Chapter 7
Cognitive Structures

1. Cognition and Reality

There is an ancient philosophical question concerning the relationship between cognition and reality. Is the world really as it appears to us, or are we simply seeing pictures created by our own minds? Everything we know about the world is derived from our senses. Is the picture they show us reality or illusion? Akin to this question is a scientific one concerning the nature of the brain. To what extent is a human being's knowledge derived from interaction with his environment and to what extent from his biological constitution, that is, from the genetically determined growth of the brain?

The philosophical question of whether by looking at a tree one perceives its true essence is of no practical concern to us. For practical purposes, even if that essence is different from what we see, it is our experience, not the unknown essence, that is reality. The second question, however, is very relevant to our understanding of intelligence and ultimately to our understanding of autism. At first it seems that this question, like the philosophical one, involves the veracity of mental pictures. It seems that if a mental picture is derived from interaction with the external world it will be an accurate representation of it (though perhaps not of its true essence) while if it is innately determined, it might be a complete fabrication that has no relationship to the external reality. If, when we look at a tree, our perception of it as a tree comes from a genetically provided concept of "tree" which we impose upon the sensations we experience, and if, when we see someone reaching for an object, our conclusion that he wants it is derived from a genetically determined concept of wanting, then perhaps neither trees nor desires actually exist. That, however, need not be so. Accuracy and origin are independent of one another. Interpretations might be innate but still be true. Indeed, if a species has evolved to interpret sensations a certain way, then the more consistent those interpretations are with the external reality, the more beneficial and adaptive they will be. So, while the imposition of innate pictures on sensations might not be genuine perception with respect to the individual, it may nonetheless be perception with respect to the species. Though they are not derived from the current interaction of the individual with the world, they are derived from the collective interaction of the species in the past.

On the other hand, interpretations that are derived from experience and reasoning are not always correct. Appearances are sometimes misleading, and reasoning can err. The mechanisms of interpretation might even be flawed in ways so fundamental that they preclude accurate interpretation. Our perception is limited by the strength and quality of our senses. We know that there are some aspects of experience that lie strictly outside our perception. We can look at a tree, but we cannot perceive the light that it reflects at wavelengths above or below a certain range. We cannot see its atoms or sense its weight or moisture. We cannot sense an object's electric charge. We are able to know about these qualities indirectly, but we cannot sense them. There may well be other properties of physical objects of whose existence we remain ignorant just as our ancestors were ignorant of electric charge. We have no words for them and cannot imagine them. Even in those qualities that we are able to sense, we are limited. Our vision is not as sharp as that of an eagle or our smell or hearing as those of a dog. So even if our interpretation of experience is not innately programmed, it may nonetheless be inaccurate.

1.1 Interpretation of Sensations

Let us consider what we do know about the relationship between our mental picture and the external reality that it is supposed to represent. A human being is continually experiencing sensations through his eyes, his ears, his skin and his other sense organs. The brain interprets these sensations and produces

pictures which consciousness considers to represent an external reality, a “world”. The mental act of interpretation, however, is not limited to the highest levels at which pictures are composed and receive significance. Even perceptions of isolated qualities are interpretations. When one hears a sound, smells an odour, sees a spot of colour, feels pressure or heat on his skin, his experience is an interpretation performed by the active brain. Without the brain’s interpretation they are just undifferentiated feelings. Then, beyond interpreting separate sensations, the brain integrates them into coherent wholes. He sees a tree, feels the earth beneath his feet and the sun shining on his face, hears a bird singing, and smells a rose.

We shall therefore rephrase our question to take this universal act of interpretation into account: To what extent are these interpretations derived from the nature of the external reality and to what extent is the brain imposing its own nature on the sensations that it is receiving? Does there really exist a tree, which the brain has succeeded in recognising by correctly interpreting sensory information, or does it innately contain the image of a tree which it imposes upon the sensations that it receives?

1.2 Identifying the Boundaries of Nature and Nurture

It is clear that the truth must lie between the two extremes. Human perception of the world cannot be entirely innately determined, but neither could a human being interpret raw sensations without the appropriate biologically provided mechanisms. The question is therefore one of degree. What part of the picture is derived from interaction with external entities, what part from reasoning (understood in a broad sense), and what part is innately provided?

There are certain aspects of our perception that must necessarily correspond to aspects of reality. That is, certain parts of the images we form could not be completely in error. Consider two objects, one of which surrounds the other on all sides, such as a nut sealed in a glass jar. It is impossible for something outside the jar to get to the nut without passing through the jar. If this is the reality, then we must perceive it as such, because any other perception would be contradicted by experience. If our perception were that the nut was not entirely contained, we might try to get to it without opening the jar and find it impossible. This is a topological reality. It involves a single aspect of reality, that which we refer to by terms such as “in” and “out”. There must be something in reality that corresponds to the “inness” and “outness” of our experience.

Consider another example: If you drop a grain of sand on your foot you may feel nothing at all. If you drop a small pebble you may feel very little. But as you drop larger and larger stones you feel increased sensation and then pain. This pain cannot be an illusion. There must be some reality corresponding to the stone and the foot, because if a large enough stone is dropped the foot will be bruised, and a larger one will break the bones. Stones and mass and feet are physical realities that must eventually be represented in some way in our internal picture of the world. Our picture of the world cannot persist in ignoring these things, because if it does we will find ourselves partially or entirely destroyed, and therefore unable to continue standing or performing other physical activity. The world has a certain structure, and no matter what the biological mechanics of our perception are, the concepts we construct will have to conform in certain ways to that physical reality.

On the other hand, consider colours and musical tones. The physical reality of the difference between red and yellow is quantitative, a matter of wave length, but the difference that we experience is qualitative. No amount of red will make yellow. We do not experience them as we do a one-foot stick and a two-foot stick, or a one-pound weight and a two-pound weight. Similarly, as a string on a violin is tightened the pitch changes. The physical change is quantitative, but we perceive them as qualitatively different pitches rather than quantitatively increasing frequencies. These qualitative differences are

therefore certainly being imposed by the mind, since no qualitative difference exists in reality. There is, furthermore, no question that this interpretation is being performed by innate biological mechanisms.

2. Elements and Structures

In our analysis of the mental act of interpretation we have begun to look at the distinction between *complex* experiences, such as looking at a tree or listening to a melody, which involve multiple interpretations, and *simple* ones like a single colour or pitch. For the simplest sensations, those for which we cannot identify any smaller components, we shall now use the term “elements”. All others we shall refer to as “structures”, because, like physical structures, they are composed of elements arranged in various ways. Similarly, we can analyse actions into the simplest ones, such as contraction of a single muscle, and complex ones such as reaching and grabbing. Cognition, too, can be analysed this way, into elementary concepts and complex ones.

The original meaning of “structure” is a physical entity composed of parts arranged in a certain way, such as a building or a bridge. This is the paradigm from which the concept of a mental structure is derived. A structure is something made of elements whose existence is independent of the structure itself. Elements can exist by themselves or can be arranged in various ways, of which this is only one. For example, sticks can be joined together to form triangles, squares, tetrahedra or complex latices. The properties of a structure are derived in part from those of the elements of which it is composed and in part from the way in which they have been combined. Triangles and tetrahedra made of sticks have rigid stability, due in part to the rigidity of the sticks and in part to their shape. Were they ropes rather than sticks, or were they arranged in squares, the structure would not have that stability.

The concepts of *structure* and *elements* differ from the classical concepts of *form* and *material* in that a structure consists not of the arrangement alone but also of the elements of which it is made. Form and material never exist without one another. Everything in the physical world has both a material of which it is made and a form that the material is currently taking. A rectangular piece of paper has the form, “rectangle” and material, “paper”. Material cannot exist without form, nor can form exist without material. Form and material are therefore *abstract concepts*, not observed phenomena. But unlike material, elements do exist without structure. Bricks exist without a building. Bricks are not just the formless clay of which bricks are made, but clay already made into a rectangular solid. Structure is not an abstraction either. It refers not to the form alone, but to the elements that have been put together in that form. A building is an actual physical entity, not just a blueprint. These are physical concepts, not abstract philosophical ones.

The elements of cognition, while not tangible like bricks, are also actual physical processes. Elementary feelings include the sensations of light, sound, pressure and heat. They also include internal proprioceptive feelings of actions such as sucking or moving the limbs, and affects such as pain and pleasure. Elementary actions include contraction and relaxation of a single muscle. Mental structures are the complex behaviours and thoughts composed of these elements. Walking is a behavioural structure composed of elementary movements of the legs and other parts of the body, and of elementary feelings of motion and of the pressure of the ground. The thought of a tree is a cognitive structure composed of the sensations experienced in seeing, feeling, or otherwise experiencing a tree.

3. The Development of Mental Structures

We have chosen to use the term “structure” to describe complex mental processes not only because there is a similarity between mental and physical structures, but also to indicate that there is an underlying relationship between them. Most mental structures are derived from interaction with the world, and the

structure of the world is among the factors that determine the course of that interaction. Internal mental structures reflect external physical ones, so the similarity between them is not an accident. They are similar because one is the origin of the other.

That is not to say that the structural composition of one corresponds to that of the other. Flowers are composed of stems, leaves and petals, while the mental structure of the concept of a flower is composed of colours, shapes and odours. The mental structure is derived not from the flower itself, but from the interaction of the human being with the flower. Nonetheless, the mental concept of a flower that is eventually formed is bound to conform to the physical one in certain basic ways.

3.1 The Composition of Mental Structures

Like physical structures, mental structures are composed *hierarchically*. Complex structures are composed of simpler ones. The components of complex mental structures therefore include not only elementary units but also other structures. They differ from most physical structures, however, in that previously formed structures are not only *components* of new structures, but also the *tools* with which the new ones are made. Mental structures such as reasoning skills and ways of learning, in particular, are important tools in the formation of new mental structures. This follows from the very nature of cognitive structures. They are not static physical objects but thought processes and behaviours, which are dynamic. In this way they are more like machines than buildings. A drill press can be used to make parts for other tools and even for a new drill press. Mental structures can therefore be described as *self-generating*, in that they include the tools of their own construction.

Mental structures and elements are not intended to be descriptions of the brain or even of the physiological processes by which the brain works. They are, rather, descriptions of certain kinds of activities, certain things that human beings do when they think and when they are active in the world. They are *functional* entities, not *physiological* ones. They are descriptions of what the nervous system *does*, not what it *is*. Their development, too, is functional, not physical, although it is accomplished physically. And, like a physical structure, a mental structure can be analysed in more than one way. A building can be divided into bricks, beams, pipes and electrical wiring but it can also be divided into kitchen, dining room and bedrooms.

3.2 Origins of the Mental Structures

Some mental structures are present at birth. The visual field, for instance, is already structured to some extent, in that adjacent spots are experienced as being somehow related to one another. This and various other basic elements are produced by the genetically determined structure of the brain. These, however, are only a small minority. Most arise in the course of mental development. They are formed through the organism’s own activity, especially through its interaction with the environment. In the course of that interaction, behaviour is moulded by the structures of the external world, and cognition is moulded by behaviour. In the first step, the infant interacts with physical objects in his environment that have various properties, and develops behaviours corresponding to those properties. In the second step, he develops concepts such as causality and object permanence, that correspond to those behaviours.

The capacity to be moulded in these ways is an extremely important quality of the human nervous system, without which human intelligence would not be possible. In particular, the endless range of human thoughts is ultimately derived from the moulding of basic concepts. Some proponents of nativism deny this process, claiming instead that basic concepts are innate, and that even those that are not present at birth are innately programmed to emerge later in the course of maturation. They maintain that the familiar processes of learning and discovery, in which an individual arrives at an idea after having certain

experiences, are illusions, and that all experience does is awaken innate ideas that were latent within him. The variety of concepts and behaviours among different cultures and among groups living under different physical and social conditions, however, is clear evidence of developmental rather than innate origin. In each situation, they develop appropriate concepts and words to talk about them. Above all, the existence of behaviours and concepts that address situations outside the natural human repertoire cannot be attributed to emergence of innate intelligence. Behaviours such as riding a bicycle or typing on a keyboard, and concepts such as those of atoms and of microscopic organisms, could not have been genetically produced.

While the capacity of the individual to produce new concepts that are neither innate nor derived from combinations of earlier ones makes innate cognitive elements unnecessary, it does not contradict their existence. It is certainly beneficial for an individual to start off with certain innate behaviours and cognitions. The evidence indicates, however, that even of those behaviours and cognitions that are universal and that appear during early childhood, most are products of development.

The formation of cognitive structures from behavioural ones belongs to the category of abstract reasoning. All human beings except for those who are very severely mentally impaired have the ability to form such structures, although there is much individual variation in this ability. Nor is it restricted to human beings. In that they are able to learn language, apes show that they too can form concepts such as “similar” and “different”, “now” and “later”.

The ability to form cognitive structures is almost certainly present at birth. The sort of mental activity that will later produce thoughts and concepts is already being performed by the infant. But the infant is so lacking in even the most fundamental cognitive structures that underlie all adult thinking that the structures it forms do not resemble the kind of thought with which we are familiar. So radically different is it that it is difficult for us to even imagine what it is like. Nonetheless, the infant already has the tendency to be mentally active in this way in response to the sensations it experiences and behaviour that it performs.

Since by its very nature this activity is internal and cannot be observed, we can only hypothesise its existence. Soon, however, the infant begins to perform behaviours that imply derivation from mental structures. Among the first observable signs that the infant has developed some kind of internal cognitive structure corresponding to the outside world is when it begins to exhibit surprise, for surprise indicates that it has expectations that have not been fulfilled. Over the next months, more and more of its activity is guided by underlying cognitive structures. As the infant gains linguistic ability, he becomes able to tell us about his inner thoughts, at first by revealing them through his utterances, and later by expressing them directly. By analysing the observable part of this process we can extrapolate about the pre-verbal period. Whether or not we can imagine the cognitive structures that were formed during those first few months, we can have no doubt of their existence.

3.3 Formation and Differentiation of New Structures

In the course of cognitive development, existing structures are continually being modified and new ones formed. When a new structure is formed, it is at first just a combination of ones that existed before. After a while, however, if an activity is repeated often enough, it becomes independent. Its components join together and the new structure becomes separated from the original ones, at the same time becoming modified to serve the specific new purpose. A boy who likes to climb trees has certain general tree-climbing skills. They include various ways of placing his feet on the branches and of grabbing branches and pulling himself up. But if he climbs a certain tree many times, he develops a specific pattern for climbing it which involves a sequence of moves suited to the positions of the branches of that particular tree. He can now scramble up it very quickly. The new specific structure no longer needs to use the

general tree-climbing structures. The more frequently a task is performed, the greater the tendency to develop a specific structure to perform it, and the more times it is performed, the better that specific structure becomes. Only those tasks that are performed infrequently continue to be performed by general mechanisms.

The result of this process of structure formation is a sort of modularism, but very different from nativist modularism. Many of the new structures are indeed domain-specific, not because they are derived from innate modules, but because they have developed to serve a certain purpose and have become differentiated. It also differs in that in this sort of domain-specificity, the domain of a structure is not limited permanently. Under the right conditions it can expand and become generalised. So even a structure that is at first domain-specific can later develop and contribute to the development of new structures in other areas.

3.4 Horizontal Décalage

With this understanding of the development of structures, we can explain the phenomenon of “horizontal décalage”. It has been found that even after an individual has acquired an ability in one area, he may not be able to use it in another. A child may be able to use a certain kind of reasoning socially, when the question involves people, but not in purely physical situations, as when it involves inanimate objects. Thus he can correctly answer the question, “If Jim is taller than Pete and Bill is shorter than Pete, who is the tallest?” but not the question, “If the red stick is longer than the blue stick, and the yellow stick is shorter than the blue stick, which is the longest?” Proponents of modularism have taken this to indicate that the ability to reason in this way is performed by innate mechanisms which are domain-specific, and that the mechanism by which it is performed in the social domain emerges before the one that performs it in the physical one. We can now see how this phenomenon can be explained developmentally, and indeed that according to the developmental explanation such separation can be expected. It occurs first in the earliest stages, when the new ability is still being performed by a combination of older structures. If it has been constructed to solve a specific problem in a specific area, it may be using structures that relate uniquely to that area, so it is dependent on them and can only function in the area in which they are found. If, for instance, it involves picturing the faces of actual people and imagining them standing next to one another, it will not be possible with objects that don’t have faces. In the next stage, in which the pattern of comparing one person to another has become established as an independent mechanism and no longer requires imagining their faces, it has still not become generalised to all objects and all qualities. It is a specific form of reasoning about human beings. Now, however, it can more easily be modified to apply to other areas.

When a mechanism is new, the connections within it are not yet strong, so even a slight modification of a single aspect of the task can interfere with its operation. Once it has become sufficiently solid with respect to the specific task for which it was originally developed, however, and that task can be performed without hesitation, it becomes possible to extend it to increasingly dissimilar variations of the task. It is now done with ease and little effort, so the mind is now free to add new complications. When a child is able to reason easily about human beings, he can begin to apply those same kinds of reasoning to sticks and finally to completely generalise them. Sometimes the same sort of reasoning develops independently in two different areas, and later they are combined to make a single new one that applies universally.

The developmental process therefore moves in two opposite directions. One direction is towards generalisation. Existing structures are expanded to form new ones that can serve broader applications. In most cases, the new more general structures are more complex than the original ones. At the same time there is a process of differentiation, in which new specialised structures evolve from existing general

ones, as when abilities are fine-tuned to serve specific purposes. The new structures are often, but not always, less complex than those from which they evolved.

3.5 The Evolution of Complex Behaviours and Concepts

Since all of cognitive development is interconnected, and structures from different areas are continually contributing to one another, examples of simple progression of concepts or abilities are rare. The most easily observed are in the artificial situation of intentional instruction. In the acquisition of mathematics, the student first learns to count, then uses the skill of counting to learn arithmetic, with which he is then able to learn algebra, and with algebra calculus. Within each, new skills are at first dependent upon earlier ones, and then become independent. When the student first learns to multiply he thinks about it as addition, but gradually he thinks less and less about addition and it becomes a separate operation. In learning to read, he first learns letters, then words, and then phrases and sentences. Even these examples are oversimplifications. In most schools, children are already taught sentences while they are still learning to read words, and some children learn to recognise a few words before they have learnt the whole alphabet. Those cognitive structures that are neither taught nor learnt consciously, such as the early acquisition of concepts of the physical world studied by Piaget, are even more difficult to analyse.

Nonetheless, whether observable or not, there is always a cumulative process within which there are certain steps that must necessarily precede others. The infant cannot learn about *family* until he has acquired some concept of *human being*. It may be only a very rough one, far from the mature concept of a living cognisant organism, but until he recognises them as somehow different from other parts of his experience such as blankets and bottles he cannot begin to see certain of them as belonging together and being separate from other ones. From family he develops the concepts of simple interpersonal relationships such as *father*, *mother*, *sister*, *brother*, and from them the more advanced ones of *friend*, *enemy*, *cooperation*, *conflict*, *authority*, *responsibility*, *law*, *society*, and *morality*.

As more complex structures are constructed, the simpler ones become modified too. Thus the concept of a human being changes through the acquisition of the concepts of family and of responsibility. In some cases the original concepts are discarded as they are replaced by more appropriate ones. Thus to a small child the concept of “father” is absolute. There is one person in the world who is “father”. Later it becomes a concept relative to the family. Each family has a different father. Still, it is only relative to the family, not to the individual. The father of the family is not only the father of the children, but also of the mother and of the grandparents. Finally these are replaced by the concept of individual relationships, and the child understands that a person can be a father to his children while being a husband to his wife, a brother to his sister and a son to his own father. Cognitive development is therefore a complex dynamic process in which structures are continually modifying one another.

3.51 Direction of Development: Specific to General

The initial flow is from the *specific* to the *general*. The infant learns about Fido, the family dog, before he learns the concept of “dog”. He learns about dogs, cats, cows and horses before he learns the concept of “animal”, and only from animals, birds and fish does he acquire the concept of “life”. He learns to recognise his own mother and father before developing a concept of a human being, although the concepts of “father” and “mother” as distinct and special people cannot be acquired until after he has come to realise that human beings are all somehow the same sort of thing. Thus during his first months he interacts with his father, his mother, and other individuals as separate parts of experience. After a while, the sounds, smells, sight and feel of each converge into the sort of mental structures that we call theories, so he constructs “Theory of Mother” and “Theory of Father”. After that, the similarity between “Theory of

Father" and "Theory of Mother" as compared to "Theory of Blanket" and "Theory of Doll" lead to the formation of "Theory of Human Being". The development of rules and behaviours proceeds in a similar way. A child first learns how to conjugate specific verbs, then, after learning several that share the same form, generalises rules of regular verbs.

The development of language is separate from that of concepts, although they are constantly influencing one another. A child may learn the word "dog" very early, but understand it as referring only to a single dog. Later, he learns that it can be used for other dogs as well. When he does, he may not at first correctly identify the boundaries of its use. He may overextend it to refer to all animals, and only later learn to restrict it to dogs alone. Learning the word may be instrumental in developing the concept. He may not be aware of the basic similarity between all dogs until he begins to use the word. (After all, dogs are very different from one another.) In other cases, the concept is acquired before the word. An infant recognises his mother and father long before he begins to learn language. By the time he begins to attach meaning to the vocalisations he hears around him, he has already learnt to distinguish between people and inanimate objects, thus he also has some concept of a human being. A word for human being, however, is generally not acquired until much later. Before he learns the word "person" he has generally learnt "boy", "girl", "baby" and many individual names. Thus word-knowledge and concept-knowledge contribute to one another in various ways.

3.52 Direction of Development: Familiar to Unfamiliar

Another characteristic of the progression of development is that it goes from the *familiar* to the *unfamiliar*. A new behaviour or concept is learnt first in familiar contexts and later extended to unfamiliar ones. The behaviour learnt in familiar contexts becomes a guide to understanding the unfamiliar things themselves. When a child first learns to read, he reads words he already knows and things he already knows about. He does not increase his vocabulary or world-knowledge through his reading. Once the skill of reading has been established, however, it becomes a tool for learning.

A familiar context makes it easier to learn new skills. The familiar parts of the context provide hints that help him understand the new parts. That is what happens when one learns the meaning of an unfamiliar word from the other words in the sentence and from the situation in which it is being used. The mental structure corresponding to the familiar context becomes modified to include the new part. Even when the context does not provide any help, it makes it easier because there is less to learn. It is easier to learn to drive on familiar streets than in a strange neighbourhood. The familiar context makes it easier to focus on the parts that need to be learnt.

3.53 Order of Acquisition: Restriction and Flexibility

Complex structures, both physical and mental, are generally built in steps, first combining a few elements to form a simple structure, then a few simple structures to form a complex one, and so on to increasing complexity. It is rarely possible to form a complex structure directly. A house cannot be built until the bricks are made and hardened, and a book cannot be printed until there is paper and ink.

The order of construction need not, however, be unique. Especially in cognitive development, there may be more than one path to arrive at a particular structure, as there may be more than one sequence of moves to arrive at a particular position in chess, or routes to travel from one town to another. A music student can learn to play by ear first and later learn to read notes, or he can learn to read music from the start. He can begin by learning to play in only a single key and later learn others, or can begin by learning a variety of keys. In this way, mental structures tend to differ from physical ones. The components of a mental structure are not physical parts that are put together. So, while it is valuable to

compare mental structures to physical ones, it is important to remember that they are not really the same and that there are significant differences between them.

4. The Role of Structures in Perception and Learning

When a person interacts with the external world, his experience consists of the structures into which he assimilates it. Whatever he interacts with, he interprets according to those cognitive structures that he already has. Though there may be many other ways to interpret it, if he lacks the appropriate structures, those ways are essentially impossible for him. Consider, for example, the experiences of listeners of different backgrounds when hearing the well known fable of La Fontaine, *La Cigale et la Fourmi*:

La Cigale, ayant chanté
    Tout l'été,
Se trouva fort dépourvue
Quand la bise fut venue:
Pas un seul petit morceau
De mouche ou de vermisseau.
Elle alla crier famine
Chez la Fourmi sa voisine,
La priant de lui prêter
Quelque grain pour subsister
Jusqu'à la saison nouvelle.
"Je vous paierai, lui dit-elle,
Avant l'oût, foi d'animal,
Intérêt et principal."
La Fourmi n'est pas prêteuse:
C'est là son moindre défaut.
"Que faisiez-vous au temps chaud?
Dit-elle a cette emprunteuse.
- Nuit et jour à tout venant
Je chantois, ne vous déplaise.
- Vous chantiez? j'en suis fort aise:
Eh bien! dansez maintenant."

To an infant who has not yet begun to learn language, this is just sound. Perhaps at first it is not even that, but only undifferentiated sensation. A little later, after he has begun to pay attention to the sounds he hears around him, he is able to recognise rhythms and patterns. Even though it doesn't yet have any meaning for him, it is not chaotic. It has form. The experience of an adult who is familiar with language and poetry but does not know French is similar. He can tell it is a poem and can recognise the rhythm and the patterns of sounds, but not the meaning. Although, unlike the infant, he knows it has some meaning, that meaning is not part of his experience.

For a person who has studied French grammar but is not familiar with the vocabulary, a great deal more is accessible than just these patterns. He may be able to recognise nouns and verbs and can tell much of the structure of the sentences, still without any idea of the meaning. All these people have experienced the poem as a structure of one kind or another, according to the cognitive structures that they already possess. Into these they have incorporated the new elements, the sounds of the words.

But now consider a person who is fluent in French but is a native of a tropical region in which there is an abundance of food in all seasons. He appreciates the poetry and, since he is familiar with insects including ants and something akin to cicadas, also understands the sentences, but he cannot understand the story or its moral. He does not understand why the cicada wants to borrow food and that without it she will soon die of starvation. He does not understand the significance of the north wind as a sign of cold weather, or that in cold climates there is no food in the field during the winter. Even if he has studied geography and understands these things theoretically, if he has never actually experienced shortage and want he may still not appreciate the need to prepare for the future during times of plenty. It is just a curious story, but he does not appreciate the moral.

But now consider someone who lives in the arctic, who is also fluent in French but has never seen an ant or a cicada. He understands in a vague theoretical way, perhaps with the help of a commentary, what the story is about, and the moral is very meaningful to him, but he cannot really picture what is happening. It is about some sort of animals, one of whom likes to sing and the other of whom has lots of food, presumably because she worked hard to store it up when it was available.

Each of these listeners has experienced the fable differently. Each has created new cognitive structures in accordance with those structures that he had already. They differ with respect to the language, the story, and the lesson learnt from it, which has nothing to do with animals at all but with human behaviour. The differences between them are qualitative. It is not just a matter of one appreciating it more than another or understanding it better. They are fundamentally different.

5. The Dynamic Nature of Cognitive Structures

Complex experiences such as this clearly require active participation. In hearing and comprehending a poem, the listener cannot be passive. The words cannot simply be impressing themselves on him. It is also clear that each listener experiences them differently, and that the differences are direct results of the current state of his own mind, which is, in turn, the result of a combination of innate factors and of past experiences.

But while the mind cannot be passive, neither is it free to impose its own structures without bounds, since external reality has its own structure to which mental structures must conform. Each of the listeners described above certainly possessed structures other than those by which they interpreted the poem. They did not impose them on this particular experience because they did not fit. The variety of individual experiences of a single aspect of the world attests to its structural richness. It is the multiple coexisting structures of reality that make it possible to experience it in so many different ways. The structures that the mind forms when experiencing the world are therefore limited on the one hand by the current structure of the mind itself and on the other by the structure of the world that it is experiencing.

Having a structure is not, however, a guarantee that it will be applied. A person might have several structures that are amenable to interpreting a particular experience, yet interpret it only according to one of them. Indeed, he might fail to interpret it according to any of them. Failing to make the connection, the interaction remains meaningless for him. When this happens, it is generally because the structures he has are weak and poorly established, or because there are few connections between them and other structures, so they are “overlooked”. If a connection is pointed out to him later, he realises and says, “Oh, I didn’t think of that!” Applying mental structures is an active process, not an automatic one.

5.1 Cognitive Development as a Process of Structure-building

The formation of mental structures is a cumulative process in that new structures are formed by combining and modifying existing ones. Such a process is possible because the underlying structures of

the world in which a human being lives and with which he interacts do not change. The mental structures that he formed in the past therefore tend to be consistent with his current interactions, since they were formed in the course of earlier interactions with the same world. They also tend to be consistent with one another, since the world in which they were formed is itself internally consistent. They are therefore amenable to combination and synthesis to form new mental structures corresponding to new situations.

But there are also many incidental aspects of the world that are not consistent with one another, and the mental structures that are formed by interaction with them may eventually be contradicted. An individual who has always lived in a place where it rains only in the winter finds the mental structure that he has developed contradicted when he comes to a place where it rains in all seasons. His mental structures are then modified to accommodate the new experience. Through this process mental structures become increasingly accurate. Some mental structures are made completely in error, as by faulty reasoning or by misinterpretation of experience. These tend to subsequently be contradicted, which weakens and eventually eliminates them. The process of structure-building is therefore not only one of growth but also of refinement, so the body of mental structures is continually being made more consistent with the unchanging structure of the world.

New structures can also be produced without external interaction. When one ponders a question and comes up with an answer, or proves a theorem in mathematics, when one dreams, when one imagines new things, new structures are being formed. The mind is continually active, and that activity involves the alteration of existing structures and the creation of new ones.

5.2 Memory as Structure-building

Understanding memories as structures that are formed through this process has several highly significant implications. The first is that *not all experiences produce memories*. Those parts of the world that do not fit into any existing mental structure are not experienced meaningfully. When the organism interacts with them, no mental structures are altered, so there is no lasting change in the organism. When one hears a lecture on a difficult and unfamiliar topic or in a foreign language, or watches teams play a game whose rules he does not know, he remembers little or nothing of it. The only interaction is on a superficial physical level, so cognitive and behavioural structures are not affected.

Another situation in which no memories are formed is when experiences, on the contrary, are so similar to earlier ones that existing structures process them without being altered. Few people have memories of every time they ate their breakfast, greeted their neighbour, or parked their car. Repetition of a familiar experience or action does not affect the mental structures involved. At most it may reinforce them, but even that is not significant if they are strong already.

Even those experiences that do produce memories are not remembered in their entirety. Memories are limited to those aspects of the world for which there are applicable mental structures. Memory is therefore not all-or-nothing. An experience can be remembered in certain ways but not in others. And since even potentially applicable mental structures are not always actually applied, their presence is not a guarantee that memories will be formed.

The second implication is that *memories are not permanent*. They may be altered and even destroyed. Such modification of the memory of a skill or a fact is very advantageous. The skill becomes more refined over time, and the fact becomes more detailed and more clearly understood. The musician retains historical memory of his early clumsiness, but when he plays now, his fingers move skilfully. The earlier behaviour patterns have been replaced and no longer exist. So too, the scientist remembers his current understanding of a phenomenon, and although he generally does remember how he understood it five years ago, he may have completely forgotten the erroneous theories he maintained thirty or forty years earlier.

With respect to historical memory, though, this can be detrimental. Structures that have been formed may later be changed so that the memory of the event or fact becomes distorted. If a room that was previously yellow is then painted blue, a person who was there before and after it was painted may remember it as always having been blue, even though before he saw it repainted he remembered that it was yellow.

The very existence of narrative historical memory is now seen as all the more marvellous. It is much easier to understand the memory of a skill, in which a certain behaviour pattern has become fixed in the mind and available upon demand. To be able to preserve structures of events and protect them from continual revision and radical alteration is a much greater feat!

6. The Universe of Knowledge

At any moment, an individual has a certain *universe of knowledge*. Within that universe there is a *core of knowledge* that is well understood and well remembered. The structures in it are interconnected in many ways, which makes it strong, firm, and resistant to change. Because of the many connections, it is also readily available to be used in multiple ways toward the formation of new structures and the interpretation of new sensations.

Surrounding the core are structures that are less extensively connected, embodying knowledge that is less thoroughly understood and not as accessible. He may require a crutch to remember or use them, like one who can play a piece only when the music is in front of him. There are certain facts that he does not know clearly, but of which he has a vague idea. He may know that a certain word is the name of a tool, but not know exactly what it looks like of what it does. He has only some of the necessary structures, and can function only as long as the environment provides the parts that he is missing. But as those structures are used they are expanded by the addition of new elements, and the internal connections of the structure, the connections between the elements, become stronger. New connections are also formed between these and other structures, and existing intra-structural connections are strengthened. Structures of this sort, if they are sufficiently strengthened, eventually become part of the core, so the core is continually expanding.

Beyond that is the *frontier of knowledge*, consisting of things that are known and understood only poorly. These are weak and incomplete structures. Beyond that is the vast realm of the unknown. New information and ideas from beyond the frontier can be dealt with as long as they can be connected to some existing structure. They then join the structures of the frontier, extending it slightly and also strengthening those existing structures to which they have been connected. But when an individual encounters something that is far removed from the frontier of his knowledge, requiring structures that he does not have, he cannot understand it at all. There is nothing to which it can be connected, so there is no meaningful experience and no new structures are formed. Thus when a person who does not know French hears La Fontaine’s fable, he understands nothing, and the only structures he has to which he can connect it are those of sounds. That is therefore all that he can remember of it. So too, when a person ignorant of physics hears Einstein’s theory, he does not understand the world any better. All he learns is a meaningless combination of letters. But for one who has the necessary structures, they are experienced as new structures that extend the old ones, and that experience is an increase in knowledge and an extension of the frontier itself. In this way the person who is learning and cognitively developing is continually extending his body of knowledge and thus its frontier.

7. Scaffolds

Sometimes existing structures contribute to the formation of a new one whose nature is radically different from their own. In such cases, we shall refer to the existing structure as a *scaffold*, by analogy to the wooden scaffold that serves as a mould for the construction of a stone arch. Mould and arch differ not only in their materials and other incidental aspects, but even in the essential aspect of shape. The mould fills the space of the arch, the stones surround it. Nonetheless, the one serves as a guide for the formation of the other. In a similar way, cognitive structures can serve as scaffolds for one another. Memorisation of verbal formulae such as rules, which may not even be understood at the time they are memorised, later serve as guides for practice, which then leads to acquisition of skill. After that, not only the verbal formulae but even the rules contained in them become unnecessary and can be discarded, as the wooden frame is removed after the arch is completed.

Cognitive development by means of scaffolds is an essentially different process from the usual one in which new structures are derived from those that preceded them. It is not simply growth and improvement, as when a child becomes increasingly skilled at eating with knife and fork or at doing sums. Nor is it even like differentiation, in which a single general structure, such as drawing lines, gives rise to several new specific ones, such as forming the various letters of the alphabet. Here, the nature of the structure that develops is different from that of those from which it was derived.

A child who is learning to read thinks about the sound of each letter and puts them together to make a word. He reads by using the rule of the sounds of the letters. Afterwards he develops the ability to read without the rule. He reads the words as units, without using the individual sounds. However, the scaffold is not completely discarded. Though it is no longer used for familiar words, it is retained for later use in reading new ones.

Sometimes the scaffold itself is so faint that it is not noticed, like the all-but-invisible scratches on the window pane that determine how the ice-flowers grow. In other cases, even though the scaffold itself is clearly visible, the relationship between it and the cognitive skill it helps produce is not recognised because they are so different from one another. Sudden appearance of a new behaviour or cognition whose source is not known is one of the phenomena that give rise to the illusion of innate origin.

7.1 The Role of Scaffolds in Cognitive Development

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Scaffolds play an important role in cognitive development. Indeed, certain new structures are difficult or even impossible to form without some kind of external support, so in these areas a scaffold is essential. It is the bridge that is needed to cross the chasm. Increasing abstraction, in particular, generally requires the use of scaffolds.

Earlier, we explained how abstract concepts could be attained without being innately provided, that is, without being hard-wired. Our rough description there was one of formation by means of scaffolds. In developing concepts of the world, the physical structure of the world itself serves as a scaffold for the construction of concrete cognitive structures, which in turn serve as scaffolds for abstract ones. The mental structures form around the structures of the elements of the environment as the arch forms around the wooden mould. Sometimes the initial mental structures are completely behavioural. For instance, by interacting behaviourally with objects, picking them up and moving them in various ways, a child learns that he must exert more effort to lift some than others, and develops the concept of weight. The behavioural structures serve as a scaffold for the cognitive one. In other cases, interaction with the physical world involves not only behaviour but also concrete reasoning. The cognitive structure involved in this concrete reasoning then serves as a scaffold for a structure of abstract reasoning. A child first learns to count on his fingers, and by practising becomes able to count without any external support. When he is older, he goes through a similar process in learning more advanced mathematics. First he does problems

on paper (which is, in fact, partially concrete reasoning even though it is rarely thought of as such), and later becomes able to solve them without writing anything down.

For the older child and adult, it is more often cognitive structures themselves that serve as scaffolds for others that are essentially different and generally more abstract. This begins to happen very early, as soon as a few cognitive structures derived from behaviour have been formed. The evolution of the concept of "father" described above is a good example. Here, the concept of relationships between individuals, which the infant completely lacks, develops through successive cognitive steps, from the concept of "father" as an absolute, to "father" as relative to the family, to "father" as a relationship between two individuals. Each contributes to the formation of the next. To have made the jump directly to this concept would have been impossible. Only by moving up one step at a time is the child able to achieve it.

Scaffolds are therefore essential for human cognitive development. There are many aspects of human cognition that could not be attained without them. But although scaffolds are very powerful, their power is not unlimited. A scaffold can raise cognition up a certain amount, but not indefinitely. If the new cognition is too far above what the student has already mastered, even a scaffold cannot enable him to reach it.

7.2 Training and Education

One of the most important kinds of scaffolding in human development is *training*. Training involves two distinct kinds of scaffolds. First, the knowledge and ability of the teacher serve as a scaffold for that of the student. Second, the student is taught superficial structures such as memorised formulae, which are designed to then serve as scaffolds for the development of the deeper and more complex structures that are the goal of instruction. The novice is taught how to perform certain skills. He may or may not be taught the reasons for what he is being trained to do or the principles behind it. Indeed, they may be essentially beyond his grasp. When a child learns to speak he is not yet able to understand the rules of grammar, but training in grammatically correct usage enables him to practise until he has formed the deeper mental structures.

8. Multiple Mechanisms

Most goals can be attained in more than one way. It may be possible to get from one place to another by foot, bicycle, car, train, boat or plane. In nature too, we find the same purpose served by various means. Some organisms are supported by endoskeletons, some by exoskeletons; some move themselves with their legs, some, like snakes, use the muscles of their bodies to move. The same is true of cognitive mechanisms. There may be several mechanisms that can accomplish the same task. Mathematical proofs and calculations, for example, can be done in various ways. Many of the problems that we solve today using symbols and equations were solved by the ancient Greeks by means of geometric constructions. They achieved the same results, but the structures by which they reasoned were very different.

Each mode has certain advantages and certain disadvantages. In a given situation, therefore, one may be more suitable than another. Sometimes, however, the optimal one is not available, so it is necessary to use a different one. Languages that are written phonetically can be read either by the sounds of the individual letters or by entire words. The former is not as efficient, but has the advantage of broader application. The proficient reader uses word-recognition most of the time, but when he encounters an unfamiliar word he reverts to reading phonetically.

Alternate mechanisms, both physical and cognitive, can also sometimes serve as scaffolds for one another. Horse-drawn wagons served as a scaffold for development of trains and cars. A person who is

able to read can use reading as a scaffold for memorisation. The actor relies on his script until he knows his lines.

8.1 Habits

When an individual has become accustomed to behaving a certain way, it becomes difficult to change. The activity has become connected to certain mental structures, and when he wants to perform it, those structures immediately become active. The same is true of patterns of thought and ways of interpreting experience. He may have other structures that could perform it as well or better, but once a mental pattern has been established, the others do not become activated. If he tries to do it a different way, the strong connection to the habitual structures activates them and he needs to exert effort both to suppress the habitual ones and activate the new ones. It is even harder if he has never developed alternate structures and needs to learn them. The learning process itself is more difficult, because the entrenched structures interfere with the development of new ones. When a person is trying to learn something new, every time he tries, no matter how poorly he does, the structures are activated and thereby strengthened and improved. But when he tries to learn a new way to do an old task, the old structures make it hard for him to practise new ones.

Breaking cognitive and emotional habits is harder than breaking behavioural ones. Behaviour is external, visible, and, at least in principle, controllable. Conscious control and external assistance can be used to force an alternate behaviour until it has been practised enough to become established. Internal mental activity is much more difficult to change. There are fewer avenues of control, and since cognitive patterns are less apparent than behavioural ones, they are harder to identify and analyse.

One of the areas in which this is most apparent is the influence of language on thought. A person’s thought and behaviour become moulded around the structure of his language. Least significant, though perhaps most obvious, is the influence on the way he uses sounds, the accent that his first language has permanently imprinted on his tongue. That, however, is purely behavioural. More important is the way that language guides him in classifying the elements of his experience. What qualities he sees in them and what relationships he sees between them are to a large degree reflections of how they are treated by his language. Once a person has learnt one language, he thinks of the world in terms of that language and expresses ideas the way that language does.

All of this makes it harder to learn a new language. He needs to learn not only new words but also new ways of looking at the world. Often he does not even know what they are and how they are different from those he is currently using. That is why it is easier to learn a second language when one is young. The younger one is when one learns a new language, the fewer and less established are the connections with the cognitive structures used by his first language. It is also easier for someone who already knows more than one language to learn others. His thought has not become bound to a single linguistic structure, so it is more flexible. Even those ways in which the new language is different from any he already knows are easier for him to learn. In general, the more structures one has into which new cognitions can be assimilated, the more flexible he is and the easier it is for him to learn.

Multiple structures need not be explicitly recognised to be effective, because they do not require conscious activation. However, conscious recognition is advantageous because it gives one some control over which structures are applied. Without it, the one that is strongest and has been used the most often in the past will tend to be applied, even when there is another that is more appropriate.

8.2 Automatic Mechanisms

Most human behaviour is performed without conscious thought. Of the mental activity involved in walking, talking, typing and driving cars, only a very small part is performed consciously. Walking requires maintaining balance and coordination of one leg with the other. Language requires remembering the right words, applying the appropriate grammatical form, and producing the correct sounds. These are all complex processes, and a human being would not be able to direct his attention to all their components at once. It is only by means of mechanisms that function without conscious control that human life is possible.

Such mechanisms are generally referred to as “automatic”. That does not mean that they happen by themselves. They are all active functions of the nervous system and are controlled and coordinated by other neurological mechanisms, all for specific purposes. It is only with respect to the conscious mind that they are automatic. With respect to the totality of the mind they are active mental processes like any others.

Few of these mechanisms are innate. The human species was obviously not provided with specific mechanisms for reading, writing or riding bicycles. They are acquired by the individual in the course of his development. The process by which they are acquired is a familiar one that is repeated countless times in the life of every individual. It begins with conscious mental mechanisms that are constructed gradually and often painfully. The mechanism by which a cyclist automatically keeps his balance is preceded by a collection of rules, some explicit, some unstated, but all performed consciously, about such things as when and how to lean and to turn the handlebar. The music student begins by thinking of the scale, the relation of notes, and how to produce them on his instrument. In each case, the new activity is at first performed by previously acquired skills that are combined and modified for the new purpose. But as they are practised, they gradually become easier and require less and less attention, until they are being performed without any conscious thought at all. The musician becomes able to play without paying attention to the rules, and the cyclist can maintain his balance without effort. A new and different sort of cognitive mechanism has developed.

Thus conscious mechanisms serve as scaffolds in the formation of automatic ones. The inefficient but effective conscious mechanism performs the task until an appropriate automatic mechanism has been constructed. This construction of new automatic mechanisms from conscious ones is itself a natural biological process of the human species. It occurs whenever a procedure is performed frequently enough to warrant the construction of a specific automatic mechanism. For skills that are not needed as often, however, no such mechanism is formed. They continue to be performed consciously and never become automatic.

9. Mind and World

Mental development is a process of aligning the human being with his environment. Above all, it is the construction of patterns of behaviour that are beneficial in the specific environment in which he lives. However, since for the human being, behaviour depends upon cognition in many fundamental ways, his cognition, too, must correctly reflect the state of the world around him. To the extent that individuals or cultures have incorrect ideas about the world, such as superstitions and erroneous scientific theories, their behaviour is not optimally beneficial and sometimes even self-destructive. The various ways described here by which the formation of mental structures is guided by the structures of the world with which the individual interacts, are therefore mechanisms that further his survival. Indeed, our own rejection of the nativist-modularist doctrine of innate concepts is ultimately derived from its inconsistency with this universal process.