has all taken place with a set of balls that obey classical collision laws that are completely symmetric in time. Indeed, if the direction of motion of all the balls is instantaneously reversed, all the energy will return to just one ball so that the system is still symmetric in time in this sense. However, if the balls are undisturbed, then they will appear to continue in roughly the same disorder forever. How can this be understood, and why cannot all the initial energy become concentrated later on just one ball? The answer is, of course, that it can, but this is so improbable that we would have to wait an eternity for it to happen. The states of motion that are seen are just much more probable than states in which all the energy is concentrated on one ball. Each possible state of motion of the balls is equally probable, but there are few states in which all the energy is concentrated on one particle, but many states where the energy is shared out. Random chance will prefer the many states, and the balls will be found in one of these, continually changing from one fairly probable state to the next, and never visiting the improbable states.

If we just look at one of the balls, it will be seen to be moving first in one direction and then another, that is, its motion will fluctuate, and this is a general property of mechanical systems or collections of atoms. These random movements are often referred to as noise, which is the enemy of ordered behaviour and is a familiar and ever-present part of nearly all environments.

A further example can illustrate how systems go into the most disordered and most probable state. Suppose we throw six differently coloured balls at random into a container subdivided into 10 boxes. Each ball can fall into one of the different boxes, and so there are a million different ways in which this can happen. Suppose we are interested in an ordered state in which all the balls end up in one box. Where the first ball goes does not matter, but the second ball has a chance of one in 10 of entering the same box, and so on for all the other balls. The overall probability of all 10 entering the same box is one chance in a hundred thousand. This is extremely improbable and, therefore, will not often happen even in many trials.

The introduction of probability into science was entirely new and conflicted with the earlier deterministic ideas. It became clear that the laws of probability and chance that so obviously played a significant role in the everyday world also played an important role in science and engineering. These new ideas became a death sentence for Laplace's demon. No longer could the development of the world be thought of as a great unfolding of a deterministic process.

3.7 Chaos

Following the discovery of Newton's laws of motion it was assumed that once the initial positions and velocities were known for a dynamical system, the motions of the system could be calculated for the rest of time. Clearly, there is a limit to the accuracy to which the initial positions and velocities can be measured, and this will affect the accuracy of the calculations. It was widely assumed that if a more accurate result for a particular calculation were required, it would be just a matter of specifying the initial conditions more exactly.

This comfortable but incorrect idea was shown to be wrong as a result of a competition sponsored by the king of Sweden who offered a prize for the best answer to the question 'How stable is the solar system?' Among the contestants was a Frenchman, Jules Henri Poincaré (1854-1912), who considered the motion of three particles interacting with each other under the influence of gravity. Although Poincaré did not succeed in answering the king's question, his entry so impressed the judges that he was awarded the prize. What he found was that the motion of the three bodies varied in quite different ways if the initial conditions were varied very slightly. In his own words:

If we knew exactly the laws of nature and the situation of the universe at the initial moment, we could predict exactly the situation of that same universe at a succeeding moment. But even if it were the case that the natural laws had no longer any secret for us, we could still only know the initial situation *approximately*. If that enabled us to predict the succeeding situation with *the same approximation,* that is all we require, and we should say that the phenomenon had been predicted adequately. But it is not always so; it may happen that small differences in the initial conditions produce very great ones in the final phenomena. A small error in the former will produce an enormous error in the latter. Prediction becomes impossible, and we have the fortuitous phenomenon.

Although his discovery marks the beginning of the modern theory of chaos, further progress was not made for another 50 years, until the American meteorologist Edward Lorenz (1917-2008) attempted, in the 1960s, to use a digital computer to predict the weather from sets of mathematical equations that described the behaviour of the earth's atmosphere. Lorentz also found that the results of his calculations were extremely sensitive to small variations in the initial conditions, and he went on to investigate the mathematical reasons for this and founded the theory of deterministic chaos. His discoveries led to the oft-repeated idea that our weather can be influenced by the flapping of a butterfly's wings in a distant land. On short timescales, the weather will obey deterministic laws, but on long timescales, it becomes unpredictable and chaotic.

It has since been realised that chaotic behaviour is commonplace. Although all things that we see obey the laws of the universe, it is not correct to think that these laws somehow determine everything. There is considerable freedom within the laws for an enormous variety of different behaviours, each influenced by the initial conditions of the system, but this is a trail that leads backwards in time, generally into a period of which we are almost totally ignorant. The difference between deterministic and non-deterministic behaviour can be illustrated by a joke that circulated in the second half of the twentieth century when China and the Soviet Union were both ruled by communist dictators. In Russia, it was said that you could do anything that you wanted as long as you did not disobey any of the unreasonable and repressive laws. In China, by contrast, you could only do a restricted range of things that had been specifically authorised. The laws of the universe are of the Russian variety, and it is possible to have complicated behaviour that has not been foreseen by the laws of physics, but that is not in conflict with them.

3.8 Twentieth century science

In the 19th century, science was mainly pursued by a few highly gifted academics at ancient universities. As the century progressed, the number of active scientists increased enormously, fuelled by the realization that there were immense gains to be made from the application of new discoveries for practical and military purposes.

Relativity

In the twentieth century the established classical ideas were overturned by the theories of relativity and quantum mechanics, both developed from the older theories, but introducing radically new concepts. This is particularly true for quantum mechanics which provided explanations of the behaviour of the atom and the subatomic particles. Relativity was developed from some difficulties that had arisen in the study of the electromagnetic equations discovered by Maxwell. At the end of the nineteenth century, it was believed that apparently empty space was filled with an invisible substance called the ether. This substance was at rest and was thought to be necessary for the propagation of the newly discovered electromagnetic waves, in the same way that the presence of the ocean is necessary for the existence of sea waves. The Dutch scientist Hendrik Lorentz (1853-1928) investigated how Maxwell's equations would appear in a moving frame of reference and, in order to produce a new set of equations, he found the curious result that he had to introduce the concept of local time, and also that distances in the direction of motion were changed.

Because the earth continuously changes its direction of motion as it makes its yearly orbit around the sun, it should be possible to measure its movement through the ether. Extensive tests in the United States by Albert Michelson (1852-1931) and Edward Morley (1838-1923) failed to detect any motion. In addition, the Irishman Edward Fitzgerald (1851-1901) suggested that these results were best explained if the length of an object were to change when it moves and contracts in the direction of its motion. At that time, the notions of rigidly fixed time and space were so firmly entrenched that the full significance of these results was not fully appreciated, except possibly by Poincaré.

As a schoolboy of 16, Albert Einstein had pondered what it would be like to run after a light wave with the same velocity as the wave, even though he realised that it was impossible. It took him ten years to find the answer to this mystery in the form of his special theory of relativity. It was Einstein's great achievement to realise that the failure to detect motion through the ether could be explained by the fact that it did not exist, and that measurements of the velocity of light waves by individuals moving at different relative velocities would all give the same results. In particular, no one could surf on a light wave as he had imagined. This rather technical-sounding conclusion had far-reaching consequences: time and distance became relative. Your watch runs at a different rate to mine if you travel and I stay at home; in addition, you look thinner to me as you move. These conclusions seem extraordinary and to defy common sense. These changes are not noticed in everyday life as they are tiny and difficult to detect for velocities that are slow compared to that of light. However, it has been shown, using two highly accurate atomic clocks, that they do indeed run at different rates when one of them travels in a jet aircraft and the other is grounded. In the particle accelerators mentioned in Chapter 2, very high velocities are achieved, close to that of light, and Einstein's apparently strange theory has been amply confirmed. Relativity also introduced the idea that our world is composed of four dimensions: three spatial dimensions and time. The curious non-intuitive effects seen if you and I are in relative motion arise because some of your time can become some of my space, and some of your space can become some of my time. Time and space are no longer absolute. This is very astonishing, but one just has to get used to it. Equally important, and most famously, Einstein established that an object with a mass, m, has an enormous energy content, E, given by $E=mc^2$. Fortunately, this energy is safely locked away, except in nuclear (usually called atomic) bombs and reactors, and at the centre of the sun.

Einstein went on to consider the relationship between accelerated bodies and motion in a gravitational field such as that of the sun. After many years' labour, and a considerable struggle with the mathematics of tensor calculus, he propounded a general theory of relativity in 1916 in which the effects of gravitational attraction are caused by the warping of the four dimensions of space and time.

Einstein's theory replaced Newton's, and introduced a completely new way of thinking. Again, the practical differences between the two theories were very small at low velocities, but Einstein was able to explain the long-standing puzzle of the precession of the perihelion of the planet Mercury. Further, and to much public acclaim, experiments conducted to measure the bending of light rays from distant stars passing close to the sun during an eclipse in 1919 confirmed Einstein's theory and not Newton's. This made Einstein famous overnight: the old Newtonian ideas were overthrown forever.

Not long after its construction, the theory was used by Einstein, the Dutch mathematician, physicist, and astronomer Willem de Sitter (1872-1934), and other scientists to form ideas about the possible structure of the universe, but there were few other experimental applications, and the ideas languished in a backwater for many years. This changed in the last few decades of the twentieth century, when the theory was recognised as an essential and major part of theoretical science. It has been used in studies of black holes and the large-scale structure of the universe. Since 1974, it has been beautifully confirmed by the slowing down of the orbiting period of a pair of neutron stars, called the Hulse-Taylor binary pulsar after its discoverers. One of these is a pulsar that can be used as a clock to measure the changes of the period resulting from the loss of energy of the stars by gravitational radiation. The small change of 40 seconds measured over three decades is in excellent agreement with Einstein's predictions. A further vivid example is the bending of light, first seen in early tests of general relativity, by the gravitational lensing of galaxies. If there is a galaxy between us and another more distant galaxy, a distorted image, sometimes several images, of the distant galaxy are produced because of the gravitational displacement of the light passing the nearer galaxy.

The theory of relativity plays a profound role in the development of the universe on a large scale and is essential to understanding the behaviour of bodies that move at a substantial fraction of the speed of light. Relativity is an important part of all present physics and will have to be incorporated into any future new theories. However, within the scope of our everyday lives, we notice only the gravity of Isaac Newton, which acts as a constraint, which we take largely for granted, on all our activities.

Quantum mechanics

Quantum mechanics arose from the discovery that very small objects do not obey the laws that apply to the everyday world. For example, according to classical views, reduced levels of light illumination could just get dimmer and dimmer without any lower limit. This is not what happens, as first realised by the German physicist Max Planck (1858-1947) from his studies of the radiation emitted by hot black bodies. Planck showed that the observed intensity distribution of the radiation at different frequencies (or equivalently, wavelength) could be explained only if the radiation came in discrete packages, now called quanta. In quantum theory, at low levels of light illumination quanta arrive sporadically as individual packages but, on average, the total illumination is the same as would be expected classically. It is rather like the difference between the water received from a hosepipe when it is directed either in a single stream or broken up by a rose that divides it into many droplets. The total amount of water delivered is the same, but its detailed structure is quite different. Following Planck's discovery, a new system of mechanics was developed that accurately predicted the behaviour of atoms and their interaction with radiation. This new theory incorporated Maxwell's equations and is compatible with Newton's equations of motion for large objects, but it also contains many new features.

When the structure of the atom became understood as consisting of electrons circulating around a central nucleus, it was impossible to understand why the entire atom did not collapse. Classically it would be expected that the electrons would radiate their energy and end up motionless. A further difficulty was that when atoms did radiate as a result of being heated, the light produced always appeared at one of a series of fixed energies. It was then realised that the possible energies of an electron in an atom could also only have certain fixed values, and once an electron was in its state of least energy, it could continue its motion forever. We are made of such stuff with incessant but invisible movement of our electrons. The world of the quantum is quite unlike the world of our senses. It took a long time to discover as it is so small compared to our everyday world, and the energies of the quanta are tiny in comparison with what we can experience. Generally, we only know about the effects of huge aggregates of atoms and molecules that have total energies much greater than individual quanta. A possible exception is the observation that some frogs' eyes can respond to individual quanta of light.

Although these ideas were developed in the early years of the twentieth century, and considerable progress was made towards the development and understanding of the new mechanics, it was some time before the final correct mathematical theories of the quantum were developed. Two important steps forward were made in 1923, one experimental and the other theoretical. The American physicist Arthur Compton (1892-1962) discovered that when X-rays, a variety of light wave but with more energy, were scattered from a crystal, they bounced off with an energy that could only be explained by assuming that they were individual particles. It appeared that X-rays could behave either as particles or as waves, depending on the context. This was revolutionary stuff. The concept of a particle was also changed forever by the theoretical idea proposed by the French nobleman Louis de Broglie (1892-1987) that particles should also behave like waves, and this was confirmed by experiment four years later. These discoveries, which seemed to defy common sense, have been amply confirmed, and have passed into mainstream science. Some have found it hard to accept what is known as wave-particle duality, and it has generated a considerable body of philosophical discussion and debate.

The Austrian physicist Erwin Schrödinger (1887-1961) developed the idea that a particle should not just be described, in a classical way, by its position and velocity, but also by a mathematical function called a wave-function. In 1926 Schrödinger published a paper containing the equation that bears his name, which determines the behaviour of the wave-function, and hence of the particle. The wave-function is an entirely new sort of physical description of a particle, and it develops in time in a way that is exactly determined by his equation which is also symmetric with respect to the direction of time. An initial wave-function develops forever in a completely deterministic way according to the prescription given by the equation. The wave-function is a spatially extended object and, instead of determining the particle's position and velocity at a particular moment in time, gives only the probability of finding the particle in a particular place and its probable velocity. Particles were no longer thought of as point-like but as a fuzzy wavelike cloud. It is difficult to convey this idea exactly, as we do not possess the necessary analogies. Probability rather than certainty was introduced into science by quantum mechanics at its very foundations.

There is a further completely new feature of quantum mechanics that has no parallel in the classical world. Classically it is possible to know both the position and the velocity of a particle with exact precision. In quantum mechanics, this is not so, as the knowledge of the particle's position affects the precision with which its velocity is known. If you know the exact position of a particle, you have no idea of how fast it moves. This is the uncertainty principle, first stated mathematically by the German physicist Werner Heisenberg (1901-76), as $\Delta x\ \Delta p = h/4\pi$ where Δx and Δp are the uncertainties in the particle's position and momentum, which is proportional to its velocity. Planck's constant, h is very small, so the effects of the uncertainty principle become apparent only for small objects such as atoms, and at small distances. Our world is too large for us to notice the effects of the uncertainty principle.

The necessary abandonment of many long-held classical ideas and the further introduction of probabilities into science caused considerable disquiet among many eminent scientists who found it difficult to accept the new ideas wholeheartedly. Einstein famously remarked that the then-new quantum mechanics 'produces a good deal but hardly brings us closer to the secret of the Old One. I am at all events convinced that He does not play dice.' A famous exchange of views between Niels Bohr and Einstein perfectly illustrates the conceptual difficulties experienced, and some of these are still not fully resolved. Quantum mechanics and its subsequent developments have withstood the test of time: they have been tested to very highest levels of accuracy, and there are no known examples that contradict their predictions.

The interplay between the deterministic nature of Schrödinger's equation, the uncertainty principle and the probabilistic nature of the wave-function has not been fully resolved to everyone's satisfaction and continues to attract attention. A principle concern is the role of the observer when measurements are made of a system on the atomic scale. For completely isolated systems, the wave-function develops in time exactly following the Schrödinger equation in a completely deterministic way. In general, a particle is distributed over a set of discrete quantum states, each specified by integers known as quantum numbers. An act of measurement forces the particle into one of the states, and the result of the measurement is the set of quantum numbers. This process is probabilistic and irreversible, in complete contrast to classical science, and during the measurement, some of the information contained in the wave-function is lost. A complete picture is found from measurements on a set of particles each in the same initial state, determining the probability distribution of the quantum numbers. This is far removed from the classical picture, but for large objects, the two descriptions become equivalent as a result of the sharpness of the quantum probability. The discontinuity that arises at the moment of measurement is a consequence of the loss of information, making impossible the reconstruction of the original wave-function. These curious features of quantum mechanics have interested many, and some of the difficult and subtle problems are not fully resolved. Bohr thought that anyone who 'says he can think about quantum theory without getting giddy...shows that he hasn't understood the first thing about it!'

3.9 Quanta and minds

Measurements are made by observers and their essential role in making quantum measurements has led to considerable speculation that the quantum theory has a special role in explaining consciousness. The essential point is that a measurement on a quantum system makes an alteration in the system, caused by the measurements itself. In more technical terms, an isolated quantum system will continue to change over time in a way exactly determined by the development of its wave-function which must obey the Schrödinger equation. It is only when measurements are made that the system makes a discontinuous irreversible jump determined by probability into a state of the measurement equipment. This is known as the collapse of the wave-function and was originally introduced, without full justification, by Bohr and others. This was known as the Copenhagen interpretation. It was used as a way of making the transition from the wave-function to a measurement and is still used as an essential part of any quantum calculations. The unsatisfactory nature of the Copenhagen interpretation was considered by the Hungarian-American mathematician John von Neumann (1903-57) in his influential book, *Mathematical Foundations of Quantum Mechanics*. As he could not understand how the collapse of the wave-function could result directly from the quantum equations, he extended the theory to include the measuring system. The collapse then occurs as a result of the complete system interacting with a conscious observer and removes it from the mathematical part of the theory. This idea, while neat, has met with objections. Now measurements are carried out by machines that record the results in computers. These results will be observed by a conscious person, if at all, only later, and according to von Neuman, the wave-function collapse will only occur then, as there is no reason why the computer cannot also be considered as part of the measuring equipment. This would require the computer to remain in a state of suspended animation until a conscious mind looks at its results. This cannot be accepted as plausible as all parts of the computer operate outside the quantum world. The conclusion must be that the collapse occurs at some point during the measurement process and not at the later time when observations are made by a human. A conscious observer is not needed; any large piece of measuring equipment will do.

The contemplation of Wigner's friend causes an additional difficulty. In this thought experiment, the Hungarian-American physicist Eugene Wigner (1902-95) imagines that, instead of making observations on a quantum system himself, he leaves his laboratory and asks a colleague to make the measurements for him. When he re-enters the lab, he can determine from his friend the measured result, but until he is told the result he argues that the system must still be in a state prior to the collapse of the wave-function, as he does not know the result. His friend will not agree, but the apparent illogicality can be resolved if we assume that the wave-function collapse occurs when observations are made by the first conscious mind that is encountered. In the previous paragraph the computer has replaced Wigner's friend.

The use of computer systems suggests that the collapse occurs when the quantum system meets a macroscopic object. These issues are still being discussed, and although a completely general and satisfactory theory of measurements has not been developed, there is agreement that all wave-functions undergo some form of decoherence when they interact with the larger world. The important role of the observer in quantum mechanics has led to an enormous but inconclusive literature that tries to connect the world of the mind with that of the quantum.

Possible minds

Until recently, it was thought that the underlying mechanisms of the brain are of a purely classical nature, as the basic units of neurons, dendrites, and so on are just too big and change too slowly for quantum effects to be important. Recent arguments supporting this have been presented forcefully by the Swedish-American cosmologist Max Tegmark (b. 1967). However, because not all aspects of quantum systems are not fully understood, some have argued that there is still the possibility that the mysteries of consciousness can be found there.

Suppose we speculate that some parts of our brains rely on quantum processes for their operation and that these processes have been overlooked. Although quantum effects are generally associated with very small objects, there are some quantum effects that are apparent in large objects such as superconductors. While these cannot exist at room temperature, the new science of high-temperature superconductors is not fully understood. Maybe nature, through the ages, has managed to find and make use of quantum effects that are the basis for consciousness. Our brains have many distinct parts, and some of these certainly operate classically. All the inputs and outputs from our minds involve macroscopic classical objects. Examples include hearing and speech, through which all our concepts are developed and communicated. However, suppose there is a part of the brain where quantum effects reign supreme, and interact with the hearing and speech organs. One of the characteristics of a quantum system is that it cannot be fully characterised from the outside. Attempts to do this will result in changes in its state. Further, there are questions about its internal operation that, while apparently logical and well-founded, have no answer. This could produce a situation in which the speaking and hearing parts of our minds could be dependent on a quantum part of our mind, but unable to express its operation in full. This idea has some resonance with our sense of mystery about our minds and those of others.

The mind has been compared to a computer. The mind can certainly perform many tasks, such as logical reasoning and arithmetic, that can be carried out equally well by silicon chips. Because the mind can transcend mere computational activities, it has been argued by English mathematician Roger Penrose (b. 1931) that our existing physics is incomplete, and this is why we have such difficulty in understanding consciousness. Penrose has set out his story at length in two books, but has failed to provide a convincing account of the missing ingredients.

That the mind is capable of computation is beyond doubt, but it is interesting to speculate, despite Tegmark's objections, whether the mind uses quantum or classical computer methods. It might be possible to determine this from estimating the extent of calculations the mind can carry out, not just for mechanical processes like arithmetic, but for much more complex tasks such as pattern recognition. The attraction of quantum computers is that they can vastly outperform anything available now. If nature had found a way to use them in the brain they could perform tasks that would be incomprehensible to the parts of the brain that do not rely on them, and in particular the activities of my brain's quantum computations could not be conveyed to another. Perhaps the answer is around the corner.

It is often said that the physical sciences form a closed deterministic system and so there is no room for mental events. This idea is a development from the view first expressed by Laplace. However, as already mentioned, the behaviour of classical systems can be known fully only when the initial conditions are known exactly. This is also true of quantum systems, but for these, the difficulty of knowing the systems' initial state is even more acute, as instead of defining a particle by its coordinates, it is necessary to define a wave-function that varies over considerable distances. Except in special circumstances, this is practically impossible, as can be easily demonstrated by a quantum version of the argument about the classically linked rods.

This brief review of the nature of scientific change leads to an unsatisfactory conclusion. In the classical world, the behaviour of a system is determined exactly, provided that its initial state is known and it remains isolated. In the world of statistical science and quantum mechanics, probability plays a role in determining how systems develop in time. Where do we, who have legs, arms, and minds, fit into this scheme? It is not easy to provide an answer to this. Undoubtedly the chemical reactions that take place continuously in our bodies cannot be understood outside the framework of atomic theory and quantum mechanics. Equally, the effects of the motions of our limbs when we run or walk, can be understood as mechanical processes. As already mentioned, the behaviour of our nervous system is thought to be completely classical, and our experiences show that we are not continuously affected by random fluctuating events caused by quantum fluctuations, chaos, or noise. Nature has found a way of transcending them.

Our world

So in what sort of world do we grow and live? In summary, everything develops and is subject to the laws of physics, but the nature of this development can be known only if all the initial conditions are clearly known, and this is impossible except in carefully selected circumstances. Additionally, all things are subjected to noise that arises from the environment and from quantum uncertainty. Life, including ourselves, has had to operate and develop against this background. It is a great delusion to think that the laws of science give a correct insight into all the behaviour of living systems. Living systems have to survive in ways that do not contradict the laws of science, but there are so many possibilities that there can be an enormous diversity of structure and behaviour.

It is instructive to consider how initial conditions might be set for living creatures. Suppose I am in a cinema, and someone shouts 'fire', and as a result, everyone immediately makes for the nearest exit. The initial conditions for my action might be reasonably thought to have been set by hearing the alarm, but is it quite that simple? Surely the word 'fire' must be embedded in me as an initial preliminary condition, and that goes back to when I first learned the meanings of words. We could imagine going back even further in time, to the world of my ancestors, some of whom invented the connection between a particular sound and the perception of a burning object and its properties. The laws of science might try to explain my behaviour in quite different terms, involving the structures of neurons, dispositions to behave, and so on. This does not in any way seem helpful or add anything to the first explanation. The proper way to look at the word 'fire' must be to consider it as an arrangement connected either weakly or strongly by various means to many other arrangements, both in the present and the distant future, whose meaning is determined by some of these relationships. It is clear that the word can be properly and correctly used with only a small or partial knowledge of the tentacles of arrangements that stretch out, but a person with a greater knowledge of the tentacles will have a richer experience when using this or any other word. None of the uses of the word 'fire' will have disobeyed the laws of science, but neither will they have been determined by these laws. Fortunately, we can use our language unencumbered with either philology or science.

If the initial conditions of a system cannot be specified in a scientific language, then no exact predictions about its future can be made. For complex objects, these conditions are specified in the most economical way by the use of language that is outside the normal scientific vocabulary. This gives a possible route from the everyday world into the strictly scientific, so perhaps science cannot reach out to all things, not because of some in-principle difficulty, but because simpler and much more efficient methods of explanation are possible. To take a specific example, consider all that is written about horse racing (about which I know nothing). A vocabulary has been built up around the structure of the horses, their ability to run and jump, the jockeys, the racecourse, the bookies, and so on. By this means, race meetings are organised and enjoyed, and money lost and won. None of these activities is in contradiction with the laws of science even though, when the horses are running and jumping, they are constrained by Newtonian laws. The whole activity can be best explained in racing language which cannot be translated into scientific parlance, but nothing in any racing discourse is in contradiction to scientific laws.

The role of noise and chance on the living world is almost too well known, except at the local betting shop, to need description. A chance meeting on a train, or being struck by a meteorite or a falling aircraft, are chance events but do not disobey the laws of science. At a noisy party, people can still communicate despite the deafening music and the conversations of others. Life has developed and flourished in this environment, which is entirely removed from the world of Laplace's demon and the world of quantum interference.

Our world has an ever-changing flux of chance, and change cannot be understood except in a few particular circumstances by the methods of science. It is a world in which inexactitude, random chance, and the spontaneous generation of form and meaning rule our ways. This might lead to an incorrect and depressing view of what can be accomplished by scientific reasoning. Despite the obstacles to understanding things from a scientific perspective, it remains true that there are no known examples of things behaving in ways that contradict the known fundamental laws. If some future examples were discovered, modifications of our established theories would become urgent.

3.10 Science of the mind

The scientific study of the mind is perhaps the last and most complex frontier of science. The existence of the nervous system has been known in part since ancient times, but few of its details have been understood until quite recently. The great Greek physician Galen (129-210) demonstrated the importance of the nervous system by the public dissection of live pigs, and showed that they stopped squealing when the laryngeal nerve (now known as Galen's nerve) was cut; the pigs became paralysed when their spinal columns were severed. These and many other discoveries are described in Galen's surviving writings, particularly *On Anatomical Procedures*, and his authority in all medical matters lasted until Renaissance times. He recognised that the nerves transmit sensations from the eyes and ears to the brain and also control the muscles of the body, including those needed for speech.

The relationship between electricity and the stimulation of nervous tissue was first demonstrated by the Italian scientist Luigi Galvani (1737-98) in his investigations of what was then called animal electricity. He applied an electrical discharge from a Leyden jar that stored static electricity onto the nerve cells in the legs of a dead frog, making them move. He also showed that the same effect occurred when the nerves were stimulated by the application of different metals, leading to the invention of the earliest batteries. Although some of his speculations about the nature of electricity proved incorrect, his discovery has been amply confirmed by later work. The electrical nature of nerve signals, both in the body and in the brain, is the basis for all modern understanding of the mind. Measurements of the electrical signals in nerves were made in the nineteenth century when the German scientist Hermann von Helmholtz (1821-94) showed convincingly that the signals were rapidly transmitted along nerves at about 40 metres per second. This would give a human toe-to-brain transmission time of about one-twentieth of a second.

A highly detailed understanding of the structure and mechanisms of the nervous system has been developed since the latter part of the nineteenth century. A major important discovery was made by the Italian physician Camillo Golgi (1843-1926), who found that in samples of nervous tissues a small proportion of the individual nerve cells, or neurons, became stained black by silver salts in their entirety. This made their detailed structure visible under a microscope. By happy chance, this method stained only a small proportion of the nerve cells, making them individually visible and not surrounded by a mass of other cells.

The Spanish pathologist Santiago Ramón y Cajal (1852-1934) later made masterful use of this technique to produce a great variety of images of different neurons. He established their structure as consisting of many dendrites that have a tree-like structure, a cell body, and a single axon, divided into several branches. He found that the nervous system is a highly complex network of different varieties of these cells which all have the same essential structure. He also found that the neurons were directional, as he noticed that the axons on the sensory neurons point towards the central nervous system but that the neurons that stimulate the muscles point away, suggesting that information is flowing in these directions. In contrast to the dendrites that are quite short, almost always less than a millimetre, the axons of nerve cells can have considerable length and divide into several branches.

The nerves that control the muscles can be particularly long, as in a giraffe's neck. Ramón y Cajal established the general nature of neurons as the fundamental structures of the nervous system. Subsequent work has reinforced his pioneering discoveries and shows clearly that the flow of information is indeed in one direction from the dendrites to the axon via the cell body, also called the soma.

In the twentieth century, the structure, interconnections, and interactions of the nerve cells became established in even more detail, particularly following the pioneering work of the English neurophysiologist Charles Sherrington (1857-1952), who discovered much about reflex actions and about the connections between neurons and the muscular cells. In considering the transmitted signals, Sherrington remarked that 'the brain becomes an enchanted loom, where millions of flashing shuttles weave a dissolving pattern – always a meaningful pattern – though never an abiding one'.

The electrical and chemical nature of the nerve signal was explored by the English physiologists Alan Hodgkin (1914-98) and Andrew Huxley (1917-2012), who were able to make direct measurements of the electrical activity in the very thick axons of the giant squid. Hodgkin and Huxley developed equivalent electrical circuits that reproduced their findings.

In the brain, signals arrive from the various sensory organs and depart to control muscular and other activity, but in the brain itself, the neurons are connected to each other in a highly complicated network. In this way, a vast and complicated communication system is built. The number of neurons in the human brain is huge and has been estimated to be about a hundred billion. In addition, each neuron can have a considerable number of dendrites so that the number of possible connections in the brain is unimaginably large. Each neuron is connected to others by the terminals of the axons that connect, across a small gap, at the synapse to the dendrites of the next cell. The electrical signals in the axons consist of a series of short (about one-thousandth of a second) voltage spikes, all similar to each other, and produced when the soma is stimulated. Strong stimulation results a rapid succession of these spikes, also known as action potentials. They are produced by chemical changes in the surface sheath of the axons. There is some delay between the spikes because of depolarisation effects in the axon sheath.

The dendrites of a single neuron are connected to many other cells and can be stimulated by electrochemical interactions at the synapses of the preceding cells. If there is sufficient stimulation of the set of dendrites, the soma will fire a signal down its axon. This is very much an all-or-nothing effect so that low levels of stimulation will not result in any signals being produced. Some synapses are inhibitory and have the effect of making the soma less likely to fire.

The processes in the neurons have suggested to some that the mind is analogous to a giant computer that uses switches and logic gates for its operation. A considerable difference between them, however, is that the computer operates in a completely deterministic way whereas each nerve cell will fire only if it receives sufficient stimulation, and therefore a decision is made by each cell.

Although it is essential to consider the structure of the neuron as the basic unit of the brain, the complexity and adaptability of animals and humans are a result of the great variety of ways in which the neurons can be connected. At one time it was thought that the neurons in the brain were rather fixed structures and that learning abilities arose from changes at the synapses. This is an ongoing area of research, but it is now recognised that the growth and decay of the dendrites play an important role in the development of the brain. From an uninformed viewpoint, it is clear that if a new word or skill is acquired, there must be some corresponding change in the brain.

Although many aspects of individual neurons are well understood, their operation, when connected in complex ways with other neurons in the brain, is far from fully explored. Certain localised groups of neurons have been shown to be associated with specific activities.

This was first discovered by the French physician Pierre Paul Broca (1824-80) from his autopsy of a male patient who had lost his power of speech and would only answer the word 'Tan' to any question put to him, and this became his name. During his time in the Bicêtre hospital, it became apparent that Tan could fully understand speech, particularly questions relating to numbers. He later became paralysed and, after his death many years later, the autopsy showed severe damage to the frontal lobe of his brain. The brain is still on display at the Dupuytren museum in Paris. This was the first proof that parts of the brain are specialised for particular functions, and the part of the brain that is essential for speech is still known as Broca's area. Another area of the brain was identified later in the nineteenth century as essential for the comprehension of speech, from a study of patients with aphasia by the German physician Carl Wernicke (1848-1905).

There are obvious medical and ethical difficulties in trying to investigate the brains of the living by surgical techniques, and much of our information has come from procedures on patients who have already suffered damage. Within the last few decades, non-invasive methods have been developed to observe the brain in action. The most impressive results have been obtained from functional magnetic resonance imaging (fMRI), which was developed by the Japanese researcher Seiji Ogawa (b. 1934). Ogawa showed that the level of activity in a part of the brain could be imaged from the changes to magnetic activity resulting from changes in the level of oxygen in the blood. This has opened the door to a huge research effort which has greatly increased our knowledge of the specific areas of the brain associated with different activities, and the effects of drugs on them. The images are often displayed with the patient's active areas of the brain highlighted, thus showing her mental activity. As it takes time for the image to build up, this method cannot image fast-changing events in the brain, but the results so far are very impressive.

Like other sciences, neuroscience takes a viewpoint that is forever external. There is no hint from observations of neurons, individually or collectively, of the experiences that accompany them, and these are known from the reports of patients or from our own direct sensations.

3.11 The nature of time

The discussion above takes the notion of time from a scientific standpoint as the present instant, the past and future. However, time is not conceptualised scientifically either in scientific thought or literature. In his great long novel, *À la Recherche du Temps Perdu,* Marcel Proust (1871-1922) explores the idea of time in an extensive panorama of the people, places and events known to the novel's narrator and elucidates the role of memory in his and the lives of others. He was particularly concerned as to how events in the present, possibly of a quite trivial nature, can unlock the memory and bring back distant experiences long forgotten. Towards the end of the novel, when going to a glittering society party, the narrator tripped against uneven paving stones which dispelled the gloomy thoughts that had assailed him, and produced a sense of joy, removing his intellectual doubts about his literary gifts. In trying to understand the source of these sensations he several times repeated the experience of the uneven paving stones and, at once, he was transported back to the baptistery in St Mark's Square in Venice, which linked him to all the other sensations of that day, forgotten till then. At that moment, past time was forever unlocked. Proust's time is far closer to time as experienced than the scientific-mathematical concept.

Time experienced is not just of the present moment, because, while we are aware of the present instant of time in the sense that I have just typed this 'a', we are also aware of the recent past. My conception of time includes the present as a more extended moment that is embedded in a larger sweep of time, which includes my whole lifetime, and a boundless and distant landscape through knowledge of historical sources. In my experienced time there are also images of the future, similar in mental content to those of the past and joined to the past in a seamless whole, but with the proviso that these events have not and may not come to pass.

The nature of the experience of time has a long philosophical history. In particular, we do not perceive time in a way similar to the operation of the other senses. Time is not like the sensations produced when we see an object rapidly pass by, but is rather like a flow that can proceed at different rates, faster if we are enjoying ourselves and slower if we are bored. Augustine of Hippo (354-430) raised the mystery of how we can perceive time at all. What is in the past no longer exists, and the future has not yet happened, while the present is of such fleeting duration. From these considerations, he concluded that past and future times exist only in the mind. Although there are difficulties with this, it is even more difficult to imagine the processes of time without the use of our memories to recall distant events and to fix us in the present in relation to these and our immediate experiences.

Much more recently the American, William James (1842-1910), one of the fathers of modern psychology, developed the concept of the 'specious present'. He said that 'the prototype of all conceived times is the specious present, the short duration of which we are immediately and incessantly sensible'. James divided the experience of time into the obvious past, the specious present, the real present, and the future. For example, he was trying to understand the experience of listening to a piece of music in which the earlier parts of the piece contribute to the experience of the later parts, thus developing a complete experience. This is in contrast with scientific time which is only an instant: James calls this the real present. These separations certainly make psychological sense and are not incompatible with the scientific viewpoint if the elements of the specious present are considered as a selection of initial conditions. These all operate on different timescales and are needed to specify any particular mental arrangement if we want to consider how it will develop with time. From this point of view the specious, or psychological, present is caused by the interweaving of various histories together with the imagined or constructed future. By this means, the scientific present of an instant of time becomes entwined with past and future in a way that is not incompatible either with conventional scientific notions or with time as experienced. All human thought and experience takes place in one of these psychological times and not in the real or scientific present.

3.12 Summary

Objects cannot change in such a way as to contradict the laws of science, but these laws do not determine the possibilities where the initial state of an object is unknown or cannot be specified.

CHAPTER 4

Hierarchy of knowledge

4.1 Reductionism

Reductionism and emergentism are different and somewhat opposed ways of considering the complexities of the world and, as well as being philosophical positions, they are both deeply embedded in our cultural assumptions. Although reductionism is now unacceptable in many scientific circles, and its time has passed as an established intellectual position, its claims need to be considered seriously, as its legacy still informs our ways of thinking. It originally arose from the enormous advances made in the physical sciences in understanding and explaining the world. These advances range from the discovery of the largest structures of the universe arising from the Big Bang, the galaxies, stars and planets, to the microscopic scales of biological cells, DNA, atoms and subatomic particles. Many have concluded, following a tradition that started in ancient Greece, that the structure and properties of all things can be understood in terms of the simplest atoms and subatomic particles objects, and the laws that they obey. It is often somewhat uncritically accepted that chemistry rests on a foundation of physics, biochemistry on chemistry, and so on, with the added assumption that each higher level science is dependent on and can somehow be derived from the more fundamental levels. The school that I attended conveniently illustrated these beliefs by its layout. In its oldest part, mathematics was taught and, as we walked into the newer buildings, we first passed the physics laboratory then chemistry, and finally the biology and botany laboratories. When I became more interested in science and philosophy, I realised that the design of the building neatly reflected the received wisdom about the structure of scientific knowledge: mathematics gave absolute truths about numbers, geometry and other abstract objects; physics, underpinned by the mathematics, gave an objective view of what existed in the universe and the laws, established by Newton, Maxwell, Einstein, Planck and many others, that all things had to obey. Chemistry was a sort of less exact version of physics with additional rules of its own, and biology was almost like cookery, or at least that was how it seemed from the outside, as I studied Latin as a more serious alternative to the biological sciences. My prejudice, established at school against the non-exact sciences, has been a prevalent view from the start of the mathematically based Newtonian science and is still current, but not universal, today. The Frenchman, Auguste Compte (1798-1857), formally proposed that the sciences form a hierarchy as a basis for the scientific study of society. At a lecture that I attended in Oxford in the 1960s, Murray Gell-Mann, the American Nobel prize-winning scientist who made such huge advances in understanding the structure of subatomic particles, immodestly introduced his talk by reminding his audience that only those such as himself, working at the frontiers of particle physics, were carrying on in the noble scientific traditions started by Newton. Perhaps his comment did not represent his true views, and in later years he made many contributions to other subjects, including the behaviour of complex adaptive systems. After occupying a dominant position for a long time, at least in scientific circles, views on reductionism have changed. For example, the American theoretical physicist, Steven Weinberg (b. 1933), has given a more considered view of reductionism in his book *Dreams of a Final Theory*. In his chapter, *Two Cheers for Reductionism*, he defends views that are being seriously challenged both from within by physicists interested in macroscopic systems, and from without by biologists and philosophers.

There is a time ordering to the different sciences that is also suggestive of their relationships. In the very early universe, very few of the elements of the periodic table had been created, and therefore chemistry would not have been possible. The heavy elements were created later in exploding stars. Subsequently, planets were created and then early life forms that could be subjected to the laws of biochemistry. Plants, the subject matter of botany, followed. Eventually, animals, including ourselves, appeared, and the science of biology became possible. This time sequence emphasises the hierarchical nature of the so-called special sciences, and a similar hierarchy is probably present within our mental capabilities, starting with the first vertebrates. But none of this is available for our scrutiny. The division of the scientific enterprise into separate subjects is to a considerable extent arbitrary, possibly driven by the necessity of organising university departments and the restricted spheres of interest and knowledge of most scientists, but there is considerable overlap of content at the margins. For example, chemistry has parts that would be clearly recognised by physicists, and other parts would be familiar to biochemists. The boundaries are constantly shifting as new sciences arise, partially based on the old ones. Also, new relations emerge between sciences previously thought of as separate. For example, particle astrophysics has recently emerged from two formerly distinct disciplines from the realisation the very early universe was composed of exotic, unfamiliar forms of matter, formerly only known of in particle accelerator laboratories and cosmic rays.

The scientific enterprise has not always been separated into different disciplines, and in the past, an individual could have hoped to be competent over all the sub-branches of science. When the Royal Society was founded in England in 1660, it was an association of all those interested in scientific matters and only much later that the chemists broke away to form the Chemical Society of London in 1841 and, afterwards, the Physical Society of London in 1874.

In some ways, reductionism is a very seductive concept as it offers the possibility of being able to understand the world in terms of a few simple structures, laws and ideas. It has been the motivation for many developments in human thought from the early religious and vitalist beliefs to the belief of some contemporary physical scientists that a complete theory of the physical world will provide a solid foundation for all the remaining structures in the universe. This idea is clearly evident in the very active search for a *Theory of Everything* that is being conducted by theoretical physicists who seek to unify the existing fundamental laws of quantum mechanics and gravitation. The nature of this search has been clearly expressed by the English scientist Stephen Hawking in his book *A Brief History of Time*. He claims that if the search succeeds then it will 'be understandable by everyone, not just by a few scientists', and continues 'Then we shall all, philosophers, scientists and just ordinary people, be able to take part in the discussion of the question of why it is that we and the universe exist. If we find the answer to that, it would be the ultimate triumph of human reason - for then we should know the mind of God'. This view has been considerably criticised from many standpoints: Hawking's God does not seem to correspond to any that would be recognised by the Pope, the Archbishop of Canterbury or other leaders of the great religions, and his remarks have been seen by some as mere verbal manoeuvring or scientific arrogance.

However, a more exact idea of the nature of reductionism is needed in order to consider if it can be accepted as a correct way of considering the objects in our universe, and also of the laws that apply to them. All objects are thought of as consisting of nothing but the most fundamental objects in the universe, such as strings. Everything is built out of these fundamental components and can be understood in this way, rather as the structure of a house can be understood in terms of the bricks and mortar from which it is made. The idea is that if you fully understand the nature of the bricks, you understand in principle the possible constructions that can be made of them. In addition, reductionists believe that both our common sense ideas about the world, and more complex scientific theories such as psychology, can all be explained in terms of the most basic and fundamental of scientific structures and laws. This is how science has progressed for centuries, and notable examples can be found, such as the explanation of planetary motion or the explanation of the chemical behaviour of the elements in terms of their atomic structure. Within scientific theories, the example most often referred to is the reduction of the science of thermodynamics to the more fundamental statistical mechanics. Although there are still technical arguments about the actual methods of reduction, it is difficult not to accept that the concept has some considerable force and merit. What is very much more difficult to accept is that reduction is a principle that has universal application. Could it be instead that the principle is simply a guide to thinking, a sort of crutch that is an indispensable aid in trying to understand parts of the world, but not a doctrine that is either necessary to thought or that has any all-embracing scope? Many in the biological sciences are quite opposed to the claims of reductionism and, it is extremely hard to imagine how reduction might apply to creative processes in which the imagination has played an important role.

The lone atom

Let us consider the claims of reductionism and give examples of its successes, although it should be remembered that any theory, if universally true, can be proved wrong by a single example that it cannot explain. This is a very high hurdle and one that reductionism might well be thought to fail. Its strongest claims must be within the sciences, particularly in the theory of fundamental particles. A clear, and perhaps the best, example is found in the structure of the hydrogen atom, where a knowledge of the properties of the proton and the electron allow, through the use of the equations of quantum mechanics, a complete prediction of the properties of this atom when isolated. Predicted properties have been confirmed with exceptional accuracy. This is an impressive example, but how far can the reductive principle be applied to other objects, both smaller and larger and more complex than the hydrogen atom? Certainly, in the subatomic zoo of particles, the principle works well with the prospect of developing a full understanding in terms of a few simple principles that can be applied not only to the zoo but also to large-scale structures of the universe that are dominated by the effects of gravitational attraction.

There are several other examples that seem to satisfy the scientists, including the reduction of quantum mechanics to classical mechanics and, for some, at least some parts of chemistry can be reduced to physics. However, the number of examples that satisfy detailed philosophical scrutiny of a reduction of one theory to another is quite small. The concept of reduction seems reasonable as long as it is not examined too closely, and this should make us extremely wary of trying to expand its area of applicability outside the narrow confines of the physical sciences.

4.2 Thermodynamics as a successful reduction

The most frequently discussed example, and the favourite of the philosophers, is the reduction of the classical science of thermodynamics to statistical mechanics: the reduction that philosophers are most fond of is that of thermodynamics to the kinetic theory of matter. Thermodynamics grew from the study of the behaviour of heat, particularly in its effects on gases and steam engines and their efficiencies. An exact science was developed, but later after the development by Maxwell and particularly Boltzmann of a probabilistic theory of ensembles of particles it became apparent that the concepts of thermodynamics such as temperature and entropy (or measure of disorder) could be identified with quite similar concepts but which had a statistical origin. Thus the older science of thermodynamics became explicable in terms of a more fundamental theory. However, this did not mean that the older theory was discarded as it has usefulness in areas where statistical mechanics would be cumbersome and overcomplicated. The terms of one theory were identified with those of the other. Most scientists accept this, even though the concepts of temperature in the different theories are not strictly identical, and difficulties arise when a detailed comparison is attempted. For example, all the quantities in statistical mechanics have values that have different probabilities attached to them, whereas in thermodynamics, the quantities are exact. In addition, there are various theoretical procedures and possibilities in statistical mechanics that have no analogy in the classical theory of thermodynamics.

This relation between these two sciences has provided the most widely cited example of a successful reduction, although many aspects of the reduction are still a live issue leading to doubt as to the universality of this program. Despite these potential problems, this particular reduction has been taken as an exemplar *par excellence* of how this procedure might work. Presumably, other possible examples would be more difficult to try to substantiate, and it is hard to understand the wide influence of reductive ideas, considering the failures to show how the concept works by the demonstration of well-formulated examples. Probably scientists are mainly responsible for this as they often have, rightly so in the pursuit of their profession, a certain disdain for philosophical niceties.

It is certainly true that practising sciences do not try to reduce their science to another but are often inclined to borrow and incorporate concepts, magpie-like, into their own discipline. Examples of this abound: historically, the concept of the atom has completely changed the study of chemistry because of the way chemists became able to understand theories of valency and the nature of the chemical bond. More recently the science of metallurgy has similarly enormously extended its range from the study of the quantum theories of matter and the understanding of crystal structure.

4.3 Nagel's programme

From a philosophical standpoint the work of the American philosopher, Ernest Nagel (1901-1985), born in what is now Slovakia, is prominent. He set the agenda for much subsequent discussion in his book *The Structure of Science*, which takes a wide view of the nature of scientific laws, the different sciences and their relationships. However, his discussions do not reflect the actual workings of scientists but represent an account of their activities from a philosopher's point of view. It is nevertheless valuable for scientists to subject themselves to philosophical scrutiny and to step back from their everyday quest to examine, and try to explain, the nature and operation of their endeavour.

Nagel gives an extended discussion as to what might count as a scientific explanation, and these are quite different in different scientific enterprises. He identifies four different patterns of explanation: the deductive; the probabilistic; the functional and the genetic. Scientific explanations are often deductive and aim to explain to show that a particular outcome is a logically necessary outcome of a set of premises. Some of these explanations will give rise to established laws of science, such as the laws of planetary motion that can be deduced from the laws of gravitation and Newton's laws of motion. Other explanations can only give a probable outcome to a particular set of circumstances. As an example, Nagel considers Cassius's plot to kill Caesar and suggests that the explanation might lie in an elaboration of Plutarch's idea that Cassius was motivated by his hatred of tyrants. Other explanations of this sort include explaining the outcome of a horse race and the outcome of an experiment subject to the quantum uncertainty principle. Functional explanations are particularly important in the biological sciences and in the study of human behaviour, where a particular part of a system plays a role in maintaining certain traits of the system or in achieving a particular goal. The example he gives concerns an examination of the reasons Henry VIII had for seeking the annulment of his marriage to his first wife, Catherine of Aragon. He suggests that Henry's actions were driven by his wishes for a future in which he had a male heir to carry on the Tudor dynasty.

Finally, he discusses genetic explanations which aim to show that a particular state of affairs has arisen from an earlier set of circumstances such as the explanation of the fact that the English language has so many words of Latin origin which can be clearly understood from its known historical development and its etymology.

Nagel's book continues with much interesting discussion of the methodology of the sciences and also the historical development of the branches of physics such as mechanics and electromagnetic theory. The most influential part has been his discussion of the relationship of the different sciences and the claims made by some that a particular science can be reduced to another. He regards some of the developments in science, such as the incorporation of Galileo's laws into Newtonian mechanics and theory of gravitation as unproblematic, and part of the natural development of science into a new territory of understanding. However, he identifies a second sort of reduction between two sciences with different interests and vocabularies as much more problematic. His idea is that a secondary science can be reduced or recast into the terms of a more fundamental primary science so that familiar distinctions and concepts of the secondary science are then seen in a quite different light in terms of the unfamiliar concepts of the primary science. There are also concepts such as length, time and temperature that are known to everyone, and possibly animals too, that take on new and different significant dimensions when considered as a part of science. For example, Einstein showed that time and space are not absolute quantities but are related to each other; and temperature has been identified with the average motion of atoms and molecules.

Example of DNA

In his account of the discovery of the structure of DNA, J D Watson (b. 1927) discusses in some detail the processes that lead to his part the discovery, at Cambridge, UK, with Francis Crick (1916-2004), of the double helix structure. This great discovery could not have been made without a general background of facts from the physical, chemical, and biological sciences, and a knowledge of genetics. Also, there was at that time a developing interest in determining the structure of biological molecules. In particular, Watson mentions the stimulation he received from Erwin Schrödinger's influential book *What is Life* which has a wide-ranging discussion of the relationship between living things and the fundamental laws of physics, as exemplified in the laws of quantum mechanics that Schrödinger formulated with his eponymous equation. An especially particularly fruitful idea was that genetic information must be contained in aperiodic molecules that are stable over long times. Although then unknown, he suggested these molecules must obey and become part of the laws of physics.

Although Watson mentions quantum mechanics, the fundamental laws of physics are not really discussed, but great prominence is given to the results of Rosalind Franklin (1920-1958) at the University of London who, as an experimental crystallographer, took highly detailed X-ray diffraction picture by illuminating crystals of DNA. It was these that convinced Crick and Watson that DNA had a helical structure with two complementary strands. One gains the impression that the main element in their discovery derived from model building of a short strand of the DNA molecule. This was determined by a knowledge of the possible biochemical building elements and the influence of Linus Pauling's (1901-1984) earlier discovery of the arrangement of amino acid residues in the alpha-helix and his incorrect proposal that DNA was a triple helix. (Pauling is famous for his development of theories of the chemical bond firmly based on the then-new mathematically formulated physics of quantum mechanics.) The new science of genetics based on the structure of DNA was established, which depended on biology, physics, chemistry, and model building, and which reflected what was known about the DNA building blocks of amino acids. The abstract relationships of the different sciences that were involved were not considered as part of the founding process of this new science; but concepts and discoveries were taken as needed from whatever source seemed appropriate or useful without trying to construct, at the same time, a philosophical edifice.

In these, and the many subsequent discoveries in biochemistry that have transformed our understanding of the chemical nature of living creatures, the search to understand the nature of the biological world has to consider many concepts, ideas, and facts that are outside the range of the more fundamental science of physics, but although none of these is simply a deduction from the physical sciences, none can flout the most fundamental laws. It is clear that the discovery of the structure of DNA, and the many other molecules that are biologically important, did not proceed as a deductive strategy based on more fundamental sciences, although these restricted possible lines of investigation. The reason for this can be found in the enormous complexity of the structures being investigated. The number and variety of molecules that can be constructed from the basic building blocks are so large that it is impossible to try to investigate them all from some set of first principles. As in the example of the Venetian floor, the number of arrangements of the building blocks is not infinite in the mathematical sense, but for all practical purposes might as well be.

4.4 Formal reductionism

In the latter part of his book, Nagel gives a discussion of the formal reduction of one science to another. One requirement for this is that all the laws, axioms, and special ideas of both sciences that are being considered must be explicitly available. Many sciences are not formulated like this but as a much looser collection of facts, ideas, rules, and laws; but these could probably be recast into the required form. He goes on to consider a well-developed science S that has a class of statements T that are the fundamental theoretical postulates. These can sometimes be subdivided into different subgroups from the most fundamental to the very specialised. The science S will also contain theorems that can be derived from T, and will also include experimental laws L that fall within the science S.

Another underlying science will have statements and laws of its own, and the aim of a reduction will be to provide bridging laws that connect the two sets of laws and statements in a complete and convincing way. The idea has been rather uncritically accepted, and it is often assumed that it has a very wide application.

A thorough and complete reduction of one science to another has not been achieved, and so the idea hangs about as an unfulfilled philosopher's dream. Perhaps any reduction needs so many bridge laws of such complexity that the process will serve no useful purpose, and that, if achieved, the concepts and knowledge base of the two sciences would be much less complex than the reductive theories. This would not further understanding of the two sciences but provide a tedious and unnecessary superstructure. Further, each science contains facts of its own that might be difficult to reduce to any simpler explanation. Where reductions are possible and useful, they become part of established science, but without the embellishments of the philosophers. For example, insight into many biological processes has been achieved from the discoveries in molecular biophysics and the elucidation of the structure of many complex molecules.

4.5 Emergentism

Emergentism takes an entirely different point of view and appeals mainly to those outside the physical sciences, particularly biologists. The essential idea is that the properties and behaviour of complex living creatures cannot be explained in a simple way from a knowledge of their substructure. The behaviour of living things and other complex objects emerges from their structure. It cannot be explained using the reductive methods that have been so successful in the physical sciences since the time of Newton. Emergentism, as a system of thought, was championed by the English philosopher John Stuart Mill (1806-73). He wrote extensively on many subjects and is chiefly remembered as the founder of Utilitarianism; the idea that we should try to maximise human happiness and reduce suffering. (But he also remarked that pure hedonism is a 'doctrine worthy only of swine'). In his book, *A System of Logic*, he introduced the idea of the composition of causes and argued that the outcome of chemical or biological changes could not be understood directly from considering the effects of these causes separately. He thought that there are both higher and lower level laws that apply to live bodies and that 'those bodies continue, as before, to obey mechanical and chemical laws, in so far as the operation of those laws is not counteracted by the new laws which govern them as organised beings'.

Others in England also contributed to emergentism. It was considered at length by C.D. Broad (1887-1981) in his hugely influential book, *The Mind and Its Place in Nature*, in which he contrasts the two alternatives of emergence and mechanism. He suggests that a biological mechanist needs to believe that the behaviour of living bodies can be deduced from an adequate knowledge of its chemical composition. Although he sees value in this idea, especially in the order and unity it brings, he finds no trace of its self-evidence, and concludes that it cannot represent the whole truth about the world as it cannot provide a basis for explaining secondary qualities unless it is supplemented by additional emergent laws.

These ideas are still held by those who reject mechanical reductionist ideas and believe that a holistic systems approach should be followed to try to understand many of the traditional concerns of philosophy.

But does one have to take a position on the correctness of reductive or emergent philosophies? Will either of them prove ultimately to be correct and the other false, or are they both aids to thinking in different areas of science? And is the debate of any utility? From the point of view of an empirical scientist, this dispute would seem to be somewhat irrelevant. Most would concede that some chemical processes can be reduced to physics, but hardly anyone would agree that for example, the mating habits of the African elephant can be reduced to the laws of chemistry or biology. There is also the difficulty that the different sciences do not have clear boundaries and must be dependent on each other in various ways. However, many would accept that there is a hierarchy among the sciences and, that within a single science, there is an additional hierarchy. For example, chemistry does depend on physics for some of its ideas and concepts, but there are parts of chemistry where it is mistaken to think that they are a logical outgrowth of more fundamental ideas. What can be accepted as a general rule is that no parts of chemistry can contradict the laws of physics, but even here some counterexamples can be found. At the margins of two different sciences, there will perhaps always be new investigations and discoveries that will lead to modifications of both sciences, and sometimes lead to the development of a new science. However, the view that chemistry is fully determined by physics and so on for the other sciences cannot be accepted as correct. Nor can it be assumed that physics is a discipline that is self-contained and immune from influence from other sciences.

For example in 1938, experiments were made to determine the effects of bombarding various elements with the newly discovered neutron. It was discovered by the chemists Otto Hahn (1879-1968) and Fritz Strassmann (1902-80) that when uranium was bombarded with neutrons very much lighter barium was produced. This unexpected and puzzling result was explained by accepting that the uranium nuclei were split into two large fragments. This remarkable discovery, which changed physics forever, was made entirely with chemical methods, and led ultimately to the development of nuclear weapons and power. This example clearly shows that attempts to over compartmentalise the sciences must be a partially flawed enterprise.

Foundations and structures

There is however scope for formulation of a general relationship between two sciences that are part of a recognisable hierarchy. The less fundamental science will depend on the more fundamental. To take an analogy of a building and its foundations: the foundations support the rest of the building but do not dictate its form. They also impose restrictions on what can be built. Although a skyscraper cannot be built on foundations intended for a suburban house, there are many aspects of the house construction that can be considerably varied. Free choices can be made of the colour of the brickwork, the style of windows, the roofing material and many other items. For example, one of the cathedrals in Liverpool, constructed in the 20th century, was originally designed by English architect Edwin Lutyens (1869-1944), but, because of a hiatus in the building program only the crypt of the original design was completed and a different cathedral was built later of a completely different design, known locally as Paddy's Wigwam.

In Rome, there are many buildings that partially incorporate parts of buildings two thousand years old into their present structures that would certainly not have been foreseen by the original builders. The foundations do not dictate the final form of the building but do restrict the possibilities. A further analogy that may be useful is to notice that the support of the foundations themselves need not be considered as long as they remain stable and unchanged over the lifetime of the edifice. In very distant past times whole new cities were built on the ruins and foundations of buildings long decayed, resulting in remarkable tells in the middle east many metres high.

To be more definite, consider the relationship between chemistry and physics. Both of these contain facts, ideas, concepts and theories that are not features of both disciplines, but also some that are in common. But physics is recognised as more fundamental than chemistry and forms its foundations. It is impossible to understand the chemical reactions of the elements without a knowledge of the atomic structure of atoms. Of course, chemistry was pursued as a practical activity long before the atomic structure was known, but the reasons for different substances reacting differently was then something that could only be speculated on. Continuing with the building analogy, the ultimate foundations of physics are still the subject of vigorous investigation at the Large Hadron Collider and in considerations of the development of the early universe. These foundations have little or no direct effect on chemistry as long as they do not change.

In earlier times the chemical composition of matter was quite different to what we see now. Originally, just after the Big Bang, almost all matter was composed of hydrogen and helium, and the present composition was reached billions of years later, only after element-building processes in stars and supernova explosions. The timescales are so long that we may consider the present chemical composition of our world as a fixed fact. This illustrates the different timescales of events in the universe: the stars, the planets, life on Earth, mammals, humans, and you and me are later arrivals.

The relationship between the two sciences could be formulated by the principle that there are no facts, ideas, concepts and theories of chemistry that contradict the facts, ideas, concepts and theories of physics.

Within the discipline of physics itself, there is also hierarchy of concepts as it is generally accepted that the standard theory of particle physics is the most fundamental. There are many other parts to physics, but again the principle can be applied that the laws of particle physics cannot be contradicted by other parts of physics, or for that matter any other science or another part of human experience. The most fundamental laws are absolute but have limited predictive powers outside their immediate scope.

As discussed earlier, the scientific laws cannot predict the full range of what exists or how complex objects behave. There are too many possibilities and too many unknown initial conditions. Instead, what exists must be compatible with physics, and no arrangement can change in a way that defies that science.

4.6 Ultimate failure of reductionism

Having outlined some of the features of reductionism and emergentism, it has become apparent that both concepts have areas of use as aids to thought. However, claims that one or other of these opposing doctrines should be adopted as a universal principle to the exclusion of the other cannot be accepted. In particular, reductionism, as with any theory, can be defeated with a single good example, and there seem to be many of these. No doubt that the champions of this theory will claim that those things that are at present apparently outside its scope will, after further analysis and thought, eventually be seen as part of its universal scope. Examples such as the reduction of the planetary motions will be quoted in support of this. However, a weak version of reductionism could be accepted. Something along the lines that some ideas and some objects in the universe can be reduced to simpler elements. As a general principle this is bordering on the edge of being almost entirely useless, as, in any concrete situation, arguments can immediately arise about the extent and borders of the principle. In contrast, emergentism makes less universal claims from the start: some ideas and some objects in the universe emerge in an unanticipated and surprising way from simpler elements. In this case, a few good examples can substantiate the concept. Finally, is this an argument worth pursuing? The scientists generally pursue their discipline without too much concern for philosophical niceties, and it is left to those outside the field to consider the philosophical aspects. The global idea that everything can ultimately be explained in terms of fundamental physics is difficult to accept. In opposition to this, it is impossible to accept that everything in the world does not ultimately rest on a substructure of atoms, and more fundamental things down to the cloud of ignorance.

If it is accepted that the traditional opposing ideas of emergentism and reduction are simply aids to thought that have limited, but useful, application in considering the relations between different objects and theories, the question then arises as to how these relations should be properly considered and understood. A useful starting point comes from the commonplace observation that both objects and theories seem to exist in hierarchies. The cells that support life cannot exist without the complex chemicals that do their work, and animals cannot live without a range of specialised cells, and so on. To give a few examples: within scientific theories, modern chemistry could not exist without physics, biology needs biochemistry. But as has been already stated, in each case, the higher theory includes contains and concepts that are not present in the lower theory. It has already been proposed that theories of reduction cannot be considered to have any generality in their application, so what else can be considered.

I suggest that if there are two theories in an apparent hierarchy (take chemistry and physics as a concrete example) the most general statement that can be made of their relationship is that there are no elements of the higher theory that can contradict or be inconsistent with those of the lower theory. This allows for the existence in the higher theory of new terms and concepts that are absent from the lower theory and removes the necessity of establishing bridging principles, but in introducing these new terms and concepts care has to be taken to ensure that that they are fully consistent with the lower theory. It also reflects more nearly how science is pursued in practice.

The relationship between the different sciences can be restated in a way that depends on the establishment of hierarchical schemes: all that is necessary is that the different sciences have to be consistent with each other. To consider this consistency it might be convenient to think, in relation to particular issues, in a hierarchical way, but it is certainly true that laws that are clearly established in one area of science must be consistent with any other more fundamental science. The impression should not, however, be given that some scientific laws are not more fundamental than others, but the differences lie in the scope and generality of the laws. For example, the theories that pertain to the electron apply to every electron in the universe, whereas theories of the evolution of finches developed by Charles Darwin applied originally just to the Galapagos Islands. Without electrons, there would be no finches, but a similar world to our own could be envisaged with electrons but without finches, or even the Galapagos Islands.

Before considering further the relations between the different sciences, some general comments are needed on their scope and subject matter. Science is about trying to understand the world and acceptable explanations must cause a simplification in our way of thinking so that phenomena that were previously mysterious are seen in a new and simpler light. This applies equally to those trying to understand the origin of the universe and to those who are trying to understand the mating habits of birds or humans. However, the scope of the inquiry is quite different in those two cases. Any ideas about the universe as a whole will have at least some bearing, possibly quite remotely, on everything, but this property does not apply to sciences with much more restricted subject matter. Perhaps neither birds nor humans could be found elsewhere in the universe, and ideas about their behaviour will have application only in our terrestrial domain. The subject matter of these inquiries is also very different: in the first case all the detail and complexity of the universe is ignored, and everything is represented in much the simpler terms of space-time, mass, atomic and subatomic particles. Neither birds nor ourselves need exist in this Olympian view, nor will any resulting discoveries or advancing understanding have relevance or applicability to our terrestrial concerns. In the second case, the existence of the universe and our earth is taken as an established part of an inquiry which, if completed successfully, will have nothing to say about the universe in general. In both of these cases, there are facts available that are outside the scope of the inquiries.

Therefore in both cases, restrictions have been applied to make the inquiries more tractable. For the investigation of birds and humans, many facts are implicitly assumed before attempting further understanding. It is, for example, assumed that featherless bipeds are earthbound and that birds can fly. But where do these facts arise and how are they related to the global laws that under whose command we must all live? It is well known that today's birds are a result of a long period of evolution and have evolved from simpler forms of life. Most of the details of this are unknown and lost forever, but we can be absolutely sure that at no point in the complex evolution have the fundamental laws of science been broken. This need not be too inhibiting if we are considering the current behaviour of birds, and in terms of the physical sciences, the current structure of the bird population can be taken as a set of initial conditions from which all future changes must develop. But it is also fruitful to consider what can be determined from the history of the present bird's evolution and to introduce these as a way of knowing facts about the present. The present can thus not escape the past and birds, and ourselves are to a large part determined by both our past and the operation of the laws of science over many millennia, laws that, in part, have probabilistic and unpredictable random elements.

4.7 Discovery, invention and creation

These are related but separate concepts associated with changes in what exists or what is known. Of these, the idea of an invention is the simplest as it often the assemblage of a device made to accomplish something in a new and more efficient way. But there are many other inventions such as games or Windows computer programmes. Examples abound: the aeroplane; the typewriter, now replaced by the computer printer. One of the essential features is that a device or object is brought into being that had not previously existed.

For something to be discovered, it is implied that it has previously existed, such as the discovery of a lost watch or the discovery by Christopher Columbus (1451-1506) of America. But what about the discovery of a new scientific law or object. When the electron was discovered by J. J. Thompson (1856-1940), the view taken would have been that electrons had previously existed but what suddenly changed was this piece of knowledge appeared and gradually spread into the minds of others. The process has similarities with new geographical explorations. However, in the discovery of a new scientific law, a new relationship is determined between somewhat different facts or objects; but the status of the law before its discovery can be debated. It is clear that a sudden discovery does not change the facts or objects, but did the law previously exist in some Platonic space waiting for someone to alight upon, or is the law an invention or creation of the discoverer? Here we will take the second view, but many others have opted for the ethereal Platonic spaces. Our chief objection to these is that they seem to serve no useful purpose but also that if they really existed as spaces of possibilia, they would be so numerous that no mortal could hope to gain anything by their contemplation. High-temperature superconductivity is an interesting example as it occurs in materials not found in nature. The discovery process involved the manufacture of a variety of likely materials and examining their properties, and so both invention and discovery have played a role.

Before the correctness of a new law can be established a person must first formulate it as a tentative creative process that can then only be accepted as correct if it connects to the world as a new explanation of some part of the world. The discovery of a new law, therefore, provides a mental construction that has the same relationships between its constituent parts as are seen in the world. There are two elements to this: the creation of the law in the mind, and the recognition that it has a true relationship with the world. The initial construction of the law is an act of creation, and the realisation that it has correct things to say about the world is then a subsequent discovery.

Creative acts are more clearly seen in the arts when wholly new plays, paintings or other artistic objects appear. These arise in the minds of the artists but do not have to connect to or be validated by the world in the way that occurs in science. Artists are nevertheless constrained by the nature of the materials that they choose or that are available to them, and also to a considerable extent by the traditions to which they have been exposed, and the world around them. In earlier times they also generally had to consider the patrons or the reception of their efforts upon their possible audience. Many artists now seem to want to shock their audiences, but the effect of this has been generally to blunt our sensibilities. Real shocks now come from the daily news reports of violence, disease, and intolerance.

In each of these processes a hurdle needs surmounting: looking for the new in the novel or unfamiliar places; the realisation that something can be done in a new and different way; and the realisation of the as yet unimagined possibilities of an artistic medium. The new must be recognisable as quite different from what went before. These processes are irreversible, although the knowledge of them can be lost, as has happened with the so far undeciphered language, Linear A.

The concept of reduction is perhaps most difficult to accept when considering acts of creation. By this, I mean when something new and unpredicted comes into existence either by chance or by a flash of inspiration. Examples are numerous both from the arts and sciences. Advances in understanding nearly always require the assimilation of existing facts and knowledge together with a leap in imagination to create something new. Even mathematics, the most logical of disciplines, often makes its advances by the establishment of conjectures that are believed to be true, but proofs sometimes follow only slowly. It is believed that there is an infinite set of pairs of primes separated by two: (5,7) (11,13) (17,19) and so on but so far, proof of this has not been obtained. Maybe in the future by someone's act of creation, this proof will be found. In the arts, new musical compositions, new novels and poetry all require many acts of creation to bring into existence something that was not previously there. In the arts new creations often do not simply build on the foundations of others according to established principles, but great imaginative leaps are taken to establish entirely new art forms. This is clearly apparent in the development of abstract painting in the 20th century. A different but more familiar example is a sonnet by Shakespeare. How could this be considered from a reductionist standpoint? It is true that the letters and words that appear in the sonnet were in common use at the time of composition, but the essential nature of the sonnet is not encapsulated in the mere words that could be found in a dictionary. The nature and effect on a reader of a sonnet have to be considered as a whole, and this effect is something that is additional to the mere words. A shortening or précis will take away essential parts of what was originally intended by the poet. Certainly, reductionism fails completely here.

It is important to realise that the created sonnet or arrangement is not just another arrangement of words, but is an arrangement that exists in its own right with the same status as all other arrangements that exist now but has not previously existed. There is a human tendency to believe that recently created objects do not have quite the same status as those that have apparently always existed. Thus the stones and chemicals of our earth are viewed quite differently from more recently created things such as the latest play or film, even though both are examples of arrangements.

Acts of creation surround us all, though most are not of the magnitude or significance of our greatest artists. In outline, the process is easily recognised in simple cases such as occurs in the solving of puzzles: the puzzle is examined, possible solutions are mulled over, and then suddenly in a moment of insight the solution appears in one's mind. The exact nature of this final step is often difficult to explain with any clarity and probably occurs as a result of aspects of the puzzle being turned over in some backwater of the mind. There is no clearer example of the creative process in action that when we go to sleep at night confused and worried about an insoluble difficulty, only to awake in the morning to discover that the solution suddenly becomes revealed without further effort on our part.

Creative acts are clear examples of emergent events, and their consideration offers a way of understanding how arrangements are related to each other even when some extra, mysterious ingredient might seem necessary. What is this? Perhaps the acts are the result of trial and error or random events that allow for new arrangements to emerge from what existed before. These acts occur in the creation of life and composition of literary and the development of new scientific concepts. Our world is a noisy environment, and acts of creation must be made within this background.

Language

Some of the most far-reaching but now obscured acts of creation must have occurred in the early development of language. There are no records of these remote, distant events as words do not leave imprints in the fossil records like our bones, and therefore ideas about the origin of language must be very speculative. What is available to us is only our own and other languages as they exist today, having been developed and modified over the millennia. These structures are again arrangements but of enormous flexibility for expression, thought, and communication. These arrangements exist in a distributed way across the minds of the many individuals that make up a particular linguistic group. It is interesting that the size of this group can be quite small, as few as a thousand individuals in the case of some of the languages spoken in Siberia. But in all cases, language is a shared experience developed and passed on with a particular group. This distributed nature and the fact that our thoughts are often formulated in words makes it difficult for us to consider that language is an object that can be considered as an arrangement in the same way as simpler arrangements as a crystal of iron or even a single iron atom. An escape must be made from the mental strait-jacket that segregates the so-called material world from all other things.

It is also interesting to consider the extent that our own particular language constrains our methods of thought; that is the extent to which we think according to the dictionary of received ideas rather developing ideas of our own. To some extent, we are all hostages to the language of our times and to break free creative acts are needed. These will sometimes have the side effect of modifying and extending our language. For example, the word 'subconscious' was changed for all time by the works of the Austrian, Sigmund Freud (1856-1939) and anyone who chooses to use this word is tied to a considerable extent to its meaning even though she might not subscribe to Freud's particular psychological theories.

As previously mentioned, the idea of the reduction of chemistry to physics may seem an attractive idea, but it does not reflect how chemists and physicists actually work. There is a tendency among the physicists to be somewhat disdainful of the chemists and to regard their work as a somewhat less rigorous science than their own. The chemists, in turn, regard physics as a dull overly mathematical pursuit, but capable of providing useful concepts that can be used with profit. What certainly doesn't happen is that the chemists acquire a detailed knowledge of physics and then construct the principles of chemistry from these. Instead, rather general principles are established, consistent with physics, and these are then applied to various chemical problems. No chemist when contemplating her test tubes considers how the electrons or quarks are behaving.

It has also been pointed out by Michael Berry (b. 1941) that there several good examples within the physical sciences where reduction does not apply. He gives the example of uniform and turbulent fluid flow down a smooth pipe where a reduction cannot be made. He also cites the possible reduction of the ray theory of light to the more fundamental wave theory. In trying to do this, singular limits are encountered that prevent a smooth reduction. These effects would have to be incorporated into any wider theories of reduction and may have applicability outside the range of physical phenomena that he considered.

If bridge principles are introduced to relate one science to another, to which theory do they belong? A particular difficulty is that the higher theories have terms and concepts not available to the lower ones. And further, if bridge laws can be found for each of the sciences, there is a problem in deciding where these laws lie. As they are not part of either of the science, they must form part of a new sort of investigation maybe a meta-science.

An everyday example of the possible roles of reductionism and emergentism can be illuminated by considering the nearby golf club. Golf clubs are physical objects used to hit the balls, but also, there is the club itself which consists of much more than the physical objects. Both of these are arrangements. The club has rules, members, a clubhouse, and so on. If reductionism was a valid fundamental principle, then the rules could be reduced to something simpler. This seems almost nonsensical as the rules, especially about dress codes and etiquette on the greens and fairway, would seem almost arbitrary and certainly vary from club to club. The potential rules are restricted in some trivial ways by the laws of science, but there is still such a large range of possibilities that this is not a serious encumbrance. Many other groups have rules about their members' behaviour. For example, children in the playground form clubs with rules. It is impossible to envisage that there could be a reduction process that would provide an overall simplifying way of understanding all of these rules. A comparative study could be made of them, but this is not a reduction but a complication. The rules surely emerge from the interactions between like-minded people who form groups and enjoy games.

If it is accepted that the traditional opposing ideas of emergentism and reduction are simply aids to thought that have limited, but useful, application in considering the relations between different objects and theories, the question then arises as to how these relations should be properly considered and understood. A useful starting point comes from the commonplace observation that both objects and theories seem to exist in hierarchies. Just to give a few examples: the cells that support life cannot exist without the complex chemicals that do their work; animals cannot exist without a range of specialised cells, and so on. Within scientific theories, modern chemistry could not exist without physics, and biology needs biochemistry. But as has been already stated, the higher theory includes contains and concepts that are not present in the lower theory. It has already been concluded that theories of reduction cannot be considered to have any generality in their application, so what else can be considered.

It is suggested that if there are two theories in an apparent hierarchy, the most general statement that can be made of their relationship is that there are no elements of the higher theory that can contradict or be inconsistent with those of the lower theory. This allows for the existence in the higher theory of new terms and concepts that are absent from the lower theory and removes the necessity of establishing bridging principles, but in introducing these new terms and concepts, care has to be taken to ensure that that they are fully consistent with the lower theory.

Consider as a concrete example the science of Egyptology. Its limited subject matter is immediately apparent, and its most recent progress can be easily traced from the pioneering work by the French scholars, surveyors and archaeologists that went to Egypt following its invasion by Napoleon at the end of the 18th century. There were many notable developments such as the decipherment of hieroglyphics by Jean-François Champollion (1790-1832), and the development of scientific excavation methods by Flinders Petrie (1853-1942). Scientific methods have been used extensively in the analysis and dating of materials and in considering the construction methods of tombs and monuments. None of the new elements of archaeology is inconsistent in any way with earlier scientific knowledge on which they rest. This is not seen as problematical or in need of justification by bridge laws, but neither can the new concepts of Egyptology be derived from or discussed in terms of the underlying scientific concepts.

Similar reasoning can be applied to many other discrete bodies of knowledge, but the most interesting question is how this might apply to the mind. Is language, for example, in need of bridge laws to neural correlates, or should it just be seen as an activity that rests on other aspects of our human nature, but fully consistent with the universal laws of the universe, and just a construction with no need of justification outside itself? We will return to this in a later chapter.

It is also very difficult to even try to comprehend how the concepts of reductionism might apply to the evolution of mammals. With the passage of time, these have become more complex and varied, and additionally, their use of tools and language have developed into complex structures. This evolution can be seen as a sequence of arrangements that are a natural progression in space and time, and that cannot be considered in any simpler way.

It is also difficult to imagine that our minds could be reduced to something simpler while retaining their capabilities. If this was possible surely the effects of evolution would have found a way to construct such a simpler mind from the resources available.

4.8 Summary

The higher sciences rest on the foundations of the more fundamental sciences. They have distinctive laws that cannot be derived from the more fundamental sciences, but with which they cannot be in conflict.

CHAPTER 5

What we know

5.1 Knowledge and Plato

The question as to what counts as knowledge has a long history in philosophy. As in many things, Plato originally set the scene, and his idea of knowledge as recollection has already been mentioned in Chapter 1. He discusses the subject extensively in a dialogue between Socrates and Theaetetus, a famous mathematician. In the initial dialogue, examples of knowledge are given as astronomy and geometry, but this answer does not satisfy Socrates as he is not talking about a particular sort of knowledge, but he is enquiring about knowledge itself. Carpentry and cobbling are also put forward as examples of knowledge, but the objection is raised that the nature of knowledge itself is not the same as what knowledge is about. The discussion continues with Socrates comparing himself to a midwife, except that he brings forth knowledge from pregnant minds instead of babies from bodies. Socrates urges Theaetetus to provide a definition of knowledge who then suggests that knowledge is simply sense perception and states that a man who knows something also perceives it. Socrates approvingly points out that this is what Protagoras maintained when he said that 'Man is the measure of all things', but he goes on to raise many objections, none of which fatally demolish this definition. Socrates says that things can be both hot and cold, large and small, attempting to show that things are not always what they seem. As a second idea, Theaetetus offers true judgement as knowledge, and he suggests that it is implanted by observing the same thing happening repeatedly. Again Socrates objects, stimulating Theaetetus to remember that he has heard that knowledge is 'true judgement with an account', as he thinks that true judgement without an account falls outside knowledge. Socrates counters with the analogy of a dream and gives an extended discussion about the nature of composites that are composed of primary elements of which we have no account. Socrates tries to examine and expose the difficulties of any theories of knowledge and attempts to clarify the ideas of his young companion. Plato's ideas have influenced almost all subsequent discussions.

The great philosopher Bertrand Russell (1872-1970) wrote in an article about knowledge that 'knowledge might be defined as belief which is in agreement with the facts. The trouble is that no one knows what a belief is, no one knows what a fact is, and no one knows what sort of agreement between them would make a belief true'. More usefully, he developed an important distinction between knowledge by acquaintance and knowledge by description. The first of these brings an object into one's mind and provides knowledge of sense data and ourselves, but not directly of physical objects or the minds of others. Descriptive knowledge arises when we know that an object has properties with which we are acquainted and thus relates back to sense data. Although his view has been widely influential, there have been many critics, and it is not a good criterion for the truth of our knowledge as our senses can still deceive us.

Descartes

Some of the most sceptical ideas about our minds were originally developed by Descartes who applied his method of universal doubt to his experiences. He suspended his belief in God and speculated that perhaps he was just being manipulated by an evil demon who manipulated his senses so that his belief in an external world was an illusion. In his first meditation, he wrote that the demon was 'no less cunning and deceiving than powerful, who has used all his artifice to deceive me'. He considers himself as having no body or senses and prepares his mind against all the tricks of the great deceiver and determines not to go back imperceptibly into ordinary life. From his position of extreme doubt about the evidence of his senses, and by applying his principle of universal doubt he tried to establish a firm foundation to rid himself from deception; from the possibility that he was merely dreaming; or from a malicious evil demon of genius that presented all things to him such as colours and sounds as deceitful illusions. He finds this opinion difficult to maintain and falls back into what he calls his slumber, fearful that his doubt would cause him difficulties not easily dispelled. The argument is difficult to completely refute, but Descartes believed deeply in a supremely good God who he thought would not allow him to be misled by the antics of a malicious demon. In this way, Descartes was able to reconstruct the things in the world, but only at the expense of introducing another concept, that of God, to enable him to overcome his initial doubts. This is not an attractive line of reasoning and should, I believe, be rejected: if one has difficulty in understanding one particular concept, it can hardly be an improvement to introduce another concept to 'explain' the first one unless there is at the same time some considerable reduction in the difficulty of understanding of both concepts together. Occam's razor could be usefully applied. This principle, attributed to William of Occam (1285-1357) is that simple, elegant theories are to be preferred over those that are more complicated. A modern formulation might be that 'entities are not to be multiplied beyond necessity'. Had Descartes applied this principle to his reasoning he might have rejected the possibility both of God and the evil demon, and accepted the concepts of his own mind, his sensations and body, and the world around him as given undeniable parts of his experience.

Brain in a vat

Descartes' scepticism has re-emerged in recent decades by considering if it is possible that our brains are not as we think they, but are a mass of grey matter without a body, connected up by evil scientists to a huge computer so that we have the same experiences as ordinary folk. The story is that the mad scientists have done this so well that the envatted brain is completely unaware of its strange predicament. This scenario has produced much complex technical philosophical discussion without clear conclusions and inspired the *Matrix* science fiction films in which humans are unwittingly trapped by intelligent machines. Again, Occam's razor could be usefully applied to demolish this whole idea which is another example of complex phenomena being 'explained' by the introduction of many more even more complex elements. Additionally, no sane person believes it at all except as a useful vehicle for philosophical discussion or entertainment.

Gettier's response

In more recent times knowledge has been defined, with resonances from Plato, as justified true belief, but this has been shown by the American philosopher, Edmund Gettier (b. 1927), to have inadequacies. In his first example, he considers Smith and Jones who have applied for the same job, and Smith has a well-justified belief, based on an assurance from the president of the company, that Jones will get the job. Smith also knows that Jones has ten coins in his pocket and as a result, believes that the man who gets the job will have ten coins in his pocket. As it turns out, Smith gets the job, and it happens that he also has ten coins in his pocket. The important question is: does Smith's belief count a justified true belief? It appears that the answer must be yes, but it cannot count as knowledge as his belief was only true accidentally. However, this does not resolve the issue as it is also possible to acquire knowledge as the result of the accidental juxtaposition of disparate facts. This has considerably muddied the water, and various attempts of clarification have been made. There are many examples of the accidental acquisition of knowledge, for example, the discoveries of the origin of cholera by John Snow (1813-1858) who came to associate the prevalence of the disease with the use of a contaminated public water pump in Broad Street in London's Soho district.

Sense data

Many philosophers have taken a sceptical view about our dependence on sense data or perception to obtain knowledge about the external world. Sense data are regarded as what we perceive and of what we are aware in our minds, but often our senses are known to deceive us. Prominent examples include the straight stick that looks bent when partly submerged in water and the effect of rose-tinted spectacles. In addition, dreams provide us with different but imaginary experiences in which strange and sometimes impossible events occur. Those who robustly believe that the world is composed entirely of physical entities will have no truck with sense-data or mental objects, though they have difficulty in explaining the nature of what to most of us seem to be an essential part of our everyday experiences. If sense-data are regarded as examples of arrangements that have been proposed as essential and universal objects, it seems they cannot be carved off for separate consideration. In order for sense-data to exist, there must be an arrangement that includes the object in the world, the eye, neural processes and experiences. It is just not possible to experience seeing a red apple if there is no such object in the vicinity and so this must be part of the whole arrangement. The mere recall in memory of a red apple is not the same thing at all, but a poor relative of the original. The red apple experience is further complicated and extended as, for the visual experience to make sense, the observer needs to be able to connect what she sees with her store of past experiences both visual, linguistic and other things such as the remembrance of the taste of apples or the crunch on biting one.

Sorts of knowing

There is considerable disagreement about possible sources of knowledge: although some think that our senses are the source of all knowledge, others have thought that the application of reason is its source. These two positions are extremes that are hard to accept in their entirety. Without our senses, it would appear that we would be doomed to know almost nothing, but it is also apparent that all knowledge does not necessarily depend on perception. Suppose you are struggling to understand why a machine is not working correctly. You have thought about this and examined the machine, but to no avail. However, suddenly, in a flash of inspiration, you realise what the problem is and then know how to fix it. This new knowledge has not come from any perception or from rational reasoning, but from a new arrangement in your mind, not previously there, and produced without thought or perception. A person's knowledge of and about the world comes from many different sources, initially from our experiences as children, and knowledge instilled into us by parents, friends and school teachers. There is also knowledge of our own nature, invisible to others and not susceptible to their examination. Later, book learning, contacts with experts, and discoveries of our own are important. It is quite hard to escape from this background that, to a considerable extent, defines who and what we are, and which we are increasingly unable to change as we age. Dogs do not learn new tricks and many adults have difficulty in acquiring a new language.

5.2 Religious revelation

A subjective view on almost anything is easy to formulate without any concern about if it is right or wrong, true or false or shared by others person. Some thoughts are almost wholly subjective such as 'I think I will go out for a walk'. Much more interesting are those views that can potentially be clearly demonstrated to be true or objective. The search for these has occupied much attention over the past millennia. Perhaps the earliest ideas of objective truth came from religious ideas or ancient myths in which the deity or the gods were believed to have complete knowledge of the world and all its activities. Us lesser mortals could only hope to share this universal wisdom by special acts and observances, or by attention to the words of gurus or priests who were closer to the heavens than we could ever hope to be. One of the most persuasive and enduring ideas in western culture is that of an all-knowing God about whom we have only an inadequate and possibly incorrect knowledge. For some, this can be a model for ourselves: maybe we can also become mini-gods in a limited way and acquire, in part, omnipotence. But is this anything but a deluded dream and an incorrect concept of the world?

Since the start of written records, many authors have tacitly accepted different forms of religion and their gods as articles of faith, although, as mentioned in chapter 1, Thomas Aquinas has provided the Christian faith proof of the existence of God.

Now, most would agree that religion and its tenets cannot be established by philosophical or other reasoning. Of the proofs provided by Aquinas, perhaps only the last argument from design has any appeal now. Many have thought and wondered that complex parts of living creatures, such as eyes, could not arise by pure chance and are the result of intelligent design. William Paley (1743-1805) has famously argued that if, when wandering across the heath, he had found a watch he would have concluded that it could not have arisen there by accident and it must have had a designer. By analogy, he concluded that other complex objects seen in the world, including plants and earwigs, must also have had a designer who he identifies as the Christian God. Except in the backwoods of the USA, this argument has been extensively attacked and rejected. Now that the processes of evolution have become understood and accepted, it has been realised that the most complex forms of life have developed from simpler life forms by the processes of natural selection.

Our whole conception of the world and our place in it is fundamentally changed if we accept the concept of a religion and of a god of whatever faith. Non-believers do not accept elements of reality for which there is no evidence. Nor will they accept anything that has to rely on blind or other faith, received views of an elite, or divine knowledge revealed to a chosen few. If we do not accept the existence of other more refined and ethereal worlds, we are just left with the views and thoughts of ourselves, and those of others and our ancestors.

5.3 Universals and possibilia

Some words refer to particular objects such as our house that is identified by its name and address and is an object that has a clear existence in Gloucestershire: you could come to see it if invited. However, it is also possible to refer to houses in general, and these do not exist in the sense that you can visit them. The word 'house' is a universal, and different views are taken about its philosophical status. The idea had its origin in Plato. Realists believe that universals, including numbers, colours, tables and chairs, and many other commonplace things exist outside space and time. They are not dependent on the presence of the human race, and they are also thought to be causally inert. The idea that universals have some sort of independent existence is difficult to accept, and many arguments against have been advanced. One difficulty is that the universal chair must have existed before humans had started to use them so that it would then be available as a universal for the newly invented chairs to slot into as a usable concept. There would also have to be rather many universals. For example, the living objects of our world have developed from simpler creatures, and at each stage, there must be a universal for each independent species, but this must include all the unknown species that might have developed. There would have to be universal parrots, cockatoos, toucans and all of the myriads of insects neither known nor encountered by most of us. There are also objects such as aeroplanes that did not exist in Plato's time, but their universal form must have, and many forms must also exist now for all undiscovered or as yet to be invented objects that will appear in the future. It would seem that there must be universals that correspond to all of these and, in addition to all other possibilia, producing enormous armies of universals, nearly all unknown. To many, this is unacceptable and was a difficulty already recognised by Plato. There is a further problem if we consider the universal 'house' and a particular house: these can be combined into a new and different universal, and thus an infinite regress can be generated. This is not favoured by philosophers and regarded as a useless and nonsensical development by others.

One can imagine Plato's warehouse operated for him by his storekeeper. There are racks of shelves carefully labelled. When an item is delivered it is put on the right shelf. If a new and unfamiliar item arrives a new label is made, and it and the item are put onto an empty shelf. In Plato's parlance, all the labels are names of universals, but they could more simply be regarded as labels by those without a philosophical bent. The storekeeper can do her work efficiently in complete ignorance of universals, and she does not need the concept. From this aspect, universals can be regarded as labels which are more readily understood. A warehouse capable of storing huge numbers of diverse objects would have to operate in multiple dimensions as most objects could attract many different labels.

We can get on perfectly well without universals. For example, arithmetic procedures and calculations can be performed without introducing this additional concept.

Nominalists and others

Universals are rejected by both philosophical nominalists and conceptualists who are opposed to the whole idea and its related concept of abstract ideas. Nominalists argue that individual objects have qualities that are shared by others. Red apples share the quality of redness with red raspberries, red cars and so on. Red becomes a sort of label that can be attached to some objects but not others and arises because there is an element of resemblance between different things. But then the original problem changes to the necessity of trying to understand the nature of resemblances. Other nominalists have introduced the concept of tropes that have only one property; a red trope, a round trope, and so on. An individual object can then be characterised by considering its resemblance to the tropes. This explanation is rather unsatisfying and thought by some to be a circular argument.

Conceptualists consider the idea that general concepts are a feature of our minds and the way in which we have developed. They have the idea that for a general term to be applied something needs to be shared, but no great superstructure of universals is necessary. And finally, for idealists, there is no need to introduce a separate category of universals as all is in the mind anyway.

A possible approach to this somewhat intractable problem might be to consider how universal and abstract ideas originally developed, taking as a starting point that at some point back in our remote history there were no words of any variety and that language and thought developed in parallel as arrangements. The idea that everything is an arrangement would seem to rule out universals as independent entities that exist forever but point towards the idea that general terms are just a convenient way of labelling different objects. One difficulty with this is that many words have an element of imprecision, and each category of things that fall under a particular word will have a sort of vague hinterland where there can be disagreements about whether a particular object will fall into the category. The imprecision of words could be resolved if thought of as an empirical issue that could be resolved by consultation with those who habitually use them. The imprecision of things that can be measured, such as the average weight of a human, is determined in this way and there is no reason that this approach cannot be extended to arrangements of the mind.

Although labels may exist only in the mind for a person who is illiterate, they can also be thought of as physical labels that can or could be attached to different objects, rather in the way that a warehouse-woman might label the spaces on her shelves. She will, in addition, have a mental representation or image of the way this has been done, but she will not lie awake at night worrying about the nature of her labels or universals. Nor will she consider that she has just discovered a new universal when she reserves space on her shelves for a new and novel item.

If all things are arrangements, as proposed, then universals and tropes are just particular examples of arrangements. The warehouse-woman would have no problem with this, but many of the philosophical problems will remain such as the difficulty of determining which universals (as arrangements) apply to which objects.

5.4 Objective knowledge

If we do not accept the existence of other possible worlds or parallel universes, we are just left with the concrete world and the thoughts of ourselves and those of others. However, it is generally accepted that some views are true and that there is objective knowledge. If superstition and faith cannot be trusted as a source of knowledge about the world and ourselves, where should we turn? The possible answer already given is that objective knowledge is justified true belief: snow is white because of the basic facts that are available to everyone. It is also something that cannot be denied by anyone who has understood what is being asserted. There are other, more obscure facts and beliefs, such as those in the scientific world, that are regarded as objective, but only understood by a few. For these, the argument must be that nobody would disagree with the facts and beliefs if they became acquainted with them and understood the intellectual environment in which they flourish. There are many grounds for accepting objective knowledge such as an empirical scientific demonstration, or the acceptance of ideas that are self-evidently true: the sun always rises, water never flows uphill. An essential feature of the objective is that it must, in principle, be available to everyone. But where does this objective truth reside if the gods are not available as its custodians? The answer must be among ourselves and our writings, but with criteria to distinguish truths from idle opinion and gossip.

In contrast, subjective knowledge is something known only to one person. A child will start in life with only subjective knowledge, but gradually acquire objective knowledge as she matures. Some subjective knowledge is of such a nature that it cannot easily be shared. The knowledge of the sensation of seeing red and of experiencing fear are entirely subjective even though we can talk to others about our experiences. However, the objective parts of our experience should not be thought of as something lying outside human experience completely but as part of a great web of knowledge both within the mind and in written sources. This fits in well with the idea that all things are arrangements, but these arrangements are complex and extended over time, place, and minds, and generally not reducible to simpler descriptions.

It is interesting to think about how to proceed from the subjective to the objective. Part of this process must be the realisation that a particular subjective thought has a greater generality and is not dependent on the self. A strong element of this must be the confidence that others will also agree that this particular thought has an objective element. The philosopher Thomas Nagel (b. 1937) has developed a view from nowhere in which he considers how to combine the viewpoint of a particular person with an objective view of the world into a single conception of the whole. His extensive discussions raise many interesting ideas about the nature of the individual and his specific viewpoint of the world, including himself. The dilemma is that if some overarching conception of an objective world is constructed, this necessarily leaves out the individual conceiving it, but also the countless persons who may have the same viewpoint. Perhaps we can only comprehend the idea of one objective viewpoint together with own. To try to develop a perspective that includes the viewpoints of all others would provide such an enormous mental overload that we know that it is a task that we can neither contemplate nor complete. This leaves us with our world and what we feel can be shared with others; that is the subjective is some part of the objective that has been developed by other individuals and accepted by common consent. Even if a view from nowhere can be developed, it must be held by some person or persons apparently negating the purpose of this development. Ultimately all knowledge must have an origin in a mind, even if it is one that has long departed, and the knowledge remains only in written form. For this written knowledge to be considered objective, it must again be subjected to scrutiny.

Mathematics

Mathematics is considered to be objective in so far as it derives from logical principles. Whether it is invented or discovered is an interesting question. The famous but eccentric Prussian mathematician, Leopold Kronecker (1823-91), is reported to have remarked that 'God made the integers; all else is the work of man'. If alternatively the integers are regarded as empirically justified and also the work of man, mathematics can be excluded from the influence of God in the heavens and the Platonic world that mathematical realists would have them inhabit. But this argument has the unacceptable consequence that at least some parts of mathematics become subject to the uncertainties that apply to all empirical knowledge. Some mathematicians have regarded mathematical truths as things to be discovered, but this implies that they must have had some prior existence.

However, many mathematicians and philosophers still take the view that numbers *are* Platonic objects that are eternal, not subject to change and are causally inert. If this is true, then what sort of existence can they have and how can we know anything about them? In the 20th century philosophers argued that because mathematics is indispensable to science, acceptance of the truths of science automatically commits one to accept the concepts in the underlying mathematics. It is entirely possible to conduct correct mathematical reasoning, as used in ancient times by the Egyptians and now by bookmakers on the racecourse, without a philosophical superstructure. However, examinations of the fundamentals of mathematical reasoning have resulted in quite different positions being taken that require additional concepts that are not necessarily all compatible. A famous example is the law of the excluded middle; that is that a proposition must be either true or false. The Dutch mathematician L. E. J. Brouwer (1881-1966) has constructed a new intuitionist school of mathematics that rejects this law.

The nature and status of mathematics have been the subject of endless debate. Its origins are rather clear, and it developed in ancient times, from empirical procedures to developed from the practical necessity of recording numbers of animals, areas of land or quantities of corn. Tally sticks were probably the oldest way of doing this, but later the Sumerians recorded their transactions on clay. Records survive in the form of tablets that give rules for the manipulation of numbers, based on a counting system with sixty units, and examples of equations and their solutions also survive. Some of the tablets are tables to be used for multiplication, and others seem to be for use in instructing students.

In earlier chapters, we became committed to the notion that everything is an arrangement, and this, therefore, must also apply to mathematical objects and all other abstract ideas. The view was also taken that meaning must be found in the relationship any object, say a key, has with other objects. On this view, mathematics must be a construction made by its inventors to describe the world and its objects. It becomes a sort of common currency that becomes shared by its originators with others. This is then the 'space' for numbers and other mathematical objects, which are certainly allowed to be causally active and acquire and keep their meaning by their interactions. There is no room for Platonic objects.

Golden mountains

These have long perplexed philosophers. It is obviously possible to talk about a mythical golden mountain, the Jabberwock, the Jubjub bird, or the Chinese dragons that appear on much porcelain. As I type, this morning's newspaper shows a photograph of a fiery Loch Ness monster sailing up the River Foyle to confront a saint. In addition, there can be talk of impossible objects like the square circle and even drawings of impossible objects as made by the Dutch artist M. C. Escher (1898-1972). Some of this discourse may be self-contradictory, but some can be in terms that are entirely logical and comprehensible. This seems to give the objects some sort of existence, leading to the question as to how this existence can be acquired by mythical objects. Similar worries apply to figures of fiction: Mr Pickwick and the others in the pages of the novels of Charles Dickens (1812-70).

Non-existent objects have been famously discussed by the Austrian philosopher Alexius Meinong (1853-1920) who introduced a distinction between the being of an object and its existence. His concepts were roundly attacked by the British philosophers Bertrand Russell and Gilbert Ryle, who thought that his ideas were irrelevant and out of date. If all objects are arrangements, then objects that can be talked about, but do not exist, must be grounded in neurological arrangements within a person's mind. For objects that in addition exist in the world, there must also be arrangements that correspond to them somewhere in space and time but outside any mind. The relationships between all these arrangements need much philosophical clarification.

5.5 Irreducibility

Are there any non-reducible entities? In science, there are descriptions of objects that cannot be reduced to simpler elements. The fundamental concepts of space, time, mass, charge and so on cannot be spoken of in simpler terms, although it is hoped that in future times an account of their origin might be given. Although a comprehensive description can be given of mass, how to calculate it, its relation to energy and momentum, the question 'what is mass?' is ultimately unanswerable beyond saying that it is something that appears in equations in this or that way, or gives rise to a particular experience. If the question were answered in some way, it would be possible to set up a further question, eventually setting up an infinite regress. So the mass question must stop at the concept of mass and be regarded as irreducible. In quantum mechanics there are irreducible groups of functions that are used, for example, to describe the behaviour of electrons in atoms. These functions cannot be reduced to simpler functions. In some ways, in another context, irreducible things can be thought of as the endpoint of the child's persistence asking 'why?' about something that she doesn't understand and expects a satisfactory concluding answer.

A more interesting question arises as to whether living objects are irreducible. By this I mean if a simpler version of a fly could be developed by natural selection, or whether existing flies could not be significantly improved on by simplification of their genetic structures and parts. If this were possible, then it would offer these simplified creatures advantages over their distant cousins and presumably lead to their displacement. Perhaps this can also apply to ourselves and our minds. Maybe it is just not possible to find simpler mental structures that would still be able to function adequately and provide us with the same repertoire of behaviour.

Often in trying to describe the mind attention is given to this or that essential feature and consideration is given as to how these features come about and how they operate both independently and in relation to each other. One way to consider ourselves and our structure is to imagine subtracting parts in order to see which pieces are essential to our existence as human individuals. Some have lost parts of their limbs and can still function with reduced physical function, but there are essential vital organs such as the lungs and brain, without which we cannot live. Minds can also operate with reduced capacity after the onset of old age or disease.

It is also possible to try to understand an object by considering either how it has been constructed, or to dismantle it and try to see how its constituent parts operate in relation to each other to produce the whole. In considering our minds, we could consider their construction and influences formative in producing the adult or we could try to mentally remove parts and consider without which parts we could manage. Our senses play a vitally important part in our mental world, and they require things and events outside ourselves from which to receive all manner of stimuli. These are also essential to provide a scenario in which our actions can take place. There is a continually changing kaleidoscope of images and memories both at the present instant of time, going back in time both to our earliest memories and, created by imagination, forward in time. Our imagination can also create thoughts and emotions about things and events that are not reflected in any reality. For our minds to be recognisable to us, all these thoughts, both real and imagined, are needed to varying degrees. If our senses are degraded through deafness, blindness or other impairment, our minds still go on even if some of these capabilities such as sight disappear completely. But it is not possible for us to continue to function mentally if all our memories of past events, sensations, and people disappear. These then must be an essential part of our minds. Likewise, we would flounder and possibly fail mentally if our familiar environment were suddenly to vanish as is experienced by those who live through a destructive catastrophic event such as a major earthquake or tsunami. This suggests that the mind is not a simple structure that is going to be susceptible to being understood by dissection of its parts but a structure that has many features that can neither be properly understood separately nor can be understood in isolation from the environment.

New games

There must be consequences for how we think once it has been accepted that everything is an arrangement. New arrangements must be made of existing ones or newly invented ones. For example, suppose that a new game or computer language is invented. The rules of the game, although novel, must be comprehensible, logically consistent, and defined in terms that can be clearly understood. Monopoly was invented as a game that did not previously exist, but elements in its rules have some relationship to previously held ideas about property, money or older board games such as snakes and ladders, or similar games.

Many individuals are familiar with this game, but at one time its exact form existed only in the mind of its creator, Charles Darrow (1889-1967). It is clear how this then spread to the minds of others through the manufacture and sale of the boxed games, suitably altered for the markets in different countries.

Language has also been thought of as a game in the 20th century. Although virtually nothing is known about the original invention and spread of language, it is possible to at least imagine the overall process by considering the development of new words in our era. In recent times, it has been possible to undertake language studies based on the development of pidgins and creoles. Further studies have been made of the incursion or invasion of one language into another; for example, the addition of English words to the languages spoken by the indigenous populations of Australia. New words come from many different sources: technical developments, street slang, adoption of foreign words and in some cases, the pure invention of new words to fill a niche. It is impossible to study all the processes in the past that have created our present languages, but progress may be possible by considering computer simulations of the processes at work. Although this method of proceeding has great complexities of its own, there would seem to be nothing that is ultimately mysterious either about the methodology or the possible results. Clearly, our minds stand behind language and its development, but the actual process of language development does not seem to be ultimately mysterious, despite its obscurity.

5.6 Being a bat

In order to try to understand questions about the conscious experience of animals, and indirectly, ourselves, Thomas Nagel has famously asked the question 'what is it like to be a bat?' He chose this mammal because its sensory method of finding its way about and its food is quite unlike our own and depends not on vision, but on echolocation. The bat emits bursts of high-pitched notes that are reflected from insects and other objects and received by the bat. This enables the bat to efficiently catch its moving prey on the wing. Further, Nagel chose the bat because, as a mammal albeit of a different form, it is more similar to humans than other life forms such as insects or worms. He assumes in asking the question that it is plausible that there really is a bat-like experience and offers a challenge as to how us humans might imagine it with our quite different sensory systems, and an inability to fly. The question was asked to provoke a discussion about our conscious experiences and introduced the idea that there is 'something it is like' to be experienced by any creature that has a mind. He also thought that consideration of this idea would provide a very difficult challenge for physical reductionists who have introduced implausible accounts of the working of the mind motivated by the wish to recast the mind-body problem in terms that they feel able to understand.

Of course, there are a variety of other similar questions that could be asked, perhaps forming a continuum between ourselves and the bats that fly around our houses. We could ask the question about people we know, historical figures, our pet cats, the badgers that dig up our lawn and so on. Answers can be given based on our knowledge and the exercise of our imagination, but the fundamental difficulty remains that we can have no direct insight into the mind of another creature. But this is surely not a mystery in itself but just a consequence of the separation of our respective mental organs.

Suppose the question is asked not about bats but about our human ancestors and the gorillas with whom we share common ancestors. For all of these, who doubtless had different mental experiences to ourselves, there is a gradually shifting question, that in the case of the human ancestors still alive with whom we can communicate, could be answered to some extent. But distant ancestors and their experiences are not around so that although the question could have been posed in the past, to consider it now must be a meaningless, wasteful activity. Nevertheless, it is clear that there must have been a gradual shifting of experience going from ourselves back to our common ancestors and then developing along a separate path to present-day gorillas. There cannot be any way to pursue these speculations as any investigation is likely to be extremely divergent, but this does not imply that those now-dormant minds were never active. This is all related to the long-standing philosophical discussion of other minds and how and what we can know about them. And also whether zombies that are creatures without any internal experiences can exist. As we have no direct access to the minds of others, we need to be able to justify our belief that they do indeed have an internal activity that would be recognisable if we were to experience it. A plausible argument in favour of other minds is inference by analogy. Other humans are like me in many respects; we were created and live in the same way and cannot be easily confused with other creatures. It would be quite remarkable that we are different, at least in principle, in respect of having minds, but this is difficult to prove in a rigorous way. A modified argument could be applied to the minds of gorillas but with the proviso that the language element of their existence would be lacking. We could continue to consider simpler and less developed creatures, but it is clear that the argument gradually becomes weaker. It might be objected that all these questions are an irrelevant backwater, but belief in the possible answers can affect our behaviour towards others and influence whether we think it is acceptable to torture other humans; is bear baiting entertaining, or should lobsters be cooked by boiling them alive? This is elaborated on later.

Simulators

Nagel's choice of a bat was an extreme example chosen to expose the 'what it is like?' question in a challenging way. The same question can equally well be asked about our cats, friends, relatives or those pursuing specialised careers such as airline pilots. For those who have never flown a plane, this is a question that they can only answer by talking to a pilot coupled with an application of their own imagination, but they could obtain important insight into the experience by undergoing a training session in a good flight simulator. These provide a very realistic reproduction of the real experience and are also used to train professional pilots in how they should respond to rare emergencies. There will not be a great chasm in perceived experience between pilots and those trained on simulators, although there are real experiential differences, as those on the simulator do not have the responsibility of passengers. The environment of the simulator, generated by computer programmes, is an example of virtual reality that can also be used to simulate games and experiences of wholly imaginary environments. So that, in this case, some sort of answer can be given to the bat question, and it is achieved by the reproduction of the experience, but not by giving any direct insight into a particular pilot's experience.

It is possible, with computer productions of virtual reality to go much further down this route and this already exists in computer games. These are able to produce experiences of varying degrees of realism of a wide variety of different environments, including totally imaginary encounters with alien creatures in strange and unfamiliar places. There would seem to be no reason why an insect-catching game could not be made that simulates a bat's sensory system in a way that is intelligible to us. In producing this game, a simulation of an environment would have to be included as well as a bat's sensory system. This environment, which could be the region near my house, would be quite different from the environment that would need developing in a game for another animal, for example, a cat or even myself! The bat environment would need to include all things that are important to bats, including belfries, moths and other insects, whereas the catty environment would need cat flaps and small rodents! In trying to create these environments, it would become apparent that the sensory apparatus of an animal and its reaction to its environment are not two separate things that can be considered in isolation, but are dependent on and are intertwined with each other so that my garden is a different place according to whether it is seen with my eyes, the cat's or by the bat's echolocation senses. Other creatures visit my garden such as squirrels looking for truffles, birds and many species of insects. All of these will have a different conception of the environment tailored by their sensory and conceptual capabilities, and there cannot be a single objective view of the garden. It is different things to different creatures.

All this raises interesting questions about the possible objective character of our knowledge. If by this we simply mean that a particular piece of knowledge is generally accepted as true by those acquainted with the facts, then this is not problematic. Mathematics, scientific laws and discoveries seem to be much more than this and seem to have existed for all time irrespective of human knowledge about them.

But in considering the experiences of others, although we may concede that they do have experiences, however, there is no unique viewpoint. Other experiences can be explored with computer games, and even further with applications of virtual reality. With an advanced virtual reality that could simulate any environment in an enormous computer, it would seem possible to give at least a partial answer to the bat question.

Our linguistic, imaginative and other capabilities make it impossible for us to recreate direct experiences for ourselves or transmit them to others. However, we can develop objective viewpoints that do not rely on our particular niche in the universe, but that are such that they can be adopted by others. Nevertheless, of ourselves, this is never going to become possible as we cannot escape from our direct experience or pass this on to others. Objectivity is somewhat like language in that it relies on others for its effects.

It must be true that language followed after a considerable part of human development was complete. It is inconceivable that by the time that language developed, after our separation from the great apes, that as a species, we did not have sexual feelings and/or feel hunger. We must also have had, like our close relatives, organs to see, feel and hear. Language must have been added onto these capabilities and separated us from the apes by its development together with the parallel development of our much larger brain size. This development cannot be followed as it requires a knowledge of the mental activities of our departed ancestors. But is it possible to believe that all our fellow humans and their ancestors have not had thought processes somewhat similar to our own and, by analogy, also the apes?

The development of language must be seen as a social process that developed against a fully functioning background of activities which form the backbone of our lives. The arrangements that give rise to vision and other capabilities are supplemented and attached to other arrangements that are uniquely stimulated by the appropriate visual clues. So that when a red object is presented to us, we experience the sensation, but the word 'red' may only come into our mind as the result of other circumstances. When I look through my study window, I see all sorts of images and colours including daffodils, but the word 'yellow' does not spring into my mind unless perhaps I am explaining to another the differences between the different species of daffodils, or explaining to a child, ignorant of garden plants, how to recognise daffodils. The essential point is that the language element of any visual experience is not an essential part of the experience, and this is because at some time in the remote past it has been added to our experiences. We have choices about how to use it, and one particular experience will produce a different linguistic reaction in different individuals.

Consider what happens when I see a daffodil and articulate 'daffodil'. First, there must be a daffodil growing in the garden. The light from the sun is retransmitted by the daffodil, enters my eye, stimulates the retina, my neural system that finds the right word and I say it out loud. All of these processes are irreversible in the scientific sense. My saying the word 'daffodil' does not produce a visual image of the flower in the mind of another, but what is produced is a stimulation of the person's memories, knowledge, and experiences of the flower. So there is a one-way path from experience to language, but not from language to direct experience, only from language to past memories.

Contrast this with a conversation between friends when they re-experience a past common experience with which they are all familiar. The conversation, while perhaps bringing back happy (or unpleasant) memories, does not recreate the past experience as it was experienced, but only of the memory of that happy (or sad) occasion.

5.7 Hidden knowledge in cycling and swimming

Some of our abilities, such as swimming and reading, are the result of learning, and we can give a reasoned account of their operation and acquisition. Other capabilities are innate that we possess as humans. Many examples come to mind: our senses, a baby's ability to suckle, or feeling hungry. We cannot provide full explanations of how these capabilities come about or fully describe their operation. This is particularly acute for sexual attraction for which it is even difficult for the opposite sexes to properly understand each other's experiences. It is interesting to consider how a new innate capability could arise in a particular population and how a transition might take place within the population from an understood capability to one that is innate.

Many things that we know well, such as the perception of pain or colours are innate, and although we cannot adequately describe or account for them, they exist as a fixed background to our lives. The difficulty in being able to describe sensations or qualia has often been seen as an insuperable obstacle to understanding our minds.

Many of our abilities are acquired, and some of these we can only partially or inadequately describe. The acrobat, cyclist, or the professional tennis player can only give a limited account of her skills. However, in the skill learning process, it must be that, as well as some muscular changes, there are neurological changes that are permanent. It is possible to imagine that there are two different sorts of neurological processes that can happen within the training process. The trainee must first form some conception of what is required of her, and neurological changes must take place to correspond with these. Then a further set of changes must occur that coincide with the acquisition of the ability. For cycling, the child must first understand what is needed by observing others riding on bicycles and as a second stage, learn the skill. Most of us have passed through both stages, but for unicycling most of us have not advanced further than the first stage. Once we have learned to cycle the first stage can be discarded.

It is possible to imagine, by means of an example, a mechanism for the creation of these innate abilities. Consider a girl who learns to swim and suppose that this ability is accompanied by a change in her neurons, S. Although she can recall the learning process, she has no direct access to the actual neurological changes, which remain invisible to her. It is reasonable to suppose that the changes leading to her ability to swim are gradual and are not the result of a single change as swimming involves the coordination of many different parts of the body. An essential part of the learning process is that when fully trained, all the learning process itself is suppressed, but not forgotten. This is most clearly seen in fast-moving sports such as tennis. A professional player will spend months and years in training but when playing in an important match will not have time to recall all of this, and her response will be a result of neurological and muscular changes that have accompanied her training.

Other individuals in the human population may be born or develop with some of the parts of S as innate properties. The idea is that any individual will have some sort of genetic scatter about their inherited neurological structure, as analogously observed with a physical characteristic such as the length of the nose. If the conditions of human existence changed substantially so that the ability to swim had major survival advantages, then gradually the whole population, in successive generations, would be better able to swim without instruction as they would gradually acquire the necessary changes as innate properties. The ability to swim would then become part of the set of the population's innate properties, but a side effect could be that individuals would have no insight about why they could swim as there would be no cognitive access to the neural changes involved. The existence of this mechanism might be testable by comparing swimming abilities in populations that are landlocked with those who live on small islands.

Further, the modified population will have a conceptual gap as they cannot conceive of being unable to swim or therefore of the learning process. The original and the modified population between them will know many different things about swimming, but no individual will know everything! The modified population will have acquired new capabilities but will have also lost some: that is, the ability to understand what it is like to be unable to swim.

If the race of swimmers is considered as a whole, it can be imagined that their experience of swimming will range from those who cannot swim at all to those born generations later with innate swimming ability. If the process over the generations is sufficiently slow, then the two groups cannot communicate their experiences. In this process, knowledge is gained by part of the population, but knowledge is also lost. Therefore, group Y will be unable to understand that there could be a group N who are unable to swim.

In conclusion, it can be possible to have an ability without understanding the nature of that ability or its method of acquisition. The understanding of the acquisition of the ability is spread over several generations of the population being considered and is, therefore, not available to any one individual. The individuals at either end of the process are constructed in different ways, and they would be unable to understand each other properly in that respect.

This mechanism also produces an 'explanatory gap' as the various steps in the acquisition of the innate capabilities are gradually lost as the older generations die, taking their particular piece of the entire process with them. Some things an individual can never know in its entirety.

Although the acquisition of the swimming ability is one simple example, the same principle can be applied to any other innate ability and can explain how as a race we have developed our capabilities from early man to today's humans. The principle would seem to have general applicability that by analogy can apply to our senses. The idea that abilities can be acquired by the population and that the population is unaware of the underlying mechanisms is exactly what seems to be needed in relation to qualia: we all know about the sensation of seeing the world, but none of us can say anything from our direct experience about the processes involved. Going back in time one can imagine our ancestors had gradually less capability of vision, but a knowledge of the different steps would have spread thinly over the generations, with communicating individuals being insufficiently different to recognise that changes were occurring. So as a race, we can have a collective understanding of processes that is unavailable to individuals. The difficulty in understanding the nature of qualia is not one of a single explanation that cuts through all its complexities, but one of explaining and understanding relative small differences between one person and another. This seems conceptually much less difficult. If the small differences can be understood, then the overall picture is simply the sum of the parts, but an explanatory gap between the generations will remain.

CHAPTER 6

The mind and its experiences

6.1 Other minds

Some extreme sceptics are not prepared to admit the existence of minds other than their own and others regard such discussions as meaningless. Although there certainly are considerable difficulties in understanding the operations of our minds, those of other persons, and creatures similar to ourselves, the difficulties we experience have a much larger dimension. There are certainly many different approaches that can be made even though we have only limited access to the minds of others, and practically none to the minds of other animals such as pet or wild animals, or much simpler creatures such as snails. Although we cannot, by direct experience, prove that other minds exist, this is stretching scepticism too far. It is also difficult to imagine what sort of arguments might convince the sceptics that other minds exist; there are many things in the world which we believe exist but for which we have no direct experience or evidence such as the south pole or the far side of the moon.

Twins and ancestors

If I were an identical twin, it would be most difficult for me to believe that my twin's mind was not quite similar to my own, with experiences similar to mine. Although not provable by logic, is not credible that individuals with identical genetic make-up, raised in the same environment, are substantially different in their experiences, even though their experiences and memories will diverge as time goes by. There is the possibility that this divergence is greatly increased by accident or disease, but these are special cases.

In passing, it should be noted that identical objects of any size do not exist except as concepts. Perfect spheres can be imagined, but a set of even the best 'identical' ball bearings will have minor differences. However, the general idea that things made in the same way are very similar must be a good guiding principle. There is a clear and familiar analogy with mass-produced goods as all cars of the same model leaving the Ford factory will, like the twins, be essentially the same, even if all are not black. If the principle relating the minds of identical twins is accepted, then it is difficult to resist the idea that siblings have broadly similar minds, and then, without too much of an extension of belief, also our close ancestors, some of whom we know, or have known, directly. And if them, more distant unknown ancestors must have had minds, and so on to earlier and different species, going back down the evolutionary chain into earlier epochs. Once the first step in this reasoning is accepted, there is no obvious place to stop: perhaps at mammals that cannot use languages such as cats and dogs, or reptiles, fish, or molluscs. If neural systems are essential for a creature to have a mind and experiences, inert objects such as stones, viruses, and bacteria are excluded. On this reasoning, minds are everywhere, but there will be differences between different species as they do not satisfy the criterion of being created in the same way. The only clear, logical alternative to this view is that nothing apart from myself has a mind and experiences, but this is too fantastical to accept.

When trying to understand the operations of our minds and those of others, it is not plausible to suppose that there are great differences in principle between our grandparents and us, and only smaller changes can be envisaged between parents and their children. There have been enormous changes in the environment since our grandparents' times, but the fundamental of life, death, eating and procreation have not altered. But there will have been many small changes that we have not noticed and cannot easily conceptualise. Some of these changes will be smaller than the differences between those of our contemporaries who we know personally. Over successive generations, these changes can gradually aggregate to create major changes so that one can conjecture that the earliest recognisable men and women probably had quite different minds from us, less versatile and effective as reflected in their physically smaller brains. Again, the difficulty with this sort of argument is knowing where to stop as no intergenerational gap would seem likely to be significant. Could it be that the minds of medieval humans were quite like our own, but those of stone-age humans significantly different? Certainly, the conceptual repertoires of these different groups must have been quite diverse as their lives experiences were so hugely dissimilar. The progression of this argument becomes much more speculative the further back down the evolutionary chain we try to travel. It is very problematical to try to decide which creatures, far removed from ourselves, have conscious experiences even if these are entirely different from our own. Opinions vary, but many would agree that it is a question about where to draw the line. Many would agree that their pet cat is conscious but exclude earthworms. There seems no way of resolving this question, and perhaps this does not matter from a logical viewpoint, but the question has a bearing on our view of our consciousness. The question also has a moral aspect as it will determine our attitudes to the treatment of animals, their nurture and demise within our food chains.

As an alternative to trying to conceptualise the mental changes that occur over the generations, the variation in mental capabilities and experiences can be considered by comparing the apparent mental capacities of different individuals. Here it is clear that the mental processes of a university professor must be of quite a different nature to those of an elite athlete or a normal person. But we are hard-pressed to explain the nature of these differences in a usefully objective way. There must also be very different experiences that are difficult to quantify adequately between musicians, artists, scientists, actors or politicians.

Consciousness is continuous

The concept of the quantity and quality of consciousness can be thought of as something that continuously varies between one person and another and from one species to the next. We can see this idea in ourselves, as at different times our experiences of the world have different intensities. When tired or about to sleep, our conscious experience falls to a lower level. Also, each of us needs to be understood against our background and also the development of our species. Further, consciousness should not be seen as a single object for dissection but as part of a continuous process with elements spread among the population and back in time.

The argument by analogy suggests that other humans and other creatures have been conscious since early times and that they have had experiences of either greater or lesser intensity than our own. Our pre-linguistic ancestors must have had much-impoverished experiences. The consciousness of our race could be thought of as a continuum of very loosely interacting parts with each individual possessing a piece essentially, but not completely, disconnected from the rest.

The advantage of thinking of consciousness as something that can vary continuously is that to understand it we only need to understand why we have a higher level of experience than some other person or a lesser one than another, or the relationship between the states of our own minds when either highly active or somnolent. The problem can then be split into a large number of separate links going back to the origins of mind. If this is accepted, the problem of understanding consciousness is not a single large problem, but one of understanding many small ones, but with no grand syntheses. This is somewhat like the structure of the physical sciences where there is not one grand edifice but many interlocking self-consistent parts, or a building where the parts do not fully constitute the whole. I seem to have no difficulty in understanding that I am less conscious than other greater persons than myself and at this moment, more conscious than myself in a state of illness or just before I sleep. Again this suggests the continuous nature of consciousness and is a warning against trying to find a single overarching explanation of the life of our minds. Consciousness should be thought of as continuous and variable with instances large and small but its manifestations in others mainly incomprehensible to us not for some deep-seated unknown reason but simply that we are, as individuals, mainly detached from other creatures.

However, although this might make it easier to understand some aspects of our minds such as loss of memory or hearing, the big problem of why we are conscious at all and the nature of our consciousness does not go away. For some, this is *the* problem, with no obvious solution in sight.

Perhaps another way to consider our minds is to contemplate what would happen if some parts were removed. Suppose our memories were gradually erased, followed by our ability to recognise things in the world, and then our senses stopped working. Would there be anything left except a faint shadow? The mind might equally be thought of as these elements brought together, acting as a great symphony, and nothing more.

Zombies

Zombies appear in African folklore, lurid films and most recently in philosophy. All devotees of horror movies will know that zombies are just like us, except they have arisen from the dead and have no internal conscious experiences. They have attracted the attention of film producers with a taste for the macabre and also philosophers. It is interesting to ask how we can distinguish them from the rest of humanity, and how we know that there are not some of them about, maybe living unrecognised in our neighbourhood. They are philosophically useful to probe questions about consciousness, the nature of experience, and their relationship to the physical world. They are thought to be conceivable, and this is argued to make them possible, but only madmen believe in their existence. They are interesting because it is impossible to *prove* that other creatures have conscious experiences. And from this, it is argued that the physical world does not encompass all there is and that there must be some form of dualism with mind and physical objects being somehow fundamentally different. I once thought that it would be an amusing idea to go as a zombie to a conference about the mind where there was going to be a philosophical discussion of zombies. Even if I had eventually admitted it was a hoax, I wondered if any of the delegates would then feel that they could believe what I had said either earlier or later.

From my point of view, the world is composed of arrangements, and from this, it can be argued that even if zombies are logically possible, then this does not interfere with this ontology and its unification of the older categories of mind and matter. Much has been written about zombies with no established conclusion, but there is always the underlying difficulty that we can never enter into the mind of another in the sense that we can experience their experiences. However, experiences in an individual's brain are accompanied by neural activity that can be observed by others and presumably this could be used to see if putative zombies were like the rest of us in this respect. Of course, this would not convince those who thought that Descartes' evil demon was lurking with his hidden deceitful ways, re-emerging as a zombie.

6.2 The worm

Many might be prepared to accept that our ancestors of say fifty million years ago had minds and experiences that would be recognisable to us, but what about non-mammals such as insects and worms? One of the simplest of these is the nematode worm. This tiny worm (length 1mm) exists in huge numbers, has thousands of species and has been chosen for study because of its relative simplicity. The nematode worm has a nervous system that has been studied in considerable detail from reconstructions of scanning electron micrographs of sections, and a complete mapping of their neurons is possible because of their simplicity and small numbers (302). The relative simplicity of their neural structure has stimulated research programs, not yet completed, that try to develop computer simulations of their activity and behaviour. This has some way to go and may lead to a complete understanding of the worm's behaviour, but, even if successful, it will still be impossible to determine if the worm has any conscious experiences. The question as to whether they do have experiences as some form of consciousness at a very elementary level would seem to be undecidable, and conceptually difficult to formulate even if we knew everything about the nematode. I cannot see that a definite answer can be given, but if they do not have experiences then further up the evolutionary chain internal experiences must gradually develop and it would be desirable to have an explanation as to how and why, and to which species this happens. Even if we can identify creatures that have experiences, it would be useful if they were sufficiently simple for us to have a complete understanding of their lifestyles, environment, and experiences. And it might be possible to be able to conceive and imagine these experiences. But this imaginative exercise would not produce in ourselves the same experience as those of other creatures any more than we can recreate for ourselves the experiences of another human. It is just that for species very different from ours the difficulty is more extreme, and it seems that we, as individuals, are forever excluded from the conscious experiences of others. A similar argument could be mounted about more complex creatures, very much simpler than ourselves, but further up the evolutionary chain. Perhaps the only possible route into the minds of others is through language, but maybe this is insufficient for this task.

Virtual reality

One use of the increased computer power that has become available is to simulate environments, either real or imagined. An environment is presented on a screen with which the onlooker can interact. Familiar examples include the great variety of computer games and aircraft flight simulators, or we can fight aliens in a distant part of the universe. These simulations have been developed to a high level of sophistication so that their users have their attention fully engaged and are completely transported into unfamiliar and sometimes fantastical environments. Using the capabilities afforded by virtual reality, it must be possible for us to have an insight into the total possible range of experiences of simple creatures. If an arrangement was set up which simulated the nematode worm's environment and allowed us to act for the simulated worm by providing inputs to our senses and output messages to its supposed locomotory system, we too could experience crawling through a compost heap devouring bacteria. But we would still not have had the actual experience of the worm but found out what it was like for a human to be the subject of a worm-like experience. We can, therefore, imagine to some extent what the experiences of other creatures might be like; we can simulate them to some degree; but ultimately we cannot know about other experiences in the way that we know about our own experiences, not for some deep unknown reason, but because we are ourselves only and cannot become another being except in our imagination.

First creatures

Creatures became recognisably individual when the first single-cell creatures appeared. Ever since, individual creatures have lived apart from each other but have communicated first by inter-cellular messengers and eventually by sounds and languages. This separation of creatures occurred at a very early stage in the development of life on our planet when unicellular creatures first appeared. One important feature of unicellular creatures is their self-sufficiency and closure from the rest of the universe. They have a somewhat impenetrable carapace that defines their exterior, and this feature is present in the individuals of all higher lifeforms including our own. Within this carapace, creatures have to be self-sustaining with only limited interaction with their environment compared with the incessant activity within.

From that moment, the separation of life forms was a permanent feature that continued when multicellular creatures appeared, and eventually birds, animals, and us. In complex organisms, particular functions are performed by specialised cells that communicate with each other. This activity was established many millions of years ago and still takes place, unnoticed, in our bodies. It is only the results of the activities of our neurons that come to our immediate attention, and here, although we are aware of the messages from parts of our bodies, and indirectly the world at large, we are not aware of the signals themselves, or those we send out, except by their results on our bodies and the consequential effects.

Feeling uneasy

However, there are many unanswered questions that can be raised about the mental experiences of others that can only be given partial answers that will always leave us unsatisfied. Although it is difficult to imagine, suppose that we could have a complete picture of another's mental activity. Her thoughts and experiences no doubt fully occupy her mind, and for us to have a full picture, these would then have to occupy our own minds fully. However, experiences are considered against the background of the accumulated residue of previous experiences, and we cannot acquire the residues of another without becoming that person. To some extent, this occurs when an experienced, proficient actor almost becomes her character for the duration of her performance. But if we could enter the thoughts of another, we could also enter the thoughts of a further person and so on. What mental capacity we have would be quickly overwhelmed by the tumultuous experience and the overload of experiences and information.

Archaeology of the mind

The general principle of the development of a species over time is well established in relation to Darwinian concepts of evolution based on fossil records. The development of human artefacts such as weapons, buildings or cooking pots can also be studied from archaeological remains. Over the last century, this principle can be clearly seen in action in the development of aeroplanes, as there are extensive records for these. Processes of trial and error and gradual improvement can be seen. Today's aircraft have evolved in a series of steps from the first powered aeroplane flown by Orville Wright (1871-1948) in 1903. This established the principle later developed into military planes for the First World War and subsequently civilian passenger airliners. A major change came with the introduction of jet engines, but otherwise, each new generation can be seen as incremental development. For someone unaware of this historical development or of aircraft factories, the existence of present aeroplanes would seem to be a complete mystery, in a similar way to the mystery that existed about the different species of animals before Darwin explained that they had all arisen as an evolutionary development from simpler creatures.

Although many long-dead creatures leave traces of their lives as fossilised skeletons, nothing remains of their thoughts and experiences as these die with them and disappear forever, making it impossible for us to study or consider them except as a form of cultural history. There can be no scientific archaeology of the mind, but it is difficult not to imagine that the same principles must have been at work, gradually expanding and refining humans' mental repertoire. Some elements of this could perhaps also be explored by computer simulations by developing self-organising programmes of gradually increasing complexity. Although it is impossible to deny that the thoughts and experiences of our ancestors did once exist, we must accustom ourselves to the fact that they are forever beyond our reach.

Haeckel

Although we cannot know much about the minds of long-gone creatures, there is an analogical way of thinking that might be helpful. Charles Darwin's theory of evolution was championed in Germany by the biologist Ernst Haeckel (1834-1919) who also introduced the controversial theory of recapitulation that he popularised with much vigour. Resulting from his studies of the development of embryos he proposed that the development of each embryo follows the sequence of forms the species has followed over the millennia of its evolution. He supported this with detailed drawings showing the embryonic development of both fish and mammals. He had many opponents, both religious and academic, some of whom accused him of fraud, and he has always been a target of attack by creationists. His theories were used to support political ideas and the ideas of racial superiority that were commonplace in the 19th century and which were taken up later by the German National Socialist Party to justify their wicked genocide.

His idea of recapitulation went into decline in the early part of the 20th century as it became apparent that it was simply incorrect. However, his recognition that embryonic development and its relation to the evolution of species was important and has been revisited in recent years. Parallels have been found between the embryonic development of closely related species, and the determination of the genetic structure of different species has added a new dimension to this branch of biology. For a particular living creature, we can consider its structure and behaviour during its lifetime, its embryonic development and the development of the species to which it belongs. Looked at from a distant prospect all current members of a species will look the same although we would not like to admit being very similar to our close relatives, nor would owners of pet animals agree that their favourite is at all like any others.

These studies are directed towards the physical attributes of a species, which may include audible signals and sexual displays. For the mind, only some of this is possible. The physical development of the brain before birth, the size of the skull, and the mental development of human infants can all be subject to scrutiny. However, the evolutionary development of the internal activity of the mind is completely beyond our grasp, as also are the experiences of the newborn. There seems to be no way out of this, and perhaps we should accept the inevitability of our continuing ignorance. However, some of the concepts of recapitulation can be applied to this and other areas where an unknowable evolutionary development has occurred. An example would be a comparison of language learning in infants with theories about the original development of a language of which there is no surviving trace.

6.3 The senses

Aristotle devoted chapters in his major treatise, *On The Soul,* to the five senses: sight, hearing, smell, taste and touch. As has long been recognised, without our senses, we would know nothing of the world, but some things of which we are aware have no existence in any concept of an objective world outside human experience. Colours are the best example of this. Aristotle also pointed out that the senses can work in conjunction, and two different senses can both perceive the same property such as squareness. A major advance in the understanding of our senses was made by the English philosopher John Locke (1632-1704) who proposed that objects have both primary and secondary properties. The primary properties such as shape or weight are independent of the presence of an observer, whereas the secondary properties of colour, sound, or smell are a result of the effects of the object on an onlooker and are thought to be all in the mind. Although we continuously experience colour, we cannot describe it, nor can we create by speech, experiences of colour either in ourselves or in the minds of others. Much has been written about the senses, but here I just want to make some points to try to further our understanding of their relationship with each other and their connection with our thoughts about ourselves and our minds.

Consider a person who reports seeing a red object. For this to happen the following (at least) must be present. An illuminated object, the eye, its receptors, the neurons to the brain and their interactions, and finally the sensation itself which results in the person saying, 'I see red.' This is an irreversible sequence of events in the sense of the physical sciences. Remove any of these and the report cannot be made. The sensation and its report need all the previous events. Therefore, the red experience is a joint event that includes things outside of the person. Attempts to carve off the sensation separately are therefore doomed to failure. Further, the sensation cannot be recreated directly by talking or thinking about it. We know to a considerable degree what a red experience is like and can refer to it. We can think about it, but we cannot recreate the sensation either in ourselves or others. According to this view, red is not a property of either the object we are contemplating or of our minds, but is a joint property of both, and should be thought of as an event; that is a sequence of arrangements. This undermines a long tradition in the philosophy of colour that started with Locke. Further, when I say that I can see red, I do not mean that I experience some abstract thing called a quale, or that I expect to be able to recreate the same sensation in others. All I am saying is that what I see produces the same sensation that I had in previous 'red' experiences. I may think that your experience will be similar, but I will never know if this is true.

As well as ourselves, it is known that our close relatives, the great apes, can distinguish three different colours. Therefore, this ability can be possessed without a linguistic ability. In the development of present-day humans, language must, therefore, be seen as an addition to previous capabilities, including that of being conscious, and this is reinforced by the knowledge that there are specialised areas of the brain that are especially important for speech. The fact that speech cannot create an experience of colour must be related to the unidirectional flow of information from the conscious parts that we have in correspondence with the great apes to the parts that provide our linguistic capabilities. This should not surprise us as signals flowing along neurons have a definite direction and are irreversible. We could conceive of minds which had the ability to construct colour sensations from linguistic sources, but ours are not constructed like this.

Although taste and smell are closely connected, the senses usually operate independently, although their separate effects are often combined to produce an integrated experience as occurs when eating a tasty meal. The pathway between hearing and sight is not completely blocked in those who have synaesthesia, a neurological condition. These individuals have unusual experiences that range from seeing letters in colours different from their real colours, and seeing colours associated with sounds or music. But these are only partial visual effects, and the construction of complete visual experiences by sound has not been reported. This connection between one sensory path and another has been important for some major artists and musicians such as the painter Wassily Kandinsky (1866-1944) and the composer Nikolai Rimsky-Korsakov (1844-1908), but the existence of this effect does not affect the general separation of the senses, and the very different bandwidths will always prevent the complete reproduction of the visual by the aural as will be discussed below.

The senses help to establish features of the world about us and also allow us to receive information that we and others around us can generate chiefly by our voices and the movements of our limbs and facial muscles. These can set up loops that have powerful continuous feedback. The loop of voice to hearing is particularly potent and, without it, the power of speech can only be acquired with much difficulty. The movement-sight loop is of great importance when learning a new manual skill or a sport and is also used as an elementary means of communications when pointing to something interesting or making offensive gestures.

In addition, we use lesser channels of communication when we blush or exude pheromones to stimulate the visual or smelling organs of others. For humans, these channels of communication are not used for rational messages. An interesting but different channel of communication has been developed by cuttlefish (cephalopods). They can create many different coloured patterns on their skin by rapidly changing their pigment and light-reflecting cells. These patterns are then used, particularly in courtship rituals, to communicate with others of their species, and sometimes, in a laboratory environment, with university research students. Many different patterns can be produced, but the full nature of their communication is not known.

Bandwidth

Our senses can be considered from an information processing aspect. This will be a familiar idea for those who have considered the information content of their photographs or the performance of their TVs and audio systems. A single digital photograph might contain 30 million pixels, and we can digest many pictures each second when watching a movie on TV or at the cinema. Commercial TV programs have bandwidths of about 8 million cycles per second. In contrast, a sound system does not need to work above the upper bound of the frequency response of the ear at about 20,000 cycles per second for the youthful. There is an obvious large difference of many hundred times between these that is also reflected in the very different numbers of active sensors in a person's eye and ear. The ear has about 20,000 hair cells that vibrate in response to sound, whereas the eye has about 120 million rods and 7 million cones. Therefore, the eye has 6,000 more sensors than the ear. To determine their respective bandwidths from these figures is not straightforward as the signals are subjected to processing, and this seems to reduce the potential bandwidth.

Nevertheless, it is clear that the quantity of information that can be obtained from these two sources is quite different. Detailed analysis by scientists at the University of Pennsylvania has concluded that the human eye can transmit data to our brains at a rate of 10 million bits per second. In contrast, telephone lines transmit conversations using a bandwidth of only 3 kilohertz which can transmit bits of information at a rate thousands of times less than can be achieved by the eye. This considerable difference is also reflected in the much smaller volume of the brain that is required to process sound stimuli compared with the volume devoted to the processing of visual images.

The much smaller information-carrying capacity of the ear compared with the eye imposes strong restrictions on what can be achieved by sound and language alone and provides a physical basis for the impossibility of producing direct visual images in our minds by the use of language. This makes part of our experience inaccessible to language, and this must be properly recognised in any philosophy, not as an insoluble problem to be wrestled with, but as a reflection of the separation and different physical construction of our senses. This difference has long been recognised by artists. The Irish painter Francis Bacon (1909-1992) said, 'If you can talk about it, why paint it?' In contrast, the eye can reconstruct aural objects as occurs in reading aloud. So sight can stimulate speech, but speech cannot stimulate visual images because of the huge difference in their respective information contents, and a verbal account can only suggest what a person has seen but cannot recreate it. This fact provides a high level of insulation of visual experiences from language, and the link between them allows almost exclusively one-way traffic with the consequence that visual experiences can be recreated by language in a small part only.

Despite these disparities, our mental attention can be fully occupied by either of these very different sources of information about the world. To illustrate this, consider someone watching a fast-moving sport such as tennis on the centre court at Wimbledon. Even in the absence of a commentary, enthusiasts will be fully occupied by watching the game as it unfolds. Those not attending might listen to a radio commentary and will find the match almost equally absorbing. Judged purely as information streams, it would seem that the listeners to the radio must be enormously impoverished compared with the spectators, but their attention can be almost as fully engaged as the spectators at the match, although it is possible for the listeners to carry on with a manual task such as ironing or woodworking. Therefore, it appears that this can only happen if the visual experience is reduced in its information content with only particular salient features being extracted whereas the aural experience must be inflated by the additional stimulation provided by the stirrings of memory, and recalled experience.

Another aspect of this example is that the visual experience can connect with the spoken word. This is the role of the tennis commentator. However, her words cannot recreate the visual experience in the mind of a listener. From the standpoint of neurology, this must reflect the fact that signals can flow from the eye to the conscious experience, from the conscious experience to the voice, but not from the voice to the production of a visual experience. Language and its uses are therefore in a somewhat backroom, detached from visual experience, and it is in this room that philosophy, mathematics and science exist, and it is from this room that the written creative arts set forth, always subject to the limitation that speech cannot create or recreate any sort of copy of a visual experience.

Senses and exactitude

An important aspect of speech is that it has the unique ability to reproduce accurately the parts of a thought formulated in words both for transmission to others and to provide feedback to ourselves via our hearing. An extremely important feature of a verbal report is that it can be repeated any number of times with complete accuracy, but all this takes place outside the visual arena as discussed above. However, this does not imply that the total experience of each person hearing the identical words will be the same as each will create a different experience for herself that will depend on her store of memories and experiences. Further, if I repeat a sentence containing many obscure, technical, scientific words, only those with the relevant background will be able to experience more than the sounds of the words. That particular words can have quite different effects are caused by different minds' ability to construct something in addition to the words they have heard. Their experience is in two intimately connected parts: the hearing of the words, and the thoughts generated. My words will have the effect of stimulating trains of thought or mental, but not visual, images in the listeners.

The words of our language derive their meaning from usage and the ability of others to understood what we mean. For a speaker of English, the sounds heard trigger further neurological processes that produce recognition of what we are trying to say. There are two stages to this: a recognition of the words followed by an understanding of their meaning. The first part will be the same for everyone, and if they repeat our words to others these will also be exactly recognised. The second part may vary considerably from person to person because our words will generally have different connections except for the simplest statements, and this can often lead to disagreement. It is this second part that is the most important. In finely nuanced talk about ourselves and our lives, this can be considerable. Just consider the simple words 'our God' and how this will produce quite different responses in atheists, Christians, or those with other religious beliefs.

But what of an utterance that consists of singing a single note? The first recognition is the same for all of us but even here, with a sound outside of language, the total effect on the hearer will differ widely between the professional musician and someone who is tone-deaf. Hearing is quite different from the other senses as it is used mainly for the reception of sounds produced by other humans. The other senses are not like that. Feeling cold or suffering from aches and pains do not need others, neither is there a second step beyond their recognition to give them meaning, although this can sometimes be present if I recognise that a particular pain in the neck is the same as the one I experienced last week.

However, some combinations of words can produce in the hearer an accurate copy of the experience of the originator as well as a copy of the sound of the words. The statements of mathematics and science are like this. An important feature of mathematics is that it can be pursued outside the visual arena, and different individuals can agree with mathematical statements and be sure of the exact similarity of their thoughts, leaving no room for disagreement. My idea of *1+1=2* is exactly the same as yours, and the same experience is revisited every time the speaker or listener repeats the utterance, either silently to themselves or out loud. Prime numbers are another good example. There can be no direct experience of these through the senses, nor can it be argued that ultimately they rest on experience, as the concept is learned from others, who themselves have no direct experience of them.

Although much of our knowledge of the world comes from sight, the totality of what we see is not translated into a linguistic equivalent. For the most part, we just absorb and contemplate our images. Striking features are the colours we can communicate by name to others. Although the listener will have a clear conception of what is being seen, hearing the word will not produce a visual experience of a colour. Instead, their ideas of redness, for example, will arise from their memories. This can lead to doubt about the similarity of different individuals' direct experience of colour. I cannot recreate an experience of redness in myself. I can recognise the experience, but I cannot produce the sensation. It is a production of a moment's interaction between the world and me that can only be created by displaying a red object or shining a red light. Observing red should be thought of as a joint arrangement of the world and myself that cannot be carved into separate parts. Whether or not your experience of red is the same as mine is unanswerable as it is impossible to make a direct comparison of my experiences with yours. This is a consequence of the separation of our experiences as two separate arrangements.

When a red object is put before me and seen by me, there is an irreversible series of events in the scientific sense that one event follows another, but the sequence cannot be reversed. The object stimulates the eye and its neurons, leading to a sensation of redness. I can then formulate and articulate the word 'red' which can then be heard both by me and others. But the word will not stimulate the sensation of redness. An irreversible pathway will have this effect, and neural signals have precisely the right property as they travel in only one direction along the axon. The reasons for this are not some profound secret of the mind but a simple consequence of the way our particular minds have been created over the generations. There can be no in-principle obstacle preventing a skilled neurosurgeon reconnecting parts of the person's brain so that particular words could create specific sensations.

As the development of language almost certainly followed the ability to see colours, the part of the brain that accompanied this development would have been an addition to what was already there. From this perspective, colours should be thought of as a pre-linguistic capability that can be labelled by language but not recreated by it. Further, the experience of seeing a colour must be thought of as an irreducible event of many parts that includes both the mind and the world. The failure to recognise this accounts for the many difficulties that individuals have experienced when contemplating the nature of colour.

6.4 Language

One thing that distinguishes us from animals is our extensive use of tools, from stone axes to computer-controlled metal cutters and 3D printers. Any useful tool will allow its user to do something either much better or faster than before or sometimes carry out a completely new activity. Sharp stone axes were developed over very long periods into tools of considerable sophistication, displaced only when metal implements became available. These implements were all used to cut other materials, whether trees or an animal trapped to eat. All though each new axe was an improvement of its predecessors, and each tool had limitations that were an intrinsic part of its construction. Stone cannot cut metal, and modern machine tools are often designed for a particular specialised purpose but are not useful when eating food.

Language and communication must also be thought of as the greatest of humans' tools on which nearly all of their activities rest and which must be used as a tool for all discussions of the world and our lives and times, in literature, philosophy, and conversation. It is interesting to consider if language is a universal tool that can be applied to anything or if it has by its nature limitations or errors of construction that restrict its scope and cramp the style of its user.

The range of linguistic activities is quite remarkable: everything from the best literature to vulgar jokes, from science to religion, from shouting at football matches to expressions of love. We also use language when thinking silently by ourselves, but for a language to work, there must be others, maybe only a few, who can understand our utterances. However, language is an imperfect tool that often, in part due to our difficulty in formulating our thoughts, does not convey to a listener the content of our thoughts with any exactitude. Some of my thoughts will have no greater dimension than that expressed by my choice of words as that is also how the thought is represented to myself. Other thoughts will have many more dimensions involving my whole being and will evade my best efforts to express them properly. These may stretch back in time to encompass some of my most important experiences of life. Consider saying the contrasting experiences from the trivial to the profound if someone talking to me says, 'Pass the salt,' or, 'Father has died.'

Purely factual matters are most easily formulated, but many of my sensations or thoughts cannot be conveyed to another with any great precision. This is in part owing to weaknesses in my expressive abilities, but also a facet of my means of communication. The greatest wordsmiths can convey much more than most of us by their choice of appropriate words arranged into succinct and expressive phrases and sentences. One of the great masters is William

Shakespeare, who can transport us to different worlds in a few sentences, but even he cannot exactly transfer his thoughts to ours, as with sentences of any complexity different interpretations can be made, and even apparently straightforward texts are bound to be nuanced differently and can be the subject of endless further discussion. These nuances will often depend on the life and experiences of the listener. This difficulty is acutely experienced by philosophers who, by confining themselves to the simplest propositions, cut themselves off from the much more complex thoughts that occupy most of us and this is particularly apparent in their efforts to reduce language to conform to a logical structure.

For mathematical ideas, great exactitude is obtained. A particular number, say 1729, can be transmitted to another and a whole succession of others without alteration or distortion, even though the response produced in the listener will vary considerably. Some readers will recognise this as the number of the taxi that the eminent mathematician G. H. Hardy (1877-1947) took when he visited his friend and collaborator Srinivasa Ramanujan (1887-1920) who was ill in bed. Hardy remarked that his taxi number was rather dull, but Ramanujan disagreed, and pointed out that 1729 was very interesting as it is the smallest number expressible as the sum of two cubes in two different ways (1^3+12^3 and 9^3+10^3).

6.5 The tiger

The totality of different modes of expression is impossible to categorise, but some of the different processes at work in the use of language can be illustrated by a simple example. Suppose I climb a ladder to look over a wall and report to another at the foot of the ladder that I can see a tiger. She could report my experience to others also at the foot of the ladder either by saying simply, 'There is a tiger beyond that wall,' or just shouting, 'Tiger.' My experience is quite different from that of all the others as I have just experienced the sight of the tiger at first hand, whereas the others know about the sighting as a reported fact. All their experiences of this event will be very similar, but suppose there is a child present who does not yet know the meaning of the word for the animal. She will have to enquire and will no doubt be told of the tiger's striped fur, its large sharp teeth and so on. But this experience will still not be that of those who already knew about tigers either by direct experience or educative processes. If I descend the ladder and a conversation ensues, everyone's thoughts about the tiger, except for the child's, will be to some degree similar and based on their ability to recall particular images into their minds, but their thoughts will be different and divergent. These conversational experiences will also be direct but will be of the discourse and without the presence of the tiger. Linguistic acts are unable to completely recreate my recent experience or the past experiences of the others, and this will be a general feature of discourse: past direct experiences cannot be totally recreated though they can be talked about. But the recollections will be different from the original experience as they will be without the actual experience. However, experiences that consist essentially of conversation can be recreated as they lack the direct experience element. The child will just have to speculate as best she can until she meets the real thing. Even a detailed verbal description of the tiger will not be the same as a direct experience of seeing it but would reduce the child's sense of surprise. There are three distinct experiences: direct observation, second-hand report, and the introduction of new knowledge to the child. The mental activity induced in the bystanders will not be the same as mine, but similar in intensity to my experience if I recall the event at a later date. Although I may have a very clear recollection of the event my recollection will be devoid of the immediate experience, showing this experience, recreated by language, has an important element missing and showing that language cannot recreate the exact nature of the direct experience. This example clearly suggests that discourse and experience are separate but sometimes related activities with three possibilities. There is what might be called the raw experience unaccompanied by linguistic embellishments. This would be experienced by a child who has neither seen nor heard of a tiger before. Then there is the person who sees the tiger and articulates the word. And finally, there is the recollection of a tiger that you, the reader, is experiencing right now. It follows that anything spoken or written can be entirely devoid of any direct experience but can create in the mind of the reader or listener an experience that has similarities with the speaker or writer. The war correspondent can create vivid and unpleasant impressions in our minds that are similar to her recollections, but they will always lack the recollection of the correspondent's, though this can be replaced in her readers to a considerable extent by the exercise of their imaginative powers. The point of this digression is to make it clear that there are direct experiences that cannot be recreated by language, although language can be used to partially recreate these experiences in our minds and those of others. People often say that they can recall something of the distant past as if it happened yesterday. We can all recall the faces of departed friends and relatives, but that does not mean that an actual image appears in our minds. We can certainly recall something and give a partial account of this that would enable the listener to develop images of her own. This again illustrates the failure of language to exactly reproduce a previous experience. In conclusion, language cannot recreate all parts of an experience, and that is the feature of it as a tool that is missing. But for things that do not depend on direct experience, language is the perfect vehicle.

It is useful to recapitulate the experiences of the different actors in our story in some more detail. At the top of the ladder, I have a direct experience of seeing the tiger as a result of an image formed on my retina. This then stimulates connections to my tiger knowledge and experiences that in turn lead to my utterance to the others at the ladder foot. For bystanders, my words will stimulate tiger thoughts in these, but there will be no direct image for them to contemplate. Further, although the message they have all received is the same, their thoughts will not all be similar as these will all be influenced by their previous lives. The big game hunter, the conservationist, and the parent who sometimes takes her children to the zoo will all have different thoughts springing to mind, united only by the word 'tiger'.

The very young child is probably puzzled; if perhaps she has never heard the word before and learns from the event only a new word and that it is something that can be seen over a wall. Maybe she has a knowledge of the word but does not know its meaning. Her next steps are to enquire what it is that is being talked about, or better still, to climb the ladder herself to have a look. She will then be in a similar position to the other bystanders. The conclusion from all of this is that language cannot substitute for experience and that the mental events that are stimulated by linguistic means are devoid of the immediacy and content of direct experience.

Some sentences can exactly recreate an experience in the mind of another. Consider the cinema queue. The person at the head of the queue is told that the cinema will not open for some time because of an electrical failure and this message is passed down the line, with the experience the same for everyone. This is because language can create an exact replica of itself but not of things outside its scope. These inadequacies of our language are often forgotten.

The above scenario could be repeated with my reporting that the far side of the wall is painted red. Although this will be well understood by the bystanders, the direct sensation will not be experienced by them, again showing that language cannot invoke direct experience: it is something quite different, perhaps akin to a labelling system. If the child did not know about the colour 'red' and, although difficult to imagine, had not previously seen a red object, it would be quite impossible to explain what had been seen. The child's experience could differ although it is difficult to believe that a child who can understand words does not know about red things.

Many different activities are illustrated by the above example, and it should also be observed that the initial experience of seeing the tiger would be quite similar to that of our pre-linguistic ancestors or today's chimpanzees, so that language can be said to post-date experience. Although some experiences can be envisaged as happening without language, there are others that cannot. In an English court of law, wigs, gowns, or the judge all give rise to particular visual experiences, but it is not possible to imagine a court in session without the use of language, but it is possible to imagine the court proceedings being fully experienced by blind plaintiffs or lawyers so therefore this experience language may be sufficient, except for the appearance an demeanour of those in the court room.

Different sorts of knowledge are clearly illustrated by inaccurate, but beautifully executed, drawings of exotic animals made in Europe when they were known only from travellers' tales. The most well-known of these is Albrecht Dürer's (1471-1528) woodcut that shows a rhinoceros protected by armour plates and is somewhat anatomically inaccurate. It originated after Dürer heard reports of an animal that had been shipped to Lisbon from India as a gift, but as another rhinoceros was not seen in Europe for a long time, it remained as a definitive picture of a rhino. Drawings of elephants also exist created by artists who had not seen the animal first hand. Various versions exist, always with trunks, but sometimes with the feet of a horse.

6.6 Colour and physicalism

Some philosophers have tried to develop a view of the world in which talk about experience is a branch of folk psychology that will be discarded when a proper scientific theory of the mind is established in the future when the world and our minds can be described in purely physical terms. It is quite difficult to penetrate their motivation of these philosophers, and quite different approaches have been developed by others. A very famous and much-discussed argument against the idea that everything is physical has been put forward by the American philosopher, Frank Jackson (b. 1943), and which we will repeat here. His thought experiment was intended to try to refute the idea that everything is physical.

Mary is a brilliant scientist who has always lived in a black and white room and has explored the world only via a black and white television. She has become an advanced specialist in neurophysiology and knows all the physical information that is available about the processes that occur when we see red tomatoes or the blue sky and can correlate these with the different wavelengths of red and blue light. She also understands how these stimulate the retina in different ways and how these, in turn, affect the brain and cause it to say 'tomatoes are red' or 'the sky is blue' as appropriate. One day she is taken out of her room and shown the real world. Will she learn anything new? The most obvious answer is 'yes', as she will be *experiencing* colours for the first time. This proves that there is something additional to the physical and neurological facts and that physicalism, the view that everything is physical, must be incomplete. This conclusion, and variants of the Jackson narrative, have been extensively discussed by philosophers without generally accepted conclusions.

One possible answer to Jackson's problem can be constructed from our earlier observation that language is an incomplete and inadequate instrument that can label colours but not create them as sensations. They are not linguistic objects but events encompassing the world and our minds. Another interesting thought experiment is to suppose that suddenly a girl, Jane, is born with an extra set of light-sensitive cells in her eyes so that she can distinguish four primary colours instead of the usual three. Tests could be run to establish that this was so as the information content of four colours is higher than that of three. Some images could be made in which Jane could see features invisible to normally sighted girls. How could physicalists react to this? They could not rationally disbelieve Jane, but they would not be able to visualise or imagine the extra colour which is outside the physicalists' vocabulary. Neither would Jane be able to explain her sensation to them. In contrast, by fitting Jane with glasses with special filters, she would be able to get an understanding of what normal sight was like. The conclusion from this is that colours cannot be properly represented by language: they can only be labelled and pointed to in minds of the right sort; that is, in minds similarly constructed to our own. It is also very difficult to imagine the additional colours that can be distinguished by other creatures, including insects and birds.

6.7 Language cannot recreate experience

An attractive conclusion is that language cannot fully recreate experiences, and it can only partially recreate original experiences as mere shadows. This can most clearly be understood in the use of words for colours. When I see red, say 'red', and you understand, a sensation of red is not created in your mind that is the same as your experience of seeing a red object. Similarly, if I recall seeing a red tomato, my experience is that of recollection; a red sensation does not appear before me. Something is missing, and my experience is similar to that which you experienced when I told you that I could see 'red'. Also, if I see a red object the word does not necessarily spring into my mind. There are several different processes at work here. Just now I looked around my study thinking about this and looking for red objects in order to contemplate this thought, but I soon realised that while doing this I was conscious of the green walls and carpet, but the word 'green' had not entered my mind. Similarly, on the football pitch, the players do not start talking to themselves or others about 'red' every time they see their opponents' shirts. They just experience the sensation.

There are several different elements at play:

- The experience that accompanies the actual sight of a red object
- The recall and expression of the word 'red'
- You and me hearing the word 'red' and recollecting earlier experiences
- My thinking in isolation about 'red' things and recollecting earlier experiences

For those of my thoughts that are transparently clear to me, I have to undertake many different steps to transfer them to another person. These are subject to inadequacy and omission as may be seen most clearly by considering a thought that I might pass on to another and which eventually returns to me as a damaged and inadequate version of the original that is almost unrecognisable. This is particularly so in the case of original experiences that are primarily of a visual nature. Rumours are made of such stuff. In considering these processes, it needs to be clearly recognised that the verbal expression of a particular thought does not completely capture the essential essence of its original. The word 'red' does not produce a visual sensation of the colour but allows me to recollect what I know about the colour. This presumably is in part an effect of the architecture of my brain as the verbal part cannot send signals to the colour experiencing part. Further, perhaps if my brain were partially rewired by natural or artificial means, particular words could directly create sensations.

There are neurophysiological changes underlying these different processes that could be in principle investigated empirically. It is now possible using functional magnetic resonance imaging (fMRI) to detect the activity of different areas of the brain by measuring differing levels of oxygen in haemoglobin. With this method, it might be possible to distinguish the different activities listed above.

It is clear that language can recreate only a limited experience of colour in most people, but does it have to be like that? Why is it like that? This can be explored more in a thought experiment. Assume that the experience of the perception of colour already existed in pre-linguistic humans. It must follow that this perception must be accompanied by neural activity in some part of the brain and that this capability will continue in the humans' descendants. Some of these will learn to speak, and they will develop part of their brains to accommodate this new capability, and for the linguistic acts to make sense, there must be some neural connection between the original experiential part and the new linguistic part. Typically when a red patch is seen, this will stimulate the word 'red', and listening to the word 'red' will invoke memories of red objects, and the colour itself. In exercising the memory of red objects, the person will be able in her memory to consider different shades and versions of red: pillar box red, a sort of maroon colour, and so on. But the corresponding visual sensations will not be produced. It follows that there is a path from sensation to word but not from word to sensation, and neurologically speaking this must correspond to signals going from the experiential part of the brain to the speaking part but not the other direction. Any irreversible connection will have this effect, and neural signals have precisely this property as they travel in only one direction along the axon. The reasons for this are not some profound secret of the mind but a simple consequence of the ways our particular minds have been created over the generations. There can be no in principle obstacle preventing the skilled neurosurgeon reconnecting parts of the person's brain so that particular words create specific sensations. From this perspective, colours should be thought of as a pre-linguistic capability that can be labelled by language but not recreated by it.

In terms of arrangements, the experience of seeing a coloured arrangement (or object) requires several different elements including the patch of red, light transmitted into the eye, and the internal neurology that creates the sensation. Therefore, seeing colour is an event that is a sequence of arrangements in time, and the experience of 'red' cannot be dissected into brain elements and world elements as both are required. Take one part away, and there is no experience and attempts to make a separate analysis of the parts of the experience will certainly be inadequate.

Once away from direct experience, language can transmit ideas from one to another with some exactitude in the part of our thinking that relies on acquired knowledge, but here it must be recognised that our concepts have varying degrees of completeness and complexity from person to person. Most have some knowledge of medical matters, the role of the heart, lungs and so on, but the knowledge is partial and limited compared with that of a fully trained medical doctor. However, there is sufficient conceptual overlap for the patient and doctor to have a meaningful conversation about symptoms and possible treatment.

6.8 Thinking about oneself

It is certainly impossible to experience the full extent of one's mind as there are so many hidden and forgotten or inaccessible crevices. One problem in trying to understand ourselves is that it seems difficult for our minds to represent themselves. This may be because a complex thought will occupy the full resources of our mind which will have elements arranged to correspond to the thoughts. If we are to make a conceptual examination of a particular thought, more resources are needed not only for the original thought but also for its examination. And this whole process can be repeated, setting up an infinite expansion, which, because of our finite extent, must be impossible. Introspectively, this can easily be experienced. Try thinking about a person who you know well, and then move on to thinking about your thoughts *at that instant* about the person, and your thoughts about thoughts. You can try this yourself, but my reaction to such an attempt is the production of a feeling of frustration that leads my mind to wander onto other more useful preoccupations such as typing this sentence, and wondering how long it will be until coffee. Thoughts about thoughts can only ever make limited progress and lead to meaningless confusion. Generally, our thoughts follow a sequence with an awareness of recent thoughts somehow still present together with the present thought and the stirrings of the next thought, all in some sort of messy melange that is not isolated in a moment of time.

I can think about a dog, either the particular dog that lives next door or dogs in general. As I can do this with my eyes closed, it follows that whatever resources are needed for these thoughts must be contained within me. I have known various dogs in the past, seen images of dogs, talked about dogs, and my idea of dogs, in general, must be an amalgam of these. I can also marshal up and recall thoughts about dogs that I have had in the past; I can think and talk about these as, 'my thoughts on dogs...' and continue to elaborate the theme. But what I cannot do is concentrate on a particular doggy thought to contemplate its nature, nor can I image what another is doing when she turns her thoughts towards what she is thinking of at a particular moment. I can imagine another person thinking about a dog, but I cannot imagine what she is doing when she tries to think, at the same instant, about her own thoughts about a dog. The conclusion must be that although I have inner resources for my commonplace thoughts, I do not have the resources for thoughts about thoughts. This makes sense as the mind needs to avoid endless regressions or extravagant endless constructions as these have no meaning.

I would have further difficulty in trying to explain to you the exact nature of my doggy thoughts because, in addition to the parts that can be verbalised there is the actual experience that I cannot transmit with any exactitude. The linguistic part of the doggy thought is only part of the story.

6.9 Emotions

Emotions do not fit well, or even at all, into the present ideas and comments about the mind. This is somewhat surprising as they play an important and sometimes dominant role in humans' lives, particularly in motivating our lives and providing many of its satisfactions. This is a big subject, and here I want to make a comment on the important connection between language and emotion.

Very interestingly, although language cannot reproduce in a person a direct experience, it can by somewhat circuitous means produce in a person the exactly the same emotion as might have been produced in another. Fear, elation, sadness and joy are just some of the many emotions we can feel. These seem to be quite different from the experiences of our senses and the reports of others discussed above, as the emotion felt by one person can be directly invoked in another. This is the route into the human experience that is used by all authors of fiction. This part of human activity uses creative acts which involve the coming together of arrangements to produce an art form, also an arrangement. However, this interesting and enormous subject cannot be considered in any depth here.

Emotional experiences are, of course, not all triggered events of a visual nature. If in a crowded place, I suddenly see a fire and shout 'fire' my immediate emotion of fear will be instantly communicated to others. Further, a skilled dramatist novelist who has directly experienced a particular emotion can by their writing directly invoke the same emotions in the reader. It is this possibility that is exploited by written and the other arts of the human race. Fear is an interesting example as its neurological basis has been extensively investigated, and it has been shown that a specific part of the brain is stimulated when a person experiences fear, and that fear is absent when that part is damaged or impaired. However, in normal brains fear can be stimulated in a variety of ways, such as the approach of a ferocious animal, or, more likely, being confronted on a dark night by a group of knife-armed youths intent on robbery. But just hearing the word does not produce the same immediate response, although reading a novel or seeing a film can produce intense feelings of fear. By this means, it seems that the emotion has to be built gradually by the provision and escalation of suitable aural and visual cues, such as the sound of heavy footsteps in Stephen Spielberg's Jurassic Park leading up to the appearance of the monstrous Tyrannosaurus Rex. When visual cues are present, as in a film, what is seen, if reasonably realistic, is close in character to seeing the actuality. Reading a novel must work in a different way with the gradual build-up of the background story leading to the production of a feeling of fear in the reader. This is a quite different experience so that although, as we have already seen, language cannot recreate visual experience, it seems that emotional experience can be recreated that is quite similar to the feeling present when the described event was directly experienced. Emotional experiences quite similar to the original can also be recreated by acts of recollection. Many will be able to reconstruct their feelings of joy on seeing, for the first time, their newborn child, or the sombre and painful feelings that accompanied the death of friend or relative of whom they were particularly fond.

In conclusion, words are different to experiences, but they can be used to recreate them but not in their entirety and, in particular, the visual part of the original experience will exist only partially in imagination.

We only start to philosophise when our understanding of the world is relatively complete. A fixed position in our development is reached, and our way of thinking about the world is crystallised by the experience and development of our ancestors. Much philosophical investigation, particularly in the analytic tradition, has concentrated on detailed and narrow investigations of individual propositions. It has been hoped that this would lead to a greater understanding of the scope of all that language can offer. A particularly prominent theme has been to understand how meaning is attached to particular words and propositions.

6.10 Experiences

Most experiences are multifaceted and involve the senses, language and memory. To try to split off different parts is perhaps difficult as the disparate elements unite to form a whole and our most vivid experiences encompass our whole minds. However, it is known that different parts of the brain are specialised for different functions

Despite these misgivings, I want to try to carve up experience as direct and indirect and separate these into linguistic and non-linguistic parts. As language is a relative newcomer to humans' repertoire, this seems reasonable. The four different categories are:

1. Direct with a linguistic part
2. Direct without a linguistic part
3. Indirect with a linguistic part
4. Indirect without a linguistic part

Examples would help illustrate the differences between these. The first two could be exemplified by a visit to the theatre to see a play and watching a play in a mime theatre. The second pair could be the recollection of these the following day. The most important part of these distinctions is that the first pair can be the originators of the second pair but not vice versa. Again this can be imagined as possible in scientific terms as the result of an irreversible link between the separate categories, just as exists between the senses and language. Any concepts or ideas that attempt to try to reverse these links will be destined to failure.

6.11 Arrangements and the mind

In earlier chapters, it was argued that everything in the universe is an arrangement or a succession of arrangements, changing over time because of the laws of science, random chance or the effects of previous historical events. Before continuing, we need to consider further some particular arrangements of mind. Representations play a particularly important role, and it is necessary to consider what is meant by this, and how it differs from a copy which is a different but essentially similar version of its original. There are such things as exact copies (e.g. numbers and words), but these are exceptions to the general run of things. A good copy of a Rembrandt painting may have minor differences in its arrangements from the original, but it will have many features in common, the same image and size and so on. The picture of the artist's mother will be familiar to many, but when they think of it, a representation must be involved. The original is in the Netherlands, copies abound, but any thought processes must involve an arrangement that is a representation, that is brought to mind for the specific purpose of contemplating this particular image. Although the image might be extremely vivid in some minds, its selection will not produce an actual image but a recollection of its different features and its relation to other facts and emotions that the person has, over the years, attached to this particular image and the memories it arouses.

Our minds can represent many other different objects, but we will take the stance that both the object and its representation are both arrangements with a relationship between them. How this state of affairs is set up and maintained is complex and varies for different arrangements. The simplest case occurs when the initial arrangement is entirely outside my mind, and its representation is entirely within, but the most interesting cases are much more complicated than this.

CHAPTER 7

Philosophical reflections

7.1 Possible theories

All theories, scientific, philosophical or otherwise, are constructed from a combination of language, mathematics and logic, together with any other marks that can be put on paper such as sketches, drawings or photographs. An essential property of theories is that they can be communicated and discussed with others. It is important to know if there can there be elements of the universe that are forever outside the scope of any possible theories, or that things can exist that cannot be properly captured by these theories.

The aim of theories is to bring greater understanding about ourselves and the universe in a general way. Physical science theories have an extensive scope so that, for example, theories about the carbon atom apply to every carbon atom in the universe. Mathematics, on which the physical sciences depend, also has complete generality over all space and time. But is it possible to have a theory about a particular object such as a particular stone or dog, or is a theory possible of an irregular object such as the shape of the coast of Ireland or a Rorschach ink blot? Examples abound of theories about minds in general, but a theory about a particular mind is more problematical. Any theories about my mind have the defect that my mind is not available to others, and any theory that I might have about another's mind has a related difficulty as I do not have access to their mental activities. It is also apparent that formal theories occur only in humans, although birds and animals seem to have beliefs. Our pet cats clearly cling to the belief that they will be fed every morning, but this cannot stand as a theory because this belief cannot be communicated nor is it a belief of any generality.

In addition to language, logical, mathematical and physical science theories use abstract symbols, often in equations, as an essential part of their structure. In contrast, the sciences of entomology or botany could not exist without the extensive use of drawings. Philosophy, except those parts that impinge directly on logic, mathematics, and the sciences, is mostly conducted through the medium of language. These differences both enhance and restrict the scope of all these different areas of inquiry.

A characteristic of physical and mathematical theories is that their elements are the same for all of us. My conception of two apples is the same as yours. There is not really room for us to disagree on the meaning of ‘two’ or ‘apple’. And this allows us to construct theories on which we can all agree. If I say ‘two apples’ out loud, this will produce in your mind an image that is based on your existing knowledge and experience of apples. Without these, the words will be meaningless to you.

However, this is to be contrasted with your experience of seeing an apple: here the same knowledge and experience of apples will be invoked, but there will also be a visual experience, particular to you, that is additional to your response to the spoken word. This visual experience can never be reproduced in you by language. If I close my eyes, I can say ‘two apples’ repeatedly, but I will never succeed in invoking a visual experience. From this, it is apparent that theories that are constructed from language will not be able to include direct visual experiences but can refer to them only as something remembered and that direct experiences can only be considered in an indirect way.

From an evolutionary viewpoint, this makes sense. The ability to have visual experience must have preceded the development of language that must have been an addition to what already existed, and this must be reflected in the structure of the brain. Here lies a gap in our attempts to understand the world, not as a deep philosophical conundrum, but a direct consequence of our evolution and construction.

Useful theories also need to be parsimonious in the sense that they offer an explanation that is compact compared with what is being considered. It is just not useful to provide an explanation of some fact or event that is of enormous complication compared with what is being considered. It is possible to wonder if this might be of relevance to any theories of the mind.

7.2 Physicalism

Much of the modern philosophy of the mind is heavily based on a scientific view of the world. Contemporary discussions have their origins more than half a century ago when the first serious attempts were made to find a systematic solution, inspired by scientific methodology and compatible with the extensive new findings of the physical sciences, to the mind-body problem. As a doctrine, it has displaced materialism that had a very long history and played a substantial role in philosophy particularity in its contrasting role to idealism. The problem remains of finding the right place for our minds in our conception of a world that some regard as primarily physical. A possible solution to these difficulties finds expression in physicalism, the view that everything in the world is physical and is completely characterised by the language of physics. Here the physical embraces familiar objects such as sticks and stones, the properties of these, and many other things that common sense would not normally consider as physical such as things of an emotional, ethical or legal nature. Physicalists insist that ultimately these and all other things can be shown to be physical in the sense that they supervene on the physical. All mental events and objects of the mind are also thought to supervene on the physical. This view is persuasive in that it is difficult to imagine the existence of any object or thing that does depend in some way on what might be termed inert matter. It is impossible to imagine that mental events and processes can take place in some part of space and time that contains no material objects. Physicalists also take the view that the physical world is closed and complete so that any physical event that has a cause has a physical cause. This leaves no room for mental causation.

Before starting to consider alternatives, the ground needs clearing with a diversion into the objections to physicalism raised by Hempel who pointed out that science, as currently understood, is certainly incomplete, and some parts of it may even be wrong. Therefore, it is an unsuitable basis to use to formulate a philosophy. He looked forward to the future availability of a complete science that could then be used with confidence as a correct foundation of philosophy. Either of these possibilities makes it impossible to formulate a correct philosophy right now. However, in his argument, Hempel is assuming, incorrectly, that science is a single monolithic structure that has to be considered in its entirety. It is certainly true that science is continually changing as exemplified by the developments over the past few decades in particle physics and theories of the very early universe. Other parts of science are well-established, well-understood, and unlikely to change in the future: a lone neutral carbon atom will continue to have six electrons, gravitation will not stop acting, nor will water start flowing uphill. Hempel's objections do not apply to the well-established core of science, even though we may have difficulty in delineating it exactly, particularly at the forefronts.

The nature of a physical object has been considered in detail an earlier chapter. There are many and varied objects of interest to the physical scientists, but a common feature of all of them is that they have mass. This applies both to subatomic particles, large things such as the sun, and everyday things such as tables and chairs. It is then clear that there are many other things that do not have mass, including the laws of physics, and are therefore not physical objects in the sense discussed earlier. But these laws are an essential part of the physical sciences and are included in the philosophy of physicalism. Other non-physical objects include the rules of chess and the laws of the land that are outside the scope of the physical sciences, but not in conflict with it.

7.3 Supervenience

An important part of physicalism is the notion of supervenience that may be conveniently introduced by an example given by an American philosopher, David Kellogg Lewis (1941-2001), of a picture made up of a set of dots: 'a dot-matrix picture has global properties - it is symmetrical, it is cluttered, and whatnot - and yet all there is to the picture is dots and non-dots at each point of the matrix. The global properties are nothing but patterns in the dots. They supervene: no two pictures could differ in their global properties without differing, somewhere, in whether there is or there isn't a dot'. His idea is that the dots form the physical features, but the psychological features are contained in the global properties of the dots that make up a picture of a horse or other subject matter. The picture of the horse is said to supervene on the dots. In this example, it is clear that without dots, there can be no picture.

However, when we look at a picture, we do not say to ourselves that we are just looking at a set of dots arranged to form an image, true though this may be. Considering a picture in this way would remove the whole purpose of the picture and reduce it to a mere collection of physical objects. The image that supervenes on the dots is an arrangement that *is* the picture that is a consequence of the way that they are set on the paper. The way in which it is constructed is a secondary and to some extent an irrelevant sidetrack. No-one will deny that without her material, an artist cannot produce anything, but it is dispiriting to look at her efforts as just a set of dots or brush marks. According to this view, any picture is just a set of dots, and somehow the myriad possibilities can be overlooked as some sort of additional but secondary features. In our view, each dot is an arrangement with an independent existence of its own and is composed of paint, the paper it sits on and so on to atoms and further, but the picture is the arrangement of all these dots. From this perspective, both the dots and the picture have the same status as arrangements. Further arrangements are generated when someone sees the picture, on their retina and in their mind and perhaps their memory, and the whole of this set of arrangements comprise the experience of seeing a picture. All these arrangements are interdependent on each other, and it seems perverse to split the arrangements at what must be an arbitrary point with the notion that one side of the divide is physical and that the other side supervenes on the physical. Within a particular observer, there is the question as to where the divide can be placed. Is it on the retina, the signals from the rods and cones of the eye, or maybe further into the brain where the experiences start to be generated? Our view is that all arrangements rest on others and will continue to exist unless some of the supporting arrangements are destroyed. This idea has an amusing analogy in the story of the turtles or other creatures that some have believed support the world. There are many versions of the story, including one attributed to the American philosopher William James (1842-1910). He recalled meeting an old lady who told him that the earth rested on the back of a huge turtle.

'But, my dear lady,' Professor James asked, as politely as possible, 'what holds up the turtle?'

'Ah,' she said, 'that's easy. She is standing on the back of another turtle.'

'Oh, I see,' said the professor, still being polite. 'But would you be so good as to tell me what holds up the second turtle?'

'It's no use, Professor,' said the old lady, realising he was trying to lead her into a logical trap. 'It's turtles-turtles-turtles, all the way!'

Our concepts of arrangements are like the turtles except they change as they descend, eventually disappearing into the fog of an unknown multidimensional alien world of fundamental physics. For us humans, our minds are the top turtles.

Lewis's example gives us one way to introduce the fundamental idea of physicalism. The basic idea is that the physical features of the world are like the dots in the picture, and the psychological or biological or social features of the world are like the global properties of the picture. Just as the global features of the picture are nothing but a pattern in the dots, so also the psychological, the biological, and the social features of the world are nothing but a pattern in the physical features of the world. To use the language of supervenience, just as the global features of the picture supervene on the dots, so too everything supervenes on the physical if physicalism is true. There is a much more fundamental objection to the idea. For the argument to work the dots have to be regarded as some sort of fixed objects and, although this is arguable for largish objects, it is not true if the objects become small as they succumb to noise and quantum effects. So that at best, the supervenience concept has a limited domain of applicability and cannot be regarded as a general principle.

Supervenience has been much applied to mental things which are said to supervene on a physical substrate. However, within this description, there are two sorts of objects: things that have an independent physical existence and things that supervene on them. This must be viewed as a variety of dualism, a doctrine from which the physicalist wants to escape.

The challenge that physicalism faces is that it has to explain in a convincing way, at least in principle, how mental events can be related or reduced to the purely physical. Although supervenience may provide a useful way of considering how the mind and body are related, it does not give an explanation of the mind-body problem.

The apparent difficulties that remain have led to a resurgence of dualism of various sorts in which the differences of mind and matter are seen as so different that they must be regarded, following Descartes, as quite different substances. These ideas can never escape from the difficulty of explaining how these quite different substances can interact with each other. It is a great challenge for physicalists to explain the problem of mental causation and the nature of experience and consciousness.

Possible worlds

David Lewis has defined physicalism in terms of possible worlds and stated that if a duplicate is made of a physical world there can be no duplicate that differs in any biological or mental property, or in other words: once the physical facts are fixed, everything else is fixed. For this to work, there must be at least a conceptual way of imagining duplicate worlds, and these worlds must develop in time in the same way so that they can continue being identical. This perhaps can be done in a conceptual way, but it is not something that can be achieved or tested for any but the smallest and simplest objects such as atoms. The argument also has at least some degree of circularity. Most things that we think of as being the same are really only very similar, and if this idea is reformulated in terms of very similar worlds, it loses most of its force. Even two apparently identical pieces of DNA will have slightly different isotopic composition, and identical twins are subjects to the variations caused by their growth and different experiences as they are never in the same places at the same time.

If the definition is accepted at face value, the question of its truth is much more problematical. For the concept to be useful, the identical world must remain identical with the passage of time, that is, these worlds must be deterministic. This is simply not true at the quantum level and therefore not true of a potentially deterministic classical system that interacts with a quantum system, all of which must be clearly in the physical domain. If two identical systems are initially set up, they will not change in the same way. An essential feature of a quantum system is that its future behaviour is subject to the rules of probability and as all objects at the fundamental level are subject to the laws of quantum physics, they are also subject to the uncertainties of probability. Away from the realm of the quantum, a further difficulty can be found in the behaviour of noisy physical systems. It is difficult to see how these perplexities can be overcome, and certainly, in the quantum world, the concept of identical systems is only true for systems that have no interaction with the world at large. For all other systems, the concept of identical worlds in space and time is entirely incoherent. This approach to physicalism must, therefore, be rejected as untrue.

The alternative to physicalism

However, if the idea presented in chapter 2 that every object of any sort that we know of is an arrangement is accepted then, the arrangement *is* the object, and the nature of the arrangements of which it is made is to some degree an irrelevance as long as they persist for long enough to sustain the dependent arrangements. If everything is an arrangement, then any attempt to split some arrangements from others must be viewed with some suspicion and not accepted on what might seem to be persuasive but arbitrary grounds. That is not to say that different sorts of arrangements cannot be categorised, but it must be recognised that the process of categorisation produces new arrangements compatible with existing arrangements. There is a time element to this so that new arrangements of existing arrangements must be comprehensible in terms of existing arrangements and future projections. In addition, there is no necessity for arrangements to remain identical, even if they start off that way.

Before returning to physicalism, we remind the reader of our point of view that everything of which we know or experience is an arrangement that changes in a way that is not in contradiction with the laws of fundamental science, but in a way that is determined wholly or in part by previous arrangements. This is a form of philosophical monism in which there are only arrangements, both as simple and complex systems. In chapter 3 the enemies of determinism were outlined, leaving the conclusion that determinism is just a hopeless dream, and that any search for the causes of any change for complex arrangements must be looked for outside the scope of the physical sciences. Further, the fundamental causes of some changes are so deeply buried in the distant past, and mainly unknown, that it is a hopeless task to try to have anything more than a general idea of the origin of the causes of a particular action. Sexual attraction is a particularly interesting example: it motivates and determines large parts of most individuals' lives, but its origins are deeply buried in the past. We all know this as a powerful force that acts on us, but the modus operandi and nature of this force remain unknown and deeply mysterious. In the earlier discussion about learning to swim it was suggested that many abilities are comprehensible only in the sense that each member of successive generations could understand how their ability was an improvement from that of their parents. This knowledge of the entire learning process was spread over generations that could not communicate with each other and therefore not allowing any individual an overview of the whole process. This same conceptual scheme must apply to sexual matters: we can understand our own urges to an extent, but we cannot comprehend how these might have arisen; again due to our inability to communicate with all our ancestors going right back through time through different species to very simple creatures.

7.4 Causality

Further comments are needed about the nature of causation and Laplace's ideas. Moving on from his classical world to that of quantum mechanics, one finds laws (equations) of physics that predict the entire future of an isolated system from an initial wave-function. The laws are symmetric regarding the flow of time, and they look the same if we are considering either the past or the future, allowing the prediction of the entire past and future of that system in a way similar to that envisioned by Laplace. We know from everyday observations that the world is not a predictable place, that time has a direction, and the future is more disordered than the past. In science, this is represented by saying that the entropy of a system, that is a measure of its disorder, always increases. There is, therefore, a conflict between these two different ways of considering the world. What makes this difficulty worse is that at the quantum level calculations show that the entropy derived from the wave-function of an isolated system never changes and indeed was same in the past as it will be in the future. Interestingly, these two opposing viewpoints have great resonance with the ancient Greek philosophers: Parmenides, who argued that nothing changes despite appearances; and Heraclitus, who had the quite different idea that everything is in a state of flux. A way out of these difficulties can be found by recognising that any system in which we are interested is of finite extent and will always be in interaction with other systems, that will, in turn, interact with further systems so that the initial information about the system will spread about here and there and effectively be lost. It is rather like losing the information embedded in a door key when it has been inadvertently dropped and lost when out for a walk. The key still exists, but for all practical purposes, it might just as well have disappeared without a trace. This is what happens to some of our collective knowledge of the distant past. It still exists in some sense, but our experience of the world would not be different if it didn't. The search for a cause should not be spread too widely as the search itself will become much more complicated than the event in which one is interested.

Discussion of causation can be motivated by a desire to explain a particular event. For some events such as accidents, a variety of contributory causes are often identified, but principle, subsidiary causes may be identified. For all but the simplest of nearly isolated systems, this will also be the case, and there will always be the difficulty of trying to decide where to draw the boundary of the search for an explanation.

The difficulty of mental causation arises from the idea that the physical world is causally closed: that is, if a physical event has a cause at a particular time, then this must be a physical cause. No further levels of explanation seem necessary, and ideas from supervenience do not seem to help. Suppose a system is initially in state P and at a later time in state P', and that mental states M and M' supervene on these physical states. According to causal closure, state P causes P' so there is no place for mental causation even though it might appear otherwise. In passing, we should note that physical causes used in the present sense can include random events in those classical systems that are subject to random noise and the probabilistic events that arise in quantum systems. An interesting analogy of the physical-mental relationship is provided by considering the shadow of a moving object. This is clearly caused by the movement of the object in the sun's rays. Someone who could only see the shadow might erroneously conclude that the shadow at earlier times caused the behaviour of the later shadows.

For a purely classical system immune to random events and noise, an exact specification of the physical state P will determine P' exactly. A digital computer works like this. At the most fundamental level, specifying P will require the specification of the digital bits in the entire computer, although this is not how its initial conditions are generally specified. Higher-level processes determine the initial conditions, such as typing something on a keyboard which is then translated into the specification of particular bits within the computer, or a program written in a high-level programming language. There are various hierarchies within the computer, operating systems, user interfaces and so on, and if an explanation of a particular outcome of the state P is being considered, then it is to these processes that reference will be made and not to the initial set of bits than in most cases will be extremely numerous. So that generally the operation of the computer will be considered in terms of concepts well removed from the basic structures, but in these cases, it would be possible in principle to translate any higher instruction or cause if you like, into exact physical parameters, the bit pattern of all the memory bits within the machine.

Mental causality

Most would find the idea that mental events have no causal powers unacceptable. Most of us think and certainly act as though our own mental activity has the power to change things in the parts of the world that we think of as undeniably physical. So what, if anything, is wrong with this sort of reasoning and its variants?

For the argument about the lack of mental causality to be correct, there must be a properly determined meaning to all of the ideas about physical causality. In particular the process P to P' must be capable of proper definition and, in particular, there must be a way of specifying the initial conditions of P as different Ps will develop in different ways. Herein lies the difficulty for physical causality, as for any activity that has a potentially mental content, the specification of P will have to be couched in terms that also include apparently mental terms. The objection can be legitimately raised that these specifying terms can be traced back to the physical by considering their origin at earlier times. Although some might find this an appealing idea, it does mean that the analysis of any process such as P to P' must have enormous length. It will gradually acquire and need many references to a considerable slice of human experience. Many of these pieces, lost in the fog of time, will be unavailable. This is a most unattractive prospect for anyone looking for a compact explanation of the relationship between the mental and the physical. Consider what happens if a fire breaks out in a crowded room caused by an electrical failure. At some point, someone shouts 'fire' and the room clears rapidly. The physical facts are clear until the alarm is given, but for the explanation to remain physical, the word 'fire' must be translated back into physical terms. The problem is that this and other words have long histories, most of which are completely unknown; histories in which many individuals, now mainly dead, have made contributions large and small. Even if these histories could be reconstructed in physical terms, one is then faced with two very different explanations as to why the room suddenly emptied. On the one hand, the explanation is that there was a fire and someone shouted 'fire'; and on the other, all that can be said is that a physical event took place that has a long, convoluted history, mainly lost in antiquity. Can this second explanation be worth considering as a serious alternative, or can it count as an explanation at all? Everyone trying to escape from the room would think I was mentally unhinged if I proffered the long-winded physical version of events, neither would they have time or inclination to listen to it.

Alternative to closure

Once the idea that everything is an arrangement is accepted, the above argument fails as P and M are part of the same arrangement, and the discussion of the mental and the physical is seen as an attempt to slice up the world in an arbitrary way that produces apparently insoluble conundrums. And if P and M are both arrangements, then there is no difficulty in understanding, at least in principle, why they are able to interact.

Another line of approach can be made by observing that the argument as standardly put forward is an oversimplification. When we considered the special sciences we noted that they form a hierarchy and that it is simply not true that the higher sciences, for example, biology, can in some way have its principles derived from the lower sciences such as physics or chemistry, even with the addition of bridge laws. Biology has content and ideas of its own, and although some of these may well have congruence with the lower sciences, in general terms all that can be said is that none of laws or concepts of biology can be in conflict with the lower sciences. If a biological event appears to contradict the laws of physics, someone is making a mistake.

The argument above about mental causation presented above can be restated in much more detail as follows. It is necessary to introduce extra steps in the argument to reflect the different sciences so that there will be additional process, for example, physical, chemical, biological and neural, with each of these, except the physical, resting on structures below. There are many ways that this can be approached, but a possible schematic way of doing this is as follows:

Mental	M	→	M'
Neurological	N	→	N'
Biological	B	→	B'
Chemical	C	→	C'
Physical	P	→	P'

Any change that takes place at the mental level will be accompanied by changes at all the other levels, but it is the physicalists' concept that the changes at the lowest level cause all those at the higher levels and that the higher-level processes have no effect on what happens. This certainly does not pass the test for parsimony as for any event in the hierarchy the full initial conditions have to be specified, and this will need a knowledge of the history of the physical part of the structure, which is not known except for the simplest cases. The nature of explanations can also be considered in relation to the structure. If I crush a fly, this might be considered as a purely physical cause, even though it has consequences further up the structure. The events following an explosion caused by a suicide bomber are initially chemical events, but with extensive changes at all the other levels. If we looked for earlier causes various cultural or religious events might be considered, but no progress could be made if a search for causes was made at the purely physical level. If a person takes a drug such as alcohol or heroin then this can be thought of as a chemical and biological cause, but to try to dissect this back into a set of physical causes would seem perverse and, even if it could be successfully achieved, would not further understanding of effects of the drugs on subsequent mental processes. However, it is undoubtedly true that the drugs will also produce changes at the physical. From this, it appears that it is sensible to talk about changes that can occur as the result of something that happens at any level, but that any change, except at the bottom level, will be accompanied by changes that happen at other levels, The levels are generally interconnected, and the operation of a cause can be thought of as occurring at any level, with the choice of level chosen to reflect the parsimony principle.

The structure sketched out above, even if it was elaborated into a more detailed view of the world, should not be thought of as a fixed structure. The parts near the bottom of the stack can be thought of as unchanging; towards the top there is incessant activity and change. New ideas develop individuals come and go, and on geological and astronomical timescales the whole structure looked radically different in the past. At some point there was no biological material and even further back in time few of the important chemical atoms on which we rely for our existence. So that in considering biology, there is a whole history of events that are precursors to the present. These are, and will remain, largely unknown. Any discourse about biological events or causes has to be seen as existing on the back of these unknown developments, the obscurity of which prevents the dissection of biological causes into the physical. Similar considerations apply to higher items in the structure, including mental events. If we want to understand these, we must first appeal to the necessary stages to all their development.

In conclusion, the concept of causal closure of the physical applies only to those physical systems for which the initial conditions can be exactly specified. These systems scarcely exist.

7.5 Intentionality

Thoughts are always about something which can have many other elements in addition to ideas expressed in words. One can be thinking about colours or a person one knows. When the mind is vacant, nothing is being contemplated. Intentionality is about how the events of the mind can be about, or directed towards, things in the world. It was first considered by medieval scholars and was reintroduced in the 19th century by the German psychologist and philosopher Franz Brentano (1838-1917). Mental states such as beliefs, desires, fear, love or hatred are very varied, but they are always about something. I might wish to buy a chicken for dinner, or a new car; or if I am afraid, I am afraid of something, the object of my fear. Rather curiously the object that I am thinking about need not exist. A child might be afraid of the big bad wolf even though there are no wolves about. I may believe that it will rain tomorrow irrespective of the likelihood of rain, or that Sherlock Holmes is a famous detective who lives at 221B Baker Street, London. In all these instances the mind presents something for consideration and intentionality is this aboutness. Brentano, following the scholastics of the middle ages, wrote that mental phenomena are characterised by intentional inexistence, which he thought could also be called reference to a content, direction toward an object, or immanent objectivity. He thought that all mental phenomena included something as an object within itself, and that intentionality is the mark of mental events and that it cannot be exhibited by any physical entity. My other bodily organs or purely physical objects are incapable of having this sort of relationship towards objects. Intentionality, which is quite separate from meaning, has been used as a way to refute physicalism.

One of the great puzzles arising from this idea is the difficulty in understanding how something within the mind can, as it were, reach out towards the world and strike its target. If I think about the planet Mars, how does what is within me allow my thoughts to reach towards that object? My thoughts are directed towards Mars and not any other planet or thing. I am quite sure of this, and the initial thought can stimulate further thoughts about Mars, including the recent pictures taken by the Mars Rover as it crawls across the surface of the red planet. It would seem that there is some sort of connection between Mars and me, and this needs to be explored. It is even more difficult to think about a person's connection to something that does not or has never existed. Intentionality has been regarded by some philosophers as just as difficult to understand as consciousness.

The presence of non-existent intentional objects has given rise to extensive philosophical activity. The sentence 'the present king of France is bald' has a clear meaning and gives some sort of ghostly existence to the king even though there is no king. However, it is neither true nor false, nor is it nonsense. The difficulty arises because the sentence, which makes sense, implies that the king has some sort of existence as otherwise, it would not be possible to talk about him.

In contrast, other sentences abut people who have never lived can be true, such as 'Sherlock Holmes's friend was Dr Watson'.

The question of non-existent objects was taken up by one of Brentano's students, the Austrian philosopher and psychologist Alexius Meinong who introduced a theory of objects which was inspired in part by psychological ideas. He thought that all mental events could have three constituents; the mental act; its psychological content; and the object towards which the event was directed. He used these distinctions as foundations for his philosophy. He has much to say about mental activity and perception but is particularly famous for his division of different objects into those that exist that are actual physical objects in space and time such as apples and pears; subsistent objects that that non-temporal and un-extended; and objects without being or non-existent objects. It is this last category that has given rise to great controversies. Typical examples of these are the golden mountain, the round square and, more recently, a large sphere of uranium. The puzzle is that we can talk to others about these non-existent objects or contemplate them in our minds, but they can never exist in the real world. There is a clear, logical objection to trying to talk about something that does not exist; for example, how can we be certain about any of its properties? There are other examples of non-existent objects that are perhaps less puzzling. Suppose I talk about two pictures that I intend to paint tomorrow, one a landscape and the other a portrait. Both of these are non-existent objects today, but tomorrow they might become actual objects, or, if I change my mind about painting the portrait, only one of them will move into existence with the other left forever in some sort of limbo. To deny the existence in some sense of my initial conception of the pictures would seem perverse as they must spring into some sort of existence at some moment of time as a possible preliminary to their execution, and initially, they exist in Meinong's third sense. Or maybe I could conceive of a new detective to rival Sherlock Holmes.

A particular difficulty is that if no form of existence is allowed for fictional characters, then sentences such as 'Scrooge was famously mean and miserable' can really have no meaning if Scrooge has no sort of existence. This is a considerable difficulty as most of us would agree that the sentence is true, resulting again in the dilemma of having to agree about things that can be correctly stated about a non-existing object. By contrast, the sentence 'Miss X was famously mean and miserable' is meaningless, neither true nor untrue unless Miss X can be named. This could be a person alive, dead, or fictional and would be understood in different ways according to whether or not the person knew the name she was given. If not the new name would be received as a piece of new knowledge to be store for possible future use. For someone to recognise the name, she must have some internal arrangement that is stimulated and brought into her conscious area. The nature and structure of this internal arrangement will perhaps not be very different for fictional characters and those long dead. Julius Caesar is known to us through books, contemporary and later, inscriptions, statues or our school teachers. The Greek god Zeus is known to us in a similar way, and our neural structures that represent these two historical figures must be similar in very many respects, and certainly, their existence as objects for contemplation in my mind must be similar, except for Zeus there is the additional knowledge that he has never existed. The most obvious conclusion must be that existence comes in different forms: objects that are here and now, the departed or destroyed, or fictional, mythical objects. New characters are created by the authors of fiction: lonely children sometimes create an imaginary friend, or we might endow our pet animals with exclusively human attributes.

Meinong's ontological jungle was famously attacked by Bertrand Russell on logical grounds, and this discredited much of Meinong's philosophy until quite recently. Analysis of the sentence 'Pegasus does not exist' leads to a contradiction, arising from the observation that meaningful propositions must be either true or false. One way to escape from this problem is to replace terms such as 'Pegasus' with the phrase 'the winged horse of Greek mythology' and analyse the sentence using Russell's theory of definite descriptions that he put forward in 1905.

There are other ways to look at this problem, that is to account for meaningful and true negative singular existence sentences. One of the objections to Meinong's ontological jungle is the sheer number of inexistent objects that can be introduced, and while this must be true as all fictional or imaginative objects need including, the number is not infinite in the mathematical sense as most of these objects need minds to reside in. In any case, this is not an objection that can have much appeal for philosophers who habitually contemplate infinite sets of integers, possibilia, the number of points on a line, or possible parallel universes.

How can our minds reach out into the world to make a connection between an object in my mind, objects of other minds, and past or present objects in the world? Some of these objects do not need to exist or have any independent reality, and in this way, a stark contrast is made with purely physical objects.

Indirect reference

According to earlier chapters, all these things must be arrangements. For objects that we concede exist or have existed in the world, there must correspond an arrangement that constitutes the object in the world. The fact that we know something about the object also implies that there is a neural arrangement structure within us that corresponds to the object. When we contemplate the object, this arrangement is exercised. For this process to be understood, we must enquire how the neural structure comes about in the first place, as if this structure is not present, we will not recognise the object. The sources of our knowledge are many and various, from direct experience and from instruction from others. This second process is the origin of our difficulties. But before exploring these, we need to realise that when we talk or imagine anything, we are not connecting directly to the world but are contemplating a secondary source. If we refer to a particular object, we refer in the first instance to our neural structures. This is a process of indirect reference, and there can be different connections between the arrangement constituting the source of the indirect reference and either an object in the world or the something in the mind of another. For fictional objects, there is no arrangement, past or present, outside a mind that has ever existed. All talk of them is through indirect reference, and to understand these references, we must understand how they are set up in the first place. This is not difficult as we can usually pinpoint the source of these. My knowledge of Sherlock Holmes comes from reading the stories when ill in bed as a child, and later reinforced by watching films starring Basil Rathbone. I know about Julius Caesar from my Latin master who thought that the Gallic Wars were suitable entertainment for Welsh teenagers. When I refer to these an indirect reference is made to the neural structures set up a long time ago. The processes at work must be similar for all four individuals, but I have known only one of them, my Latin master, directly, and only one of them, Holmes, has never lived. Although the logic surrounding these different individuals is different, it seems that they are treated the same when they appear in my mind as the result of the indirect references that I make to them.

Much of what I think about is an indirect experience built upon my earlier experience, both direct and indirect. Sometimes, for example at a football match a person's mind is fully occupied by the spectacle before her, but this direct experience will be influenced and partially created by the interplay between this and her memories of her earlier life. The whole of our mental life is too complicated to classify it all as mental acts or other simplifications. For it to operate and prosper, we have to have some aspects of the world around us which become incorporated into our neural structures, and become a part of us. The necessity of our surroundings for our minds to function has been clearly demonstrated in experiments that showed the experience of our surroundings was essential to our sense of well-being.

Our minds are arrangements of great complexity that contain arrangements related to many other arrangements in the world, other arrangements, the past, imagined future events and so on. If they could be reduced to arrangements of lesser complexity, it would be a considerable evolutionary advance for the human race, but this shows no sign of happening. Instead, humans develop new concepts, allowing older concepts to be represented in simpler ways. When some part of the brain is damaged by accident or disease, the mind loses some of the arrangements of its neurons, and its functionality is reduced.

It is helpful to remind ourselves of some of the varied arrangements that inhabit our minds and things in the world that interact with them. Some of these are invisible, but the operation of our minds involves the interactions of these arrangements. Their dissection is very difficult and complicated but has been carried out in many respects by armies of researchers in different disciplines. As a further complication, some of these should better be thought of as events as they are changing with time. A partial list must include:

- The most complex arrangement that consists of the object in the world, the mental experiences, memories, and imprints in the mind. This arrangement cannot exist if some part is taken away.
- Experience of the object that then imprints the mind.
- The memory of the object in the world before it was destroyed.
- An arrangement in the world within its finite time frame.
- Mental activity that is only an arrangement in the mind.

- The indirect experience from books and conversations that imprints the mind.
- The creative act that imprints the mind with a new arrangement.
- The neural structure that is the memory or knowledge of an arrangement.
- The indirect experience of an arrangement.

The nature of all these arrangements is not known, but their existence can be inferred from what is known about our nature and capabilities. It may be that we are in any event incapable of properly or fully contemplating some of these arrangements, except through established and pre-determined routes. For example, the arrangement of my mind that allows me to contemplate the appearance of one of our cats can be accessed or called up by naming one of them, but the arrangement that makes this possible is unknown to me and inaccessible to another. The arrangement must be present at all times so that it can be stimulated into my conscious mind when required.

The act of creation of a new fictional character is interesting as a new arrangement, the character, suddenly appears in the author's mind. Except perhaps in the extremes of science fiction, this character will have elements in its arrangement of many other characters and experiences already known by the author but welded together in a new way with additional and maybe unexpected new elements. Some authors have talked about how the characters were made or suggested by a person they had previously known.

There have been many objections to the idea that non-existent objects do indeed have some sort of existence. One objection is based on the dislike of the armies of non-existent people, objects, or things that apparently can be conjured into being. Extending the Venetian floor argument to people and complex arrangements clearly shows that there are unimaginably large numbers of possible people or things, but the number of imaginary objects or people must be very much smaller than this because of the limited size of the human mind. Sticking for the moment to fictional characters, suppose that to characterise one of them, some hundreds of words are needed. Reading these might take several minutes, implying an upper limit to the number of characters one person could create even if this was how she spent every waking hour. In a lifetime, perhaps no more than hundreds of thousands of characters could be created. Although this is a very large number, on the scale of the possible numbers, it is quite small. That most prolific of English 19^{th} century authors, Charles Dickens, managed to create about a thousand original characters. There is, therefore, no reason to reject the idea of Meinong's ontological jungle as its actual members will be quite small in number compared with the numbers of possibilia. It appears that objects that we can talk about can have various different sorts of existence and discussions of existence must recognise but not confuse the distinctions.

A partial resolution of some of these difficulties might be found by venturing outside of philosophy into considerations about the content of our minds and the representation of that content. If I close my eyes in a darkened room, I can summon up all sorts of images of objects both that exist and are imaginary. The zebra and the unicorn might appear together with persons both alive and dead, characters from fiction, and large but not infinite armies of other things with which I am acquainted. A passing knowledge of the neurophysiology of the mind would give strong support to the idea that these objects must be represented in some way by the arrangements of neurons, dendrites, or other structures. This argument must be particularly strong for imaginary objects, leading to two distinct categories of objects for which separate enquiries are needed as to how these came about in my mind and how the structures came about in the first place. If this can be agreed, then my intentional thoughts must be thought of as a multi-step process: an image or representation of the object of my desire must first be established as neurological changes within my brain, and then my subsequent thoughts are a result of contemplating these changes. The connection to anything in the world is then an indirect process, and my current thoughts require that this has happened as a necessary precursor. This also gives scope for contemplating non-existing or fictional characters: first I read about the great detective, his habits, deerstalker hat, and other attributes and, when I later think about him, it is with reference to these and other characteristics that were implanted in my mind at an earlier time. With things that exist or have previously existed, there are additional neurological structures that represent these additional facts. So my intentional thoughts do not reach out to the world, but the thoughts are possible because I have previously collected or been told about the relevant material. Intentional thoughts are a form of indirect reference, and the relationship between the indirect reference and the thing itself is different for the different sorts of intentional thoughts. The indirect thoughts are really quite different from immediate experiences.

Thoughts not about themselves

As everything is an arrangement, thoughts are also arrangements of a direct or indirect nature, so that a direct thought, DT, can have an indirect version, IT. However, if it was possible to have an indirect version of IT called IT2 then it would also be possible to have a further indirect version of IT2 called IT3. This would set up an infinite chain of indirect thoughts and must be impossible for logical reasons. It is further impossible as any finite mind would run out of the necessary resources. The conclusion is that thoughts cannot be about themselves. As mentioned earlier, to imagine the impossibility of thoughts about thoughts, try thinking at the same instant as having a particular thought, and thinking about it at the same time. The attempt just produces confusion. However, I can revisit the same thought later, but this is not a thought about a thought, but a repeat performance of an earlier thought.

7.6 Qualia

Qualia are talked about chiefly in philosophical works and are the phenomenal content of experiences such as colour, sound, pain and other directly experienced sensations. They are often characterised by saying that they are the way certain things are experienced; the blue sky, the colour and taste of a good claret, itches and pains in the neck and elsewhere. We all know and recognise qualia in their many forms, but are hard-pressed to explain to another exactly what they are, or even to be certain if the qualia of others are the same as ours. They have given rise to much philosophical theorising and speculation, and some extreme positions have been occupied. Some have denied their existence and others have suggested that it is possible that zombies can exist that are devoid of qualia. We will try to summarise some of the arguments and consider what, if anything, can be sensibly said about qualia.

The difficulty of saying or characterising colour qualia may be seen by imagining possible difficulties in explaining in English to a non-English speaker what are different words for all the colours. This would be very difficult with the restriction that the explanation cannot be made in what might be regarded as the normal way of pointing to examples of the different colours until the message got across. What is needed is a way of describing each colour without mentioning facts such as 'blood is red' or 'grass is green' or pointing to objects that have the colour of immediate interest such as a yellow flower or a red motor car. This seems impossible and has given rise to much philosophical speculation.

There are further problems lurking in the undergrowth. How can I know that your sensation of redness is the same as mine, or even if you have any experiences at all? Although you might report your experience, there is no way I can be sure that these experiences actually occur in a way that is broadly similar to my experiences. Further, how can I be sure that your colour qualia were not inverted in some way compared with mine so that when a red object appeared my sensation of redness appeared to you as what I would consider as green?

One of the fundamental difficulties of qualia is that we cannot give an account of them to another. We cannot invoke the sensation of redness by saying the word 'red', nor can we give a description of any sort about the content of our red experiences as they appear to me. These together prevent us from formulating theories about the nature of qualia: they are things that we can point to but not things that we can describe. I think it is fair to comment that the issues raised have not been adequately resolved.

There are two directions that might help to understand qualia better. First the idea that all humans are basically similar might stop us worrying about absent or inverted qualia, and second, the speculation that qualia preceded speech might lead to the idea that at least some part of our difficulty is caused by structural inadequacies of our language. The view that there is some abstract object, 'the red qualia', must be resisted. When a person calls something 'red' all they are doing is drawing attention to their experience that the object under contemplation looks the same to them as tomatoes and blood. There is not more to it than that! Neither are they claiming that the object has a property that inheres within the object. The arrangement going under the label of red does not participate in the red arrangement when it is not being observed. It is rather like the supposed jumpy existence of things in Bishop Berkeley's world.

A considerable part of our conceptual confusion arises from our attempts to consider colours in some sort of isolation, as a suitable object for philosophical and logical discussion. Consider what happens when a person, Sandra, sees a yellow flower. For this to happen, several things are essential. The yellow flower must be in her view, and the eye and the active neural processes must be operating. This, in our parlance, is a particular arrangement, albeit of disparate parts. Take away some part of this arrangement, and Sandra no longer has a yellow experience. The flower could be moved, Sandra could be blindfolded, or she could fall asleep. If then later, we try by linguistic means to recreate the yellow sensation some essential parts of the original experience (or arrangement) are lacking and cannot be recreated by any linguistic means. The misunderstanding is that qualia are multi-stage processes with only one part rooted in the mind, and they cannot therefore be reconstructed by purely linguistic means.

For example, in physics, all talk of temperature can take place as a theoretical discussion, but experiences of hot or cold also need hot or cold objects. Take these away, and the sensations depart too, so they are an essential part of the sensations.

Hearing and language have quite different properties from sight in that they can directly reproduce experience to the extent that a particular sequence can be exactly reproduced from one person to the next. In mathematics and logic, the meaning is also reproduced exactly, but outside of these, in everyday life, the meanings of the words do not have identical meanings from person to person, and the indirect experiences can vary widely, nor do they produce direct experiences.

Hearing is very different from sight in that a sound that is heard can be reproduced by speech and the exact form of words can be repeated indefinitely with exactitude. Hence those things of the mind, such as many of the concepts of the exact sciences, that exist without a direct experience element, can be talked about in an objective manner.

In conclusion, language cannot capture direct experience because it cannot reconstruct it, and it can provide only a shadow of the original.

7.7 Synthesis and conclusions

Although I hope this book has managed to dispel some of the difficulties of trying to understand our minds and the incorrect idea that mind and matter are different substances as they are both arrangements. However, there is more to say, chiefly in relation to our capabilities as humans and the limitations of our minds and the language that they use.

Our minds are a giant complex arrangement continually changing in response to the world around it. The mind also changes following its internal activity as it tries to understand itself and the world. Some of this takes place in the unknown processes during sleep. It is part of the world and intimately connected with it.

Some of these arrangements are acquired from the world, and some are acquired from the minds of others. When this latter process happens then literally a part of another's mind becomes part of one's own. This implies that when members of one's family depart to 'the undiscovered country' or a distant land part of them is left behind embedded in our own mind.

Although consciousness is difficult to comprehend, the idea of awareness is less problematic. If A is aware of B then changes in B or the mere presence of B cause changes in A. This seems straightforward and happens all the time as creatures' lives progress from one stage to the next.

This is simple but what happens when B is the same as A? Does it make sense to say that changes in A cause changes in A? This is clearly the start of an infinite regress and makes no sense. If I am conscious of myself, I can also be conscious of consciousness of myself. This ties in with the observation that I cannot think about my thoughts at the present instant although I can think about these thoughts later, but again I cannot set up an infinite regression.

A primary conclusion of the previous chapters is that although we can experience things, we cannot fully describe them or recreate them in the minds of others or subsequently in our own minds. This is a consequence of our construction and of the time sequence of our origins. In the development of our species, mental things came after physical things, and language came after our minds were created. We cannot escape from this, and explanations that ignore these basic facts are doomed to failure. This is a route in for the arts that treat our experiences as something given and on this build a superstructure that cannot be described in simpler terms.

For similar reasons, attempts to create a scientific theory of consciousness are also doomed to failure. There are things in our lives that are outside the scientific vocabulary, and there seems to be no way of including them. Think of the contrast between temperature and heat.

7.8 Speculative epilogue

In an earlier chapter, all ideas about religion, divine revelation and gods were dismissed as self-evident nonsense, with no place in a scientific or rational view of ourselves or the world. However, there do seem to be possible arguments in favour or some parts of these concepts that have been overlooked both by me in the course of writing this book and more generally by those who are interested in the operation of the mind and of human affairs more generally.

My interest in this was stimulated after thinking about the many-worlds interpretation of quantum. Of course, not everyone accepts this view, but if you do, one consequence is that the world is not subject to the probabilistic changes which are an essential part of the Copenhagen interpretation of quantum mechanics. Instead, the world is thought to be continuously splitting but with the other worlds that are branching off are not apparent to us. One consequence is that all possible outcomes of a particular state of affairs occur in one of the universes, although only a single outcome will be experienced by an individual. This idea seems to have the most unfortunate moral implications as there will be both good and evil outcomes, albeit in different universes. If this is so, why should an individual oppose some course of action that she believes will have an evil effect? The evil will occur in some universe anyway so there is apparently little point in trying to oppose it, particularly if the act of opposition comes at some personal cost to the individual. If this argument is accepted all ideas of moral responsibility or free will must be completely rejected. My personal point of view is that the many-worlds interpretation is simply wrong and is born of a confusion between future possibilia which are certainly extremely numerous, and the extravagant multiple universes of the many worlds. This led me to consider some much wider arrangements of the mind including the possible role of religions, gods and moral codes which, although they should not really be part of this book, I have been unable to resist their inclusion as a possible point of departure for further thought. At the start of this book, religious ideas were cursorily dismissed as irrelevant, following on from the Vienna Circle of philosophers who thought that statements that were not empirically verifiable were meaningless. They would include all of religious beliefs and statements in this. However, is it possible to deny the possibility and existence of false gods? It would be tedious to try to catalogue them all, but they are familiar to most of us as exemplified in the relentless pursuit of wealth, fame or the individual's needs at the expense of others. Everyone would understand if someone was said to have lived her life in pursuit of false gods. This would, therefore, seem to be a valid non-controversial concept, comprehensible to all. The difficulty that arises from the point of view followed so far, is that false gods would be categorised as arrangements of human minds, honed over the centuries, for us to contemplate today. However, if false gods can exist properly within a rational framework, then why cannot true gods also exist within the same logical structure. This argument seems to be difficult, if not impossible, to refute. Within our framework, all things are arrangements including both false and true gods, and both of these must be constructions of other arrangements or concepts, but with separate identities of their own. This does not imply that true gods can be identified with those of the world's great religions, but only that there is a possibility that such gods can be constructed and could be defined along the lines of the via negativia so that a god is something that is not a false god. In recent decades a brand of strident atheism has developed intent on destroying the last vestiges of religion in western society, but the arguments in favour of this set of non-beliefs have the disadvantage that they also tend to destroy much of morality. In terms of the Christian religion, it would seem that man has created God in his own image.

The history of some religions supports this idea. The ancient Greeks believed in a considerable array of gods who often were often engaged in earthly activities on a heroic scale. Zeus was their king ruling from Mount Olympus; Hestia was the virgin goddess of chastity, home and hearth; and Pluto was king of the dead and ruled the underworld. Culturally these gods and the myths surrounding them have been of enormous importance in western culture in literature and art as can still be seen in major art galleries around the world. Sadly they are no longer a major part of cultural studies in schools, thereby cutting off generations of schoolchildren from their cultural heritage. The Holy Trinity of the Christian religion also contains recognisably human forms as the Father and the Son who, from the perspective of arrangements, must be seen ultimately as collective human constructions.

Therefore, it seems that true gods can be allowed in our universe, which will have some correspondence as concepts with the gods of religion but without what might be termed the supernatural parts, the concepts of other worlds for the deceased, or the existence of divine revelation. As true gods are constructions, their nature can be modified and changed by the collective activities of all those who are committed to the search for true religion. Also, true gods could transcend existing bodies of belief, retaining and coalescing the compatible parts. This would require the rejection of most parts of existing religions that would then be thought of as some sort of folklore which was a necessary step towards the construction of a true god and historically necessary to explain the nature of gods in an unsophisticated way.

Different ethnic groups have different beliefs which often exclude other ethnic groups, often with great tragedies following from relentless self-interest when the groups decide, supported by their religion, that it is wise to fight and slaughter those with opposing beliefs. Much misery has been generated over millennia by this means and continues today by the pursuit of these unenlightened ideas. It is hard to believe that the concept of a true god would have any role to play in these activities. From our perspective, all religions are arrangements constructed over millennia, and the challenge must be to try to construct a new set of religious beliefs taking our best and most noble concepts to create a new all-inclusive religion that could be adopted by all mankind. The nature of true gods can be in part explored from ethical considerations.

It is impossible not to believe in the existence of evil. Most of us can recall many examples: the murder of children, the wholesale slaughter of the First World War, the unspeakably wicked death camps of the Second World War set up by the German Nazi Party, both in their own country and in Poland; the Russian Gulags; the rape of Nanking; the mass slaughter by Pol Pot & co. in Cambodia, the mass killings of the Tutsis by the Hutus that took place in 1994 in Ruanda. Evil is alive and well. But if evil has a place in this world, there must also be a place for its opposite, the good, and if we could not believe in this, many would have no hope. And in looking for the nature of true gods, the good must be the first contender, and also something that is a part of all religions. Whatever their unfortunate other effects, religions have always tried to improve our behaviour by restraining our selfish, and aggressive traits.

The wickedness and evil of the world are often motivated by hatred of others, and its opposite is love. This is also a part of religious teaching and has a place in a second true god compatible with the good. From these twin pillars a new all-encompassing moral code could be constructed, compatible with the older religions, but lacking their supernatural parts.

It is time that views other than the narrowly philosophic or scientific prevail, and that we accept that the pinnacles of human experience are not to be found in those dry analyses, and that the view from the summit cannot be reconstructed from the desert plains below, although there are high prominences in the lowlands below. Theories of any kind cannot completely encapsulate the true intensity of human experience, and this leaves much space for multifarious linguistic constructions that cannot be properly judged outside their sphere of reference.

A true concept of the good could be our greatest cultural construction and has the potential to embrace all the world's religions, and reconcile the differences of the human races. This is a very wide and important subject that here is mentioned only in passing.

The last word can be reserved for the English poet Percy Bysshe Shelley (1792-1822) in his defence of poetry: 'Poetry is indeed something divine. It is at once the centre and circumference of knowledge; it is that which comprehends all science, and that to which all science must be referred.'

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ABOUT THE AUTHOR

Dr Gill is an Oxford University educated Nuclear Physicist who has had a long research career. He has published widely in his field. In parallel, he has developed his long-standing interest in the difficult issues in consciousness and the philosophy of mind and has presented papers and talks on these topics at international conferences. His book is a product of all these activities.