Chapter 6
Learning and Memory

1. Memory

Even though memory is one of the essential elements of cognition, it was not designated as a separate category of intelligence in the preceding chapter. Memory is not in itself intelligent behaviour. Not only is it neither necessarily complex nor goal oriented, it is, indeed, not behaviour at all. It is a biological process like digestion or respiration. It serves intelligence, but it is not intelligence itself.

Much of the traditional discussion of memory has concentrated on memory of statements or words. There are, however, many other kinds of memory. Indeed, verbal memory is a very small and specialised category. We shall therefore begin our discussion of memory by analysing the different kinds of memory, beginning with the most basic, and dividing them into four categories of *memory of skills*, *historical memory*, *factual memory* and *propositional memory*.

1.1 - Memory of Skills

The most basic kind of memory is that involved in having a *skill*, such as being able to shoot an arrow or tie a shoe. Skills do not require propositions such as “hold your right hand above your left”. No symbolic intelligence is needed to acquire a skill. A person can have a skill without being able to describe how he does it. It is remembered, but not embodied in propositions. In that it is not propositional and not accessible to consciousness, it is similar to an innate ability, like a cat’s ability to hunt mice. It differs, however, in that it is derived from learning, and it is this difference that makes the one memory and the other not. Even though at the time of hunting the cat’s actions are produced from latent ability much as the archer’s actions in shooting the arrow, since the cat’s latent ability was not derived from learning but was innate, it cannot be called memory. If a cat lost its ability to hunt it would not be considered forgetting, although by analogy one might use that word to describe it.

Most skills, however, are not a matter of memory alone, but also of the application of that which is remembered. That application is a kind of concrete intelligence. If a person is skilled at hunting or playing chess, he is not just reproducing a learned behaviour, but applying those remembered techniques to the situation at hand. How much is memory and how much application varies. Riding a bicycle on a flat straight road is mostly memory, unlike riding up and down hills and around curves. Even those skills that are entirely concrete are a combination of memory and application.

There are certain kinds of memory that seem to be propositional and symbolic, but are really just skills. The rote memory involved in learning a poem by heart, for example, is not the same as learning the contents of the poem. Someone who has learnt a poem by heart can’t necessarily tell you what it's about. All he can do is recite it. If, indeed, he also knows what it’s about, that memory is independent of his rote memory of the words. The rote memory consists of being trained in a skill, in this case that of producing certain sounds or words. It is comparable to other skills, but since these are words and have meaning, it resembles a proposition. It is similar to remembering a tune, except that in this case the sound also carries with it certain other knowledge.

1.2 - Historical Memory

After this comes *historical memory*, the ability to remember events, scenes, sounds, or other sensations. This need not be propositional either, in that it need not involve the ability to form a verbal description. It may involve the ability to imagine the scene or object in its absence, as in eidetic memory, or to remember a sequence of events, but even that is not necessary. All that is required in historical memory is recognition, as in knowing a face or voice. This may involve knowing what it is upon seeing or hearing it, or may be no more than the feeling that it is familiar, that one has seen or heard it before. Conversely, it may be the tendency for the scene or some aspect of it to come to mind upon experiencing certain cues or reminders.

This is the kind of memory utilised in *recognition*, as described in the previous chapter. Recognition can be subdivided into several levels. The lowest is the feeling of *familiarity*. Above that is *expectation*, when the experience of a certain event produces the expectation that a certain other event will follow because that sequence has been experienced in the past. Above these is recognition that includes *recall* of an experience. This level requires that one have some sense of his own identity, because he is recognising that this is something that happened to him. Even though he cannot picture it, he knows that this is an experience that he once had.

1.3 - Factual Memory

Next comes *factual memory*, the capacity to remember that something is true. It differs from the last in that the knowledge remembered is of a general truth rather than of a specific incident. This includes the ability to know rules. It may belong to either concrete or abstract intelligence, depending upon whether the rules involved are concrete or abstract. Knowing the trajectory of a ball, not in the sense of knowing the mathematical statement that it travels in a parabola, which is propositional, but just being able to predict where it will fall, is factual memory. Being able to accurately throw it at a target or hit it with a bat, however, is only skill.

The source of the fact may be a combination of reasoning and experience in various degrees. After having been caught in a trap and escaping, a rat avoids not only that trap, but other traps as well. It may also learn how to steal the bait without getting caught. Although factual memory is derived from experience, it does not necessarily involve memory of the incidents themselves, which is historical memory, but only of the conclusion derived from them. The rat might not be able to picture the other traps or even remember having been caught in them (although it probably does) but only that traps mean danger.

For beings such as humans that have propositional intelligence, facts may also be derived from propositions. Even when they are, however, they need not be remembered propositionally, but may be remembered as pictures or in some other non-propositional, non-descriptive way. A person may know that ice is less dense than water from reading or being told about it, but his memory of the fact need not be the statement or even the proposition, but the expectation that when he puts an ice cube into water it will float, or that if he leaves a bottle of water out in the winter it will crack. His memory is the same as that of one who knows it from experience without ever having been told. It is factual memory, not propositional memory. On the other hand, facts that are expressed propositionally need not have been learnt as propositions. When one looks out the window and then says, “It’s raining”, knowledge of the fact was derived from experience, but it was expressed as a proposition.

Like historical memory, the recall of factual memories can be evoked in various ways. It may not be triggered by a cue like “What is the capital of France?” as in propositional memory, but by an experience. Seeing a bird one may know immediately to what species it belongs without being able to explain how he knows. A mechanic repairing a machine looks at a broken part and knows what tool he needs. Even though he may never have encountered a problem exactly like this one before, his memory of the various types of tools and their uses is evoked by looking at the problem and is then utilised by his concrete intelligence to find the appropriate one.

1.4 - Propositional Memory

Only after all of these comes *propositional memory*, which requires symbolic intelligence. In propositional memory, it is not facts but descriptions of facts that are remembered. Here, the situation is the opposite of that just described with respect to factual memory. The information need not have originally been acquired propositionally - it could have been experienced or deduced by reasoning - but it is remembered propositionally. Thus a person may have no recollection of a particular course that he took in university but know that indeed he did, because he sees in the university's records the statement that he once took it. His memory is of the same sort as that of a friend with whom he discussed it shortly after completing the course, when his own historical memory of it was still clear. Neither has any direct historical or factual memory of it, but both have propositional memory that it is a fact.

Propositional memory can accompany other kinds of memory. An incident can be remembered visually, which is historical memory, and at the same time there can be propositional memories about it, such as the date on which it occurred, which is not part of the experience itself and therefore must be propositional. Most experiences are remembered this way, as multiple memories that reinforce one another.

1.5 Narrative

Historical and propositional memory combine to make *narrative* possible. In the most fundamental kind of narrative, a person describes by means of propositions an experience he has had. The ability to comprehend or produce narrative descriptions of things one has actually experienced is the foundation of the ability to hear and comprehend narratives about things outside of one's personal experience. Were he not able to remember and recount his own experiences he would not be able to comprehend and remember those that he hears. Thus these two kinds of memory are essential for the abilities to tell, comprehend and remember stories.

2. The Mechanics of Memory

Memory is an empirical fact. We remember having put something in a particular place, and when we go to retrieve it, Lo, there it is! Our memory was correct! But why? Here, our introspection is misleading. It seems to be a passive experience. Events that occur before us seem to be making impressions on us (which we are taught to believe to be located in our brains) that remain there after the event is over. The apparent answer, that memories are formed by the action of the outside world upon the brain, is as false as Aristotle's theory of motion, that a force is imparted to an object when it is thrown and keeps it moving. Indeed, the underlying errors are similar in that both involve misidentification of the agent. As it is not the thrower's strength that keeps the ball moving, but the ball's own momentum, so too, it is not the external event that creates the memory, but the mind itself. Memory is not a passive experience but an active biological process. An organism remembers because its nervous system is busy responding to things that are going on outside it, and in doing so forms memories of them. It is because it occurs at such a low level, so far removed from consciousness, that it seems passive.

2.1 Passive Models

Traditionally, the illusion that memory is passive led to it being compared to impressions made on a wax tablet. Today it is often compared to a photograph or video recording. All of these are passive. It is the pressure on the wax that causes the impression, and the light hitting the film that causes the chemical change. Neither the wax nor the film are active participants in the process. The source of this illusion is the absence of effort. Since we do not feel that we are striving or working at the time memories are being formed, we are led to believe that we are not performing any kind of activity, not doing anything to record the memory, but rather that the sounds, the light and the other forces of the outside world are acting upon us and leaving marks. It is afterwards, when we recall the incident, that we feel we are the agents. We feel that we are reading the marks that were left on us earlier, reviving the images that were left in our brains. This illusion is especially strong in eidetic memory, which, since it consists only of sight, sound and other sensations without propositional interpretation, seems to be simply little bits of the outside world that have found their way into the mind and got stuck there.

There are also other experiences that contribute to this illusion. One is the apparent inability to control what is remembered and what is not. We may try to commit something to memory, but we are not guaranteed success. We feel, indeed, that we are not the ones that are really doing it. We do not feel that we are in control of it the way we are of the muscles that move our limbs. We feel that we are simply creating the conditions most conducive to the functioning of the memory process, which is done by something other than ourselves. We can only hope that it will work. Conversely, we often find ourselves remembering things that we have no desire to remember, and perhaps would rather forget. It all seems to be happening against our will.

In recalling, on the other hand, we have the feeling of agency, that we are choosing what we want to recall and causing it to reappear in our minds. When occasionally we fail, we do not see it as a contradiction, as an indication that recall is not really under conscious control. It seems, rather like failure at other activities, like trying to lift a weight and finding it too heavy or shooting at a target and missing. Though in these we are certainly in control of our actions, we nonetheless sometimes fail. Nor do we see it as a contradiction that things sometimes pop up from memory without being called for. We think of it rather as an accident, a fluke, comparable to a lucky shot. And since these beliefs are shared by most other members of our culture, they are reinforced by the consensus of opinion.

A corollary of the passive nature of memory formation is that all experiences are stored somewhere in the brain and are therefore potentially retrievable. For if indeed it is the experience itself that impresses itself on the brain, why should one experience do it less than another? Memory must therefore be unselective. Everything that has ever been experienced has been captured and stored.

This illusion, too, finds much support in our experience. The brain certainly does contain a vast accumulation of memories. There are many of which we are aware and which we can recall at will, but occasionally one recalls something that he has not thought of for a very long time and would not otherwise have believed was there. Such recall is generally brought about by some sight or sound, but hypnosis and electric stimulation of certain locations of the brain are also known to produce the feeling of re-experiencing something long forgotten. This gives the impression that all other past experiences are stored there too and could be retrieved similarly. As for our inability to recall them all at will, it is not seen as an indication that they are not there, but is attributed to the weakness of our mechanisms of retrieval. Again, it seems that storage is passive and that our own activity is confined to voluntary recall.

Furthermore, nature is replete with examples of passive storage of impressions. When a burning coal touches the skin, it leaves a mark on the body as it does on a piece of wood. Even without the formation of a scar, which is an active process, it leaves an impression. Why should one doubt that the phenomenon of memory, too, belongs to this category?

But memory is different. It is not only a matter of recording information. The record must be retrievable, and retrieval much be rapid and reliable. Future thought and behaviour must be able to access them when they are needed, which may be in circumstances very different from those in which they were experienced and stored. None of the passive records have this quality. If a leg is injured, the effects on future behaviour are limited to interfering with locomotion. So even though, like bruises, burns and severed limbs, the neurological changes that constitute memory are alterations of the body, they are a special kind of physical change because of the kind of effects they have on future functioning.

Furthermore, even a cursory examination of the brain reveals that comparisons to wax tablets, photographs and tapes are only superficial. Though, like these, the brain preserves a record, the way it does so cannot be the same. There is no mechanism in the brain comparable to a film or tape on which a succession of images could be recorded. Even if there were, such a vast collection of records stored linearly in order of occurrence would make meaningful retrieval virtually impossible. A passive process cannot store meaningfully, since the experiences that are causing the record to be made do not know what significance they have for the being upon which they are impressed. The ability to retrieve meaningfully, rapidly, and in multiple ways, is evidence that there is not only *storage*, but also *cataloguing* and *indexing*. Since these are an intrinsic part of the storage process, that process cannot be passive.

As for the belief that everything a person has experienced has been stored in the brain, that too is an illusion. While it is certainly true that there are many things stored in memory that have never been recalled, there is no basis for the inference that the collection of memories is all-inclusive. Those that are recalled, whether under normal or artificial circumstances, are very few compared to all that have ever been experienced. There is no basis for taking them as representative of a complete record of the past. On the contrary, the overwhelming evidence is that most of the things we have experienced have been completely forgotten. Often a student reviews his notes of a lecture he attended a year before and feels as if he were reading them for the first time. He cannot remember the lecture or even having been there. Occasionally one hears about an experience about which he has no recollection, even though there is no doubt that it actually happened. Even being told about it in detail fails to reawaken memories. There is no basis for the belief that a sound or smell or electric stimulation could revive them either. The few long-forgotten experiences that are recalled prove nothing about the countless ones that are not.

Moreover, not all apparent recollections are genuine memories. Some are, like dreams, simply the product of imagination. In spite of their vividness, they are distortions or even complete fabrications. People sometimes imagine having experienced things that never really occurred, especially when they have been prompted and encouraged by others to recall. Unwittingly, they reconstruct their recollection of past experiences and then become convinced that the fabrication is really a memory. This has been documented in cases of witnesses who, upon being pressed to recall details, reported memories they imagined to be recalling, but which afterwards proved to have been incorrect.

2.2 Computer Analogies

But if not in raw impressions, in what form is information stored? The advent of the digital computer provided many new metaphors for human cognition. The comparison of human cognition to the operation of digital computers follows a long tradition in Western Civilisation of comparing biological processes such as locomotion and digestion to those of machines. Almost as soon as computers became able to produce results similar to those of human beings, the process of borrowing concepts from one to the other began. The moment the store of information in a computer was dubbed “memory”, the stage was set for further comparison. Human memories came to be seen as being stored in the brain like electronic records in a computer memory. But, while such comparisons are more appropriate than earlier ones, they also contain concealed dangers.

Computers are certainly more similar to the brain than are wax tablets. Computer storage, too, is an active process, and records are not only stored but also indexed so that they can be retrieved meaningfully. Here, however, the comparison begins to break down. The structure of the brain is very different from that of a digital computer. The ways neurons are connected to one another and the ways that they function are not like electronic circuits. Storage is also physically different. In a computer, information is stored in specific locations. Storage in the brain is much more complex. The storage of a single piece of information is accomplished by a combination of many neurons in different locations.

One functional difference that is highly significant, in that it indicates fundamentally different kinds of storage, is that information stored in a computer is never vague. Whatever is stored is stored clearly and absolutely. It is either completely there or not there at all. By contrast, information in the brain can be stored in varying degrees. Some things are known perfectly, while others, though not forgotten, are remembered only poorly. One often recognises someone as familiar but cannot remember his name or where he met him. In learning a new word, one may first simply recognise it as familiar, the next time remember something about it, for example, that it has something to do with food, and only after several times remember exactly what it is. A student may not be able to recall anything from a lecture he attended, but when he learns it a second time he grasps it easily. The memories formed the first time were not strong enough to be recalled, but they laid the foundation for later learning. Sometimes the process involves learning the same thing several times, at each of which the memory is strengthened. So too in learning a skill, with practice one becomes more proficient. Partial learning like this does not happen in computers, except in programs that have been intentionally designed to simulate human learning, in which it is accomplished artificially.

The indexing process is not the same either. A computer has specific mechanisms dedicated to indexing information when it is stored and retrieving it when it is needed. Each such mechanism has specific criteria by which it analyses and classifies information, and whatever system was used for storage, the same one must be used for retrieval. If information is stored in propositions written in letters of the alphabet, it can later be retrieved by a word search, but if it is coded by properties, a different method of retrieval is necessary. There is no evidence of comparable storage or indexing systems in the brain.

In particular, the indexing mechanisms of a computer are separate from the memory process itself. They encode the information as it is received, direct it to storage locations and connect it to other information. Some of these mechanisms also retain records of how the indexing has been done which may be referred to later when the information needs to be retrieved. Human beings do something similar when consciously committing something to memory, but not in the normal course of remembering experiences. There is no evidence of such mechanisms on a neurological level. Brain and computer achieve similar results, but in different ways.

We shall continue to use the concepts of *storage*, *maintenance*, and *retrieval* in describing human memory, keeping in mind that they describe only the results of the activity of the brain, not the processes by which it achieves them. *Storage* means that something that has been experienced has had some effect on the brain, *maintenance* means that the effect does not entirely disappear, and *retrieval* means that it contributes to behaviour at some later time. These are useful concepts, so it is worthwhile retaining them as long as they are not misunderstood. In particular, they do not mean that storage of information is localised or that there are specific neurological mechanisms for indexing or retrieval.

2.3 Selectivity

Biological memory also differs from photographs, wax tablets, and computers in that it is *selective*. Since a living being does not remember everything it experiences, there must be some processes by which experiences are filtered and what is to be remembered is selected. And since such a being cannot be continuously paying attention to everything it has stored, there must also be processes by which memories are accessed when appropriate. Since these processes are both complex and goal oriented, they must be considered intelligent. It makes no difference whether the information that is stored has any actual purpose or not. It has been selected in some way, and the act of selection is goal oriented. It is the processes of selection, storage and retrieval that are intelligent, not memory itself. These processes fall in the category of learning described in the preceding chapter.

2.4 Symbols

Another misleading metaphor is the word “symbol”. When human beings want to store information outside their natural memories, they create systems such as writing, notched wood, or knotted strings. These always involve the three steps of storage, maintenance and retrieval, and all but the simplest also involve indexing. The word “symbol” was originally used to describe the elements of such systems, and this continues to be its principal use. In such systems, the use of a symbol is always a *deliberate act*. One thing is being used in place of another. The symbol might be an object, such as a road sign, or an action, such as waving a hand to indicate “come” or “good-bye”. Typically, that use originates in an act of designation, although in many cases it has evolved through informal usage or from some accident by which the symbol became identified with what it symbolised. But whatever its origin, the use of the symbol is always a deliberate act, and it is only by virtue of the intention of the one performing the act to use it symbolically that it is considered a symbol.

This term has been extended, however, to describe the elements of thought and memory, and is sometimes taken to mean that there are actual biological entities by which memories are stored. This is misleading firstly in that it implies that the mental symbol is an actual entity, and secondly that there is within the brain some controlling mechanism that designates and uses those mental entities to stand for things such as objects, actions and qualities that are being thought of. Although it is obvious that there is no “little man” inside the brain performing this task, even seeing it simply as a mechanism leads to an infinite regress, for that mechanism itself would need memory to remember which symbol stood for which thing, so it would require its own mechanism to control it and index its data.

The use of the term “symbol” in describing computers it is less problematic, since computers were designed and constructed by human beings and ultimately rely upon human beings to operate them, so there is no infinite regress. Nonetheless, even an electronic representation is not the deliberate act of a conscious mind.

Since this metaphor is of little value and only creates confusion, we shall avoid it. It appears to solve the problem of how the mind is able to think about things that are outside it, but in fact it explains neither thought nor memory. It just pushes the problem back one step.

3. A Different Approach to Memory

Rather than trying to imagine how human memory works by comparing it to machines and office filing systems, whose structure is radically different from the human brain even when their function is similar, let us take the opposite approach. Let us look at other biological processes, which, although unlike memory in the functions they perform, share certain underlying similarities because they are performed by the same organism.

3.1 Dynamic Storage of Experience

There is a broad category of biological activity to which memory belongs. These are things that cause lasting changes in the organism. Whenever an organism acts, aside from any change it has on its surroundings, the organism is itself changed by its action. A muscle becomes stronger the more it is used. When skin is rubbed, it becomes tougher and calloused. Such internal self-changes are essential for the viability of the organism because action of living cells necessarily depletes them, so without subsequent rebuilding, the organism would wear out and die as a result of its own activity. It is therefore part of the dynamic nature of life that every living being must continually replenish itself. Moreover, much of this reconstruction results not only in maintenance of the current state, but in improvement as well. These are reconstruction processes that are so designed that they build more than was depleted, so the renewed tissue or organ is stronger than the original. This is advantageous for survival, because those tissues and organs that were used and depleted are likely to be the ones that will be used again in the future. Enhanced reconstruction thereby prepares the organism for future activity. This is a kind of growth that differs from the growth that occurs spontaneously during the course of maturation, in which the organism grows according to genetically controlled programmes. In this kind, it grows in response to experience, and through this continual change and modification each individual becomes better adapted to its own specific situation.

Like muscles and skin, nerves undergo processes of deterioration and rebuilding, so they too are changed by their activities. The neural activity of the organism, whether in causing its limbs to move or in being excited by the sensations received by its sense organs, tends to modify the neural structure. Synapses that are activated are reinforced, which results in a kind of memory, because the connection, once made, is more easily made in the future. Practice thereby not only strengthens muscles but develops skills. Repeated exposure to sights, sounds and other sensations makes it easier to recognise them afterwards. Change of this sort is the most fundamental kind of learning and memory. Piaget described this process as the assimilation of new elements into existing schemes, and the corresponding modification of those schemes to include them.

Phenomena such as imagining a scene that is no longer present, for which superficial explanations such as wax impressions are clearly unsatisfactory, can now be understood as biological processes. In viewing the scene, nerves are altered by transmitting and processing sensations of sight and new paths are formed. When these nerves are later stimulated, they respond by activating the new paths, which is experienced as a repetition of the sensation that originally altered them.

Selection of what is to be remembered is a natural outcome of this process. The more the nervous system interacts, the greater the potential of its being altered. The more central are the schemes that are interacting and are therefore being modified, the greater the effect that alteration will tend to have on future thought and behaviour. So even though the storage process does not involve conscious control or direction, it is not arbitrary. Not all things are remembered equally, because the biological processes themselves favour the formation of certain memories over others.

Thus learning and memory are not experience impressing itself on a passive mind, but rather an active mind modifying itself in accordance with experience.

3.2 Complex Memories

This describes only the fundamental process of memory formation. Most learning and memory formation is much more complex, involving various kinds of combinations of existing memories. When a child learns a new word, rarely is it an arbitrary sound forging its own new pathway through his brain. It is connected to the words he already knows. When he learns the word “birdhouse”, it is built on the knowledge he already has of the words “bird” and “house”. Similarly, in learning to operate a new machine, an adult makes use of his knowledge of handles, knobs and the like gained from earlier machines. So, while each of the individual connections is made in this basic way, they are only the mortar that holds together the bricks and beams of memory.

Without such combinations of earlier memories, the burden of learning complex behaviour and cognition would be impossibly great. Even as simple an activity as counting would not be possible if every number had an entirely new name. By the simple strategy of reusing the names of the first ten numbers it is possible to describe arbitrarily large numbers using very little memory.

The components of complex learning include not only facts but also the rules by which they are combined. Thus learning language includes both words and rules of grammar such as adding ‘s’ to the end of a noun to make it plural. There are also conceptual operations such as combining elements into collections or restricting collections and categories. Thus from elementary objects such as “bread” collections such as “food” are formed, and broad general concepts such as “crime” are restricted to form limited ones such as “felony”. Similarly in physical activity, sticks and stones are elementary objects, and throwing and breaking are elementary activities performed with them.

Even this very rough description is sufficient to show that formation, storage and retrieval of memories does not require any separate mechanism to control it, nor does it need to utilise a system of coding that might be considered symbolic.

4. Dynamics of Learning

As we have already emphasised, cognition is an active process, not a passive experience. It always involves activity of the organism. Learning is not an exception, even though the active role of the learner is sometimes overshadowed by the external experience, making it appear passive. When an animal is trained by means of operant conditioning or when a therapist repeatedly moves a child’s hand through certain motions until the child performs them himself, the organism is by no means passive. The muscles are moving and the nerves are carrying impulses, and it is by means of these that the nervous system itself changes and acquires the new behaviour.

4.1 Interrelationships - Learning and Reasoning

In the preceding chapter we described various categories of intelligent behaviour. Most intelligent behaviours fall into more than one of these categories, and since higher categories are dependent upon lower ones, any behaviour belonging to a higher category will necessarily belong to those below it as well. There are also horizontal connections, an important one being between *learning* and *reasoning*. Although not all learning activities involve reasoning, the ones that are most significant for human behaviour do. A student learning to solve equations is not like an animal being trained to perform a trick. For the animal, reasoning is not typically part of the learning process, but for the student the role it plays is central. He doesn’t just memorise the rules and examples his teachers give him. He struggles to apply techniques and to understand concepts, modifies old strategies and creates new ones. Through his activity he develops new skills. So too in learning physical skills, the apprentice does not simply imitate, but reasons concretely to accomplish his task. In this kind of learning, reinforcement by means of reward for correct performance and punishment for mistakes is not the mechanism by which new skills and knowledge become established. Correctly grasping the solution a single time is often sufficient to fix it permanently in memory, while repeated punishments for wrong answers are ineffective if the correct method is not understood. In complex cognitive processes, therefore, reasoning plays a double role, first in current cognitive functioning and second in development of future skills.

For a being capable of this sort of development, every act of reasoning is a potential source of cognitive development. Aside from whatever immediate purpose is achieved by reasoning, there are internal neurological changes, and these will tend to improve future behaviour. Whether this development can be considered learning depends upon whether it is derived from interaction with something outside the nervous system itself. In concrete reasoning, this is often readily apparent. When the dog runs around the fence to chase the rabbit, it also learns the strategy of running around obstacles, in that it will be more prone to use it in similar situations in the future. In abstract reasoning too, though it is not always obvious, the internal reasoning process was begun by an external interaction. When a person has a sudden insight and thereafter gains a certain understanding or becomes capable of a certain behaviour, it is not an entirely internal process. It started with an interaction, often with a problem that needed to be solved. The mental process that eventually produced the solution started then and kept on going for an extended time. Figuring out the solution was only the culmination. By then the original problem may have been forgotten, but it was nonetheless an essential component of the process by which the new behaviour developed. Thus when a student *learns* to play the violin or to solve differential equations, it is not like a dog learning to jump through a hoop or a child learning the names of the countries of Africa. They are different kinds of learning.

In this sort of learning, reasoning and interaction are continually contributing to one another. There is reasoning that proceeds interaction and prepares the mind to absorb new knowledge. A person understands and remembers the answer to a question better if he has already wondered about it and tried to figure it out himself than if he never thought about it before. But in most cases that reasoning was initiated by an earlier interaction that raised the question in his mind. When a student encounters a problem he cannot solve, he begins to think about it, and later, when he hears the explanation, he understands it and remembers it. So too, when a mechanic has trouble repairing an engine, the experience prepares him for the next time he encounters a similar problem. He may then see a way to repair it that did not occur to him the first time, because, whether or not he is aware of it, between the two experiences he was thinking about the problem. Later, he will remember the method he has discovered better than he would had he read it in a manual without ever having experienced it himself.

Thinking about a problem before hearing the answer is superficially similar to declaring a variable before assigning it a value in computer programming. It is as if the mind has already prepared a place to put the information when it is received. But what has happened is not that an empty place has been prepared to store something, but that dynamic patterns of thought have been created which will be able to interact with the new information and assimilate it. That is why, unlike the computer, the mind can also absorb new information without any prior preparation. The mind has many different kinds of schemes and they can assimilate information in many different ways. Students are often taught facts and explanations that are meaningless to them. They memorise formulae and learn to repeat the statements as they might learn to recite series of nonsense syllables. Later, however, when their understanding of the subject has increased and they have schemes into which the information can be assimilated meaningfully, they recall the statements they learned much earlier and derive information from them. Sometimes a person reads the instructions for the operation of a certain machine before getting it, or after he has it but before he knows the vocabulary used in the instructions. He does not understand them, but later, when he gets the machine or learns the meaning of the words, he remembers them and immediately understands what to do.

This can also happen with nonverbal memory. Sometimes all the relevant components of a skill or a cognition are acquired, but for a while no new behaviour or understanding emerges. Only afterwards, when in the course of either active involvement with the physical world or of speaking or thinking without physical involvement, that is, in the course of either concrete or abstract reasoning, they become synthesized, does the new behaviour suddenly appear or is the new deeper understanding attained. This happens when children learn language. They first learn words and phrases but do not grasp grammatical rules, even though they are implicit in the forms they know. After a while, however, they spontaneously begin to produce new utterances that are grammatically correct. This delay between the learning experience and the emergence of the new behaviour superficially resembles delays due to lack of necessary physical maturation, such as that of the child who learns chords but cannot play them because his fingers are not yet long enough. The reasons, however, are entirely different. Such delayed learning is possible because experiences can be assimilated by different kinds of memory in different ways, and because schemes can interact with one another even when the person is not interacting with the outside world.

4.2 Learning and Intelligence

In the preceding chapter, we chose to exclude learning from our definition of intelligence and to consider even behaviours that are entirely innate as intelligent, as long as they were complex and goal-oriented. We chose to define intelligence this way so that the criteria by which a behaviour is deemed intelligent would be qualities of the behaviour itself, independent of its origin. However, while learning is not essential for intelligence, intelligence is severely limited without it. A spider is a marvellously intelligent being in its way. Even though it can learn absolutely nothing and can remember, at most, a few data about its current web, it has the ability to perform very complex behaviour involved in web spinning, capturing and storing prey. But, while the spider's web-spinning ability is no worse for being innate rather than learnt, there is little else the spider can do. Those things with which it was not innately endowed not only can it not do well, it cannot do them at all.

Why is innate intelligence so limited? At first it might seem to be because a brain, even the relatively large brain of a human being, is not large enough to store a sufficient array of intelligent behaviours. But learnt behaviours too must ultimately be stored, and the brain of an adult human contains a vast accumulation of intelligent behaviours that it has acquired during the course of life, so it could hold just as many innate ones. The limitation of innate intelligence is due, rather, to how it is produced in the first place. Every part of a living organism is produced by processes of growth and development, beginning with the division of the fertilised egg. There are in essence only two sources of guidance for that development, the *internal structure* of the organism itself and the *environment*. Innate abilities by definition depend entirely on the former. For an organism to have a particular innate behaviour, the physical internally directed development of the organism must cause the nervous system to develop in such a way that that behaviour be produced. Ultimately, the burden of directing that development falls entirely on the genes, so the amount of specific innate behaviours that can be produced is limited by the amount of genetic coding. To encode a small number of behaviours such as those of an insect is well within the limits of practicality, but not the vast repertoire of a complex animal. That is why learning is necessary. By utilising information from the environment as well, an unlimited variety of behaviour can be produced by minimal genetic coding.

The benefit of learning is not only in scope of intelligent behaviour. Intelligence derived from learning also has the tremendous advantage of flexibility and therefore adaptability. A being whose intelligence is entirely innate and is unable to learn may be perfectly adapted to one situation, but it cannot alter its behaviour if there is even a single small change in the environment. Such a being can only survive as long as its environment remains stable. Lack of flexibility must therefore be offset by other factors. Insects survive even though their intelligence is entirely innate because they have few needs and those needs can be satisfied in wide variety of ways. A fly can eat many kinds of food and lay its eggs on many kinds of surfaces. The loss of one kind of food is not detrimental to it because it can survive just as well on something else. The fly can therefore survive in a wide range of environments without having to adapt.

The more complex life and specific needs of a human being or even of a wolf cannot be satisfied as easily. A wolf cannot eat fruits and grasses. If the prey it has been relying on becomes scarce, it needs to be able to learn to hunt another kind. It needs to learn to escape from new kinds of predators that its ancestors never had to face. Complexity of life-form tends to increase specific environmental needs and therefore narrow the range of acceptable environments. Flexibility of behaviour is needed to broaden it. The two therefore balance each other and maintain the viability of the species.

For the human species, therefore, it is not only advantageous but an absolute necessity that mental development be guided by learning and interaction with the environment. Furthermore, the more powerful the mechanisms of learning and modification of behaviour, the less is the need for innate behaviour. For a species provided with mechanisms of learning like those of human beings, innate intelligence becomes, for the most part, redundant. There is no need to waste genetic coding on innate intelligence that the individual will be able to acquire on its own by learning.