CHAPTER 13

THE ORIGIN OF LANGUAGE

It is impossible to imagine our society without language. The society we live in, day and night, depends on it. Even as we sleep, information about us is being stored, and maybe processed. Imagine that we apply for a job on the other side of the world. We are confident, or at least we hope, that our application will be fairly treated, and that the country to which we would like to move is running properly; that is, that social contracts are observed. Our lives depend on the social division of labour, and on detailed social contracts, which could not exist without language. No ape or dolphin could comprehend, even in spoken form, a contract for a job.

During the past two decades, the conviction has grown that language has a strong genetic component. In some sense, our language capacity must be innate; we can talk and apes cannot, and the reason is that we are genetically different. Yet there are two ways in which language might be innate. We may be just generally more intelligent than apes, and the ability to talk is just a by-product of this fact. Or, and this seems more and more likely, there is a specific 'language organ' in our brain, analogous to a 'language chip' in a computer; this organ is to some degree hard-wired, in that some of its neural connections are set correctly without external stimuli.

It is Noam Chomsky and his school who have contributed most to the linguistic revolution, which has led to three major insights:

1. For each natural language—such as Hungarian or English—there is a finite set of rules. By applying these rules, one can generate all possible grammatical sentences in that language. This list of rules is called a generative grammar.
2. Children, irrespective of their genetic origin, are able to learn any human language. To a lesser degree this holds for adults as well, provided they have already learnt their mother tongue. Thus there is a general ability to cope with any particular generative grammar, which is called 'universal grammar'.
3. Universal grammar has a strong innate component.

If there is such an innate language organ, it is natural for biologists to ask how it evolved. The difficulties in answering this question are formidable. Perhaps the main difficulty, which is also a source of excitement, is the uniqueness of our language capacity in the living world. Development is relatively easy to study, because *Drosophila* and mice also develop, whereas not even apes have language in our sense. Our immediate predecessors, such as *Homo erectus* and Neanderthals, are extinct, and language does not fossilize. Things would be easier if our ancestors had started to write as soon as they could talk, but writing is a late invention. In his recent book *The language instinct* (1994), Steven Pinker aptly likened the evolution of language to that of the elephant's trunk—a complex adaptation, unique to elephants, which does not fossilize; yet few scientists doubt that the trunk evolved by natural selection. With language, many people still have doubts, though they are unable to suggest any sensible alternative.

The human condition: brain mechanisms

It has been known for a long time that injuries to particular regions of the brain may cause specific impairments to language (Fig. 13.1). Patients with severe language disorders are called aphasics: the two main types are Wernicke's and Broca's aphasics. The latter have severe difficulties with grammar, whereas Wernicke's aphasics, sometimes called fluent aphasics, produce grammatical sentences with little meaning.

Some of the phenomena associated with injuries of the brain are not only dis-

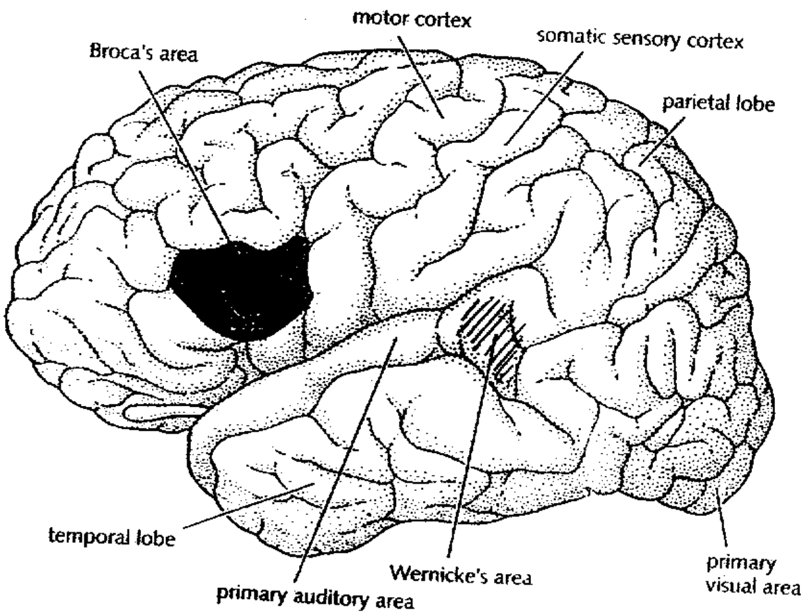

Figure 13.1 The location of the Broca and Wernicke areas in the human brain, known to be important in linguistic processing.

tressing, but at first sight paradoxical. For example, it is entirely possible for a patient to complain: 'I see the object, I know what it is, but I cannot name it'. It turns out that the formation of a concept, retrieval of the word associated with it, and establishing a link between word and concept, are localized in distinct parts of the brain. Further localizations have been discovered. Some regions of the brain seem to store verbs, other regions store nouns, and there even seems to be a neurological difference between handling nouns referring to animate and inanimate objects.

These observations are consistent with the innateness of the language organ, but they do not prove it. Imagine one starts with a network of interconnected neurones, capable of 'learning' (by strengthening the connection between two neurones if they are active simultaneously, and weakening the connections if they are not), but without any localization. It has been shown by computer simulation that, as such a network learns, some parts will, by sheer accident, become associated with particular tasks. If one adds to this model the fact that particular sensory inputs (hearing, seeing, etc.) are localized, as are particular outputs (for example, speaking), then not only will functions within the net become localized, but the same localizations will appear in different nets, or, by analogy, in the brains of different individuals.

Thus localization in the brain suggests, but does not prove, innateness. There is a second, related problem: how does the brain learn to follow grammatical rules? How, for example, do we store the rule for forming the past tense of a verb (add *-ed*)? There are two extreme possibilities. One is that rules govern everything: not only the typical case, verb + *ed*, but also *ey* → *oo* as in *take, shake, forsake,* and *i* → *a* as in *sing, ring, spring.* The alternative is that every case must be learnt as a separate item, just as the meanings of words must be learnt. Pinker (among others) suggested a fruitful reconciliation of these two extreme views. There may be a rule for the regular verbs, whereas irregular verbs are individually memorized, as 'dictionary items'. This would explain how verbs with the same stem can have different past tense forms; for example, *ring/rang* the bell versus *ring/ringed* the city.

The idea that separate brain processes are involved in forming the past tense of regular and irregular verbs is supported by the study of patients with neurological disorders. The work depends on the notion of 'priming'. It is found that the speed with which a person can recognize the word *goose* is greater if they are first primed with the word *swan*. This is what one would expect if the words are stored close to one another, or, more generally, if there is some link between the storage of one and of the other. On both the 'everything is rules' view, and the 'everything is learnt' view, we would expect that *walked* should prime *walk*, and that *found* should prime *find*: after all, there is a connection between the members of a pair, whether it is rule-governed or learnt. But W. Marslen Wilson, and

Loraine Tyler observed patients in whom *found* primed *find*, and *swan* primed *goose*, but *walked* failed to prime *walk*. In another patient, they found the exact opposite: *walked* primed *walk* but *swan* failed to prime *goose* and *found* failed to prime *find*. These patients had damage in different brain areas. This correlates well with the earlier finding that patients with agrammatic aphasia (who find composing sentences difficult) have more trouble inflecting novel regular verbs than irregulars, whereas anomic aphasiacs (who find retrieving words difficult) have more trouble with irregular verbs.

What all this suggests is that the ability to form the past tense of irregular verbs depends on the same mechanism as learning the meanings of words (each case must be learnt as a dictionary item), and is different from the ability to form the past tense of regular verbs (a rule has been learnt).This by itself says little about innateness, but at least reveals that language rules do have a manifestation in specific areas of the brain.

We have spent a lot of time on what may seem a trivial question—how do we form the past tense of verbs? But the research does show how a combination of neurological and psychological studies is beginning to reveal how the language organ works, and also how hard it is to discover in what sense it is innate.

Language acquisition

A key question is whether we learn language simply by 'trial and error', as the behaviourists would have liked us to believe, or whether there is some instinctive 'knowledge' hard-wired into the human brain, which has a genetic basis. Interestingly, the latter idea is not entirely new: it emerged in the seventeenth century in 'philosophical grammar', but was forgotten after the rise of Romanticism. Clearly, language does not develop in full deprivation of 'linguistic input': if nobody talks to you, you won't learn to talk. There have been some remarkable cases in history suggesting that there is a 'critical period', ending about puberty, when the window for learning a mother tongue closes. If you miss your chance to learn it during the critical period, you will never be able to master any natural language properly. A sad but well-documented case is that of Genie, a girl whose father kept her locked away for many years. Although later she was taught to speak, she never got beyond the level of broken, rather ungrammatical English. So linguistic input seems an absolute necessity. But input necessary for normal development is not a valid argument against a considerable degree of innatism, as can be illustrated by analogy with the development of vision.

The visual system—the eye, the optic nerve, and the associated brain regions—is an extremely sophisticated complex of organs. No one doubts that it is an evolved adaptation, increasing the fitness of the organism equipped with

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The visual system—the eye, the optic nerve, and the associated brain regions—is an extremely sophisticated complex of organs. No one doubts that it is an evolved adaptation, increasing the fitness of the organism equipped with it. It is largely innate: mutations are known affecting different components, from colour vision to anatomical details. First, by analogy with language, we can ask two questions. What happens to the visual system if there is no input early in development? Second, if all its components are needed if it is to work properly (a lens is no use without a retina), how could it ever have evolved? The answers are now known and pleasing; we discuss them in turn.

Young cats, when blindfolded, do not develop proper vision. If one removes the cover from the kitten's eye before 8 weeks, normal development resumes, but if this happens later, impairment is guaranteed for life. Thus there is a critical period during which the visual system must receive external stimuli for its development. The neuroanatomy of this system is comparatively well known. It turns out that synaptic connections between neurones develop in response to stimuli, and are eliminated in their absence. Thus in cats there is an innate vision acquisition device (VAD), which, given appropriate visual input, produces proper vision, useful for the organism. The capacity to develop vision requires a specifically pre-wired part of the brain: other parts cannot serve as substitutes. Presumably, setting up a proper visual system is such a difficult task that it is more readily achieved if the stimuli themselves are used as cues in the process. By analogy, acquisition of language requires linguistic input, but it may also depend on pre-wired parts of the brain. A system, visual or linguistic, can depend on suitable input early in life, and also depend on genetically determined brain structures.

Turning to the second question, the evolutionary origin of the eye has fascinated generations of biologists and non-biologists. William Paley used it in his natural theology as part of the argument from design. Whereas biologists accept that there is a lot of good 'engineering' in the eye, the engineer was, to borrow Richard Dawkins's successful metaphor, surely blind: it was evolution by natural selection of heritable variations. A dramatic demonstration of this principle was given by Dan Nilsson and Susan Pelger. They have shown that a smooth evolutionary pathway spans the space between a simple group of light-sensitive cells, as found today in some simple invertebrates, and a 'perfect' camera eye, similar to those of humans and cephalopods. The whole 'journey' through the sequence of intermediate structures can be taken (assuming moderate heritability, weak selection, and small genetic variation for the traits in question) in about 400 000 generations. A rudimentary eye, even if remote from our marvellous organ (or that of an octopus, which, curiously enough, looks very similar) in its complexity, is much better, from an adaptationist point of view, than none at all, if the animal needs to see. It is especially lucky that eyes of intermediate levels of complexity still exist in animals: reconstruction of the evolutionary history of the eye is an easy task compared with that of the 'language organ': language not only does not fossilize, but there are no living intermediate forms either. Evolutionists insist, however, that such intermediates must have existed.

Thus three conclusions emerge from the eye story: (1) it is easier to inherit a 'vision acquisition device' than a full-blown hard-wired visual analyser; (2) the visual analyser, once 'set up', is refractory to radical restructuring—hence the existence of a critical period in its development in cats; (3) the eye seems to have evolved in steps from a light-sensitive, innervated cell to our complex organ by common evolutionary mechanisms.

Something similar may have been taking place in evolution of the language organ, and may be occurring during individual development. An argument, put forward forcefully by Noam Chomsky and his followers, refers to the 'poverty of stimulus'. Most permutations of word order and grammatical items in a sentence leads to incomprehensible gibberish. There is no way that children could learn without some internal 'guide' which sentence is grammatical and which is not, only on the basis of heard examples. To make matters worse, many parents do not correct their children's grammatical mistakes (they seem to be much more worried about the utterance of four-letter words). Recent investigations clearly confirm that children's 'instinctive' understanding of grammatical intricacies, between the ages 2 and 4, is far better than one would expect from a conventional learning mechanism. Thus there seems to be a 'language acquisition device' (LAD) in the brain, which must be triggered by linguistic input so that its working ultimately leads to proper language. It is the LAD, and *not a fully developed linguistic processor,* which seems to be innate.

Tuning the language organ

So far so good. But why is it that children have to learn their language for many years, and why, despite admirable progress, do they continue to make grammatical mistakes during this period? Why are people without 'linguistic input' unable to master language properly as adults? Why do we have to learn grammar at all—why is it not all hard-wired? Why are there so many languages, not only in terms of vocabulary but also in terms of their generative grammar? Why is universal grammar insufficient by itself? We will attempt answers to these questions, and also to the question of whether the language instinct could have arisen by the conventional evolutionary processes of mutation and selection.

Perhaps the easiest of these questions to answer is why our vocabulary is learnt rather than innate. If words were innate, cultural evolution could not be faster than genetic evolution: linguistic innovations, such as the word *screwdriver,* would have to be genetically assimilated before they could be used. We need a grammar whereby any type of statement can be made, but the actual contents of each statement should be cultural rather than genetic.

The reason why there are many different natural languages, which have to be learnt in a critical period of development, seems to depend on two considerations: language must be learnt as soon as possible, and learning a language is easiest, and perhaps only possible at all, using the LAD (language acquisition device) method. The maintenance of the latter is presumably costly in time, because it requires that synapses be left plastic and options be left open.

Different generative grammars—for example, Hungarian and English grammar—are alternative modes of operation of the same language organ. This raises the question, are some grammars easier to learn than others, because the language organ develops some neuronal configurations easier than others? We do not know, but the work of Derek Bickerton on pidgin and creole languages suggests that the answer may be 'yes'. Pidgin is a means of communication that emerges when adults with no common language come in contact, as happened frequently in communities of 'wage slavery' in various former colonies.

We discuss pidgin in more detail below; for the present it is sufficient to say that it is a limited means of communication without grammar. Creole languages emerge when children grow up in such communities, where the main linguistic input is pidgin. Such Creole languages are proper languages, with a fully developed grammar. The startling claim is that the emerging grammars, although there is variation, are very similar in different communities, even if they are several thousand kilometres apart; one example is that the 'double negative' is usually grammatical in Creoles. One could still argue that in these cases the parents did speak proper languages, and that their influence was decisive in the emergence of the new Creole grammar. Since then, however, an independent line of evidence has shown that groups of children can evolve a language with a proper grammar, even when the only outside linguistic input is pidgin-like. Groups of deaf children learning sign languages under the influence of parents who can sign only at a pidgin level go far beyond the grammatical level of their parents, developing a sign language with a sophisticated grammar, even if there is no adult proficient in sign language to talk to. Creole languages are illuminating in two respects. They illustrate the linguistic creativity of communities of children, and, by their common features, they provide hints as to what particular generative grammar emerges most readily, given our common universal grammar.

What is really innate, or the nature of universal grammar

A widely accepted idea is that, in every language, sentences are built by combining noun and verb phrases in an appropriate way. This is explained in more detail in Fig. 13.2; English readers can get a more immediate appreciation of the idea by reciting the nursery rhyme, 'This is the house that Jack built'. The

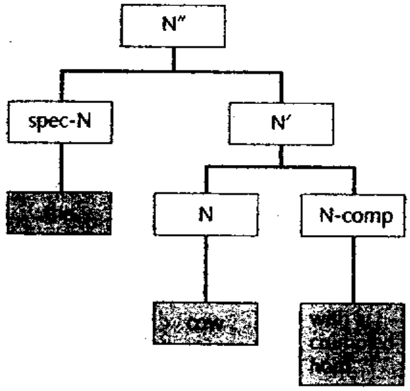

Figure 13.2 The structure of a noun phrase. N (*cow*) is the head of the phrase, and must be a single word. It is first linked to its complement (*with a crumpled horn*) via the node N', and N' is then linked to the specifier (*the*) via the node N", representing the full phrase. Although the head, N, must be a single word, the complement may itself be a phrase, as it is in this example. Thus phrases are like Chinese boxes, stacked inside one another.

actual rules in the generative grammar for a particular language can sound rather complicated. To give but one example: we know that the question

How do you know who he saw?

is grammatically correct, whereas the question

Who do you know how he saw?

is incorrect. Although most people with a moderate command of English can see this, not even highly literate native English speakers could explain why this is so, unless they happen to be linguists. The explanation is given in terms of null elements. The second question should be written *Who do you know how he saw —?*, where — marks the place from which the object of *saw*, now replaced by *who*, has been moved. But, according to linguists, there is a constraint on movement, asserting that a *wh-* word cannot be moved across a space occupied by *how*.

This constraint is subtle one, but linguists argue that the assumption of null elements is the simplest way to explain this and many related phenomena of grammaticality. They may be right, but we cannot be sure that there is no simpler rule to account for the facts. Or perhaps evolution chose a more complicated system for historical reasons; if so, the rule we are really following would be more complex than that suggested by linguists. In any case, it is intriguing that, when talking, we obey without effort a rule of which we are not conscious.

A new initiative in linguistics, favoured by Chomsky himself, is the so-called minimalist programme, which has the aim of formulating the simplest possible rules specifying how words should be combined to form grammatical sentences. We cannot go into details, but, following Robert Berwick, we will try to give a flavour of this approach by drawing an analogy with the laws of chemistry. This may seem an odd thing to do: after all, most people know less of chemistry than they do of language. Yet the laws of chemistry are rather well understood, whereas the nature of universal grammar is still largely a mystery.

First, there is a reason why we might expect such an analogy to help. In chemistry, a small number of kinds of atoms—hydrogen, oxygen, iron, and so on—can combine to form an immense number of different compounds, yet by no means all arrangements of atoms form stable compounds. In the same way, a small number of kinds of words—nouns, verbs, adverbs, and so on—can combine to form an immense number of sentences, yet not all combinations are grammatical. So there may be an analogy, and, as any reader of this book will have discovered by now, we are great believers in the power of analogies to generate useful ideas.

Chemistry is a powerful and sophisticated branch of science, largely opaque, as it happens, to one of the authors of this book. Yet the rules governing how atoms combine can be simply explained. The first is the concept of valence. Each kind of atom can be visualized as having a number of attachment points, from one to four, by which it can be linked to other atoms to form a molecule. The number of these attachments is known as its valence. For example, hydrogen (H) has valence 1 and oxygen (O) has valence 2. Hence one can form a molecule of water by linking one oxygen to two hydrogen atoms, to give H–O–H, or H_2O, but one could not link two oxygens to one hydrogen, to give O–H–O. Of course, there is more to it than this, but it remains true that simple rules of combination are obeyed. A second rule one might call the 'subassembly' rule. Once a molecule has been formed, it can behave as a unit, linking to other molecules according to rules similar to those that govern the linking of atoms to form molecules. For example, once nucleotides have been formed, they can be linked end to end to form a more complex molecule, DNA: when this is done, precisely one molecule of water is removed from each link.

The possible analogy with language should now be clear. There are rules that govern how words can be linked to form sentences. Further, phrase-structure grammar (Fig. 13.2) implies that a single word can be replaced in a sentence by a group of words: thus *cow* can be replaced by *cow with a crumpled horn*. The idea, then, is that words have a property analogous to valence, enabling them to combine only with words that match. There is an operation, *merge*, analogous to chemical reaction, that combines words into sentences. If *merge* is impaired, one has ungrammatical aphasia. If there is a problem with word features, analogous to valences, we have feature-blind grammar, which is described in the next section.

In this analogy, there is a difference between language and chemistry in the way in which meaning emerges. There is a difference in the meanings of *The dog bit the postman* and *The horse ate the grass*, although they have identical grammatical structure. In any language there are many nouns, whose meanings have to be learnt, but the rules governing their combination—their valencies—are the same.

The short answer to the question at the head of this section is that we do not know the nature of universal grammar. We cannot discover it simply by introspection. Will we ever know the answer? As biologists, we suspect that, in the long run, the most powerful tool for discovering the answer may be genetics.

Genetics

If our language faculty has an innate component, then there should be genetic variation for this trait. As we all know from our school years, there is a marked quantitative variation of linguistic skills in the human population, both in our mother tongue as well as in foreign languages. How much of this observed variation is genetic is not known, and would be hard to test. Qualitative variation, leading to some well-defined impairment of grammar, should more readily analysable. For this to be so, however, the impairment should be specific to language. It is easy to imagine that linguistic impairment would be associated with, and partly caused by, other deficiencies, such as a diminished IQ or deafness. We need to find cases in which these associated impairments occur without the language deficit; and, conversely, the language deficit should not always be accompanied by these complications. This is called a double dissociation.

Although such variation must have been around for tens of thousands of years, the first clear evidence of genetic involvement was published by Myrna Gopnik only a few years ago. The case concerned an English-speaking family exhibiting a strange type of language problem (dysphasia): they have problems with grammatical features such as past tense and plurals. Let us quote a few sample sentences:

She remembered when she hurts herself the other day.
Carol is cry in the church.
On Saturday I went to nanny house with nanny and Carol.

The problem is obvious: regular grammatical features, such as *-ing*, are missing. Note that the irregular verb, *went*, is used correctly, because the affected individual had to, and could, learn it as a special case, just like everyone else. Some members of the family have trouble in completing simple tests such as the following. An individual is shown a picture of a strange animal, and told that it is a *wug;* shown a picture of several such animals, and asked what they are, the individual cannot find the answer, *wugs.*

It seems that what the affected individuals cannot do is to learn general rules about how the form of a word must be changed to express present/past, or singular/plural, or possession (*nannie's* rather than *nanny*). Thus they can learn as a dictionary item that, for example, the past of *watch* is *watched,* but cannot generalize to other verbs; they do not then know that the past of *wash* is *washed.* The family pedigree (Fig. 13.3) shows that this impairment is caused by a single dominant gene form (allele) on an ordinary rather than on a sex chromosome. Since then, French, Japanese, and Greek cases have also been found, although more genetical work would be welcome.

This interpretation of the study has not been universally accepted.The most frequent objections are that the patients have a problem with auditory and/or articulatory processing and that grammatical complications arise as a by-product; or that we are faced with a general cognitive problem. We discuss these in turn.

It could be, for example, that patients, due to a failure in auditory processing, cannot hear the small /-d/ sound at the end of the verbs in past tense. Yet tense is marked differently in the other languages, and the problem remains. Furthermore, the patients make the same mistakes in writing as well. When they say something like *walked,* this is not an automatic *walk* + *-ed* for them, but a separate word, or a *consciously* produced form. For example, after lengthy speech therapy, these patients can learn that for plurals they have to add an /-s/ sound to the word (that is, a 'hiss', as in *plates* or *claps*), but apparently they do it via a route different from ours: they form the plurals of 'sas' and 'wug' so that they sound 'sasss' and 'wug-s', respectively, whereas we would say 'sassez' and 'wug-z'.

As to the idea that there is a general cognitive problem, it is true that there are patients who have other problems, but most of them do not; for example, one linguistically impaired individual is a rocket scientist. Just as people who are linguistically impaired often have a normal IQ, it is also true that most people with low IQ, or with other cognitive difficulties, have an unimpaired language faculty. Further, there are neurological data indicating that the linguistically impaired have an anatomically identifiable distortion in the brain. It is likely that it can cause the language impairment, either alone or in association with other problems; even if the second possibility is true, it does not follow that these associated problems are the cause of the linguistic impairment, which also occurs in their absence.

The past two decades have witnessed a remarkable advance in the genetics of development (see Chapter 10). Now we are able to dissect genetically various component processes by developmental mutants: it is the malformations that

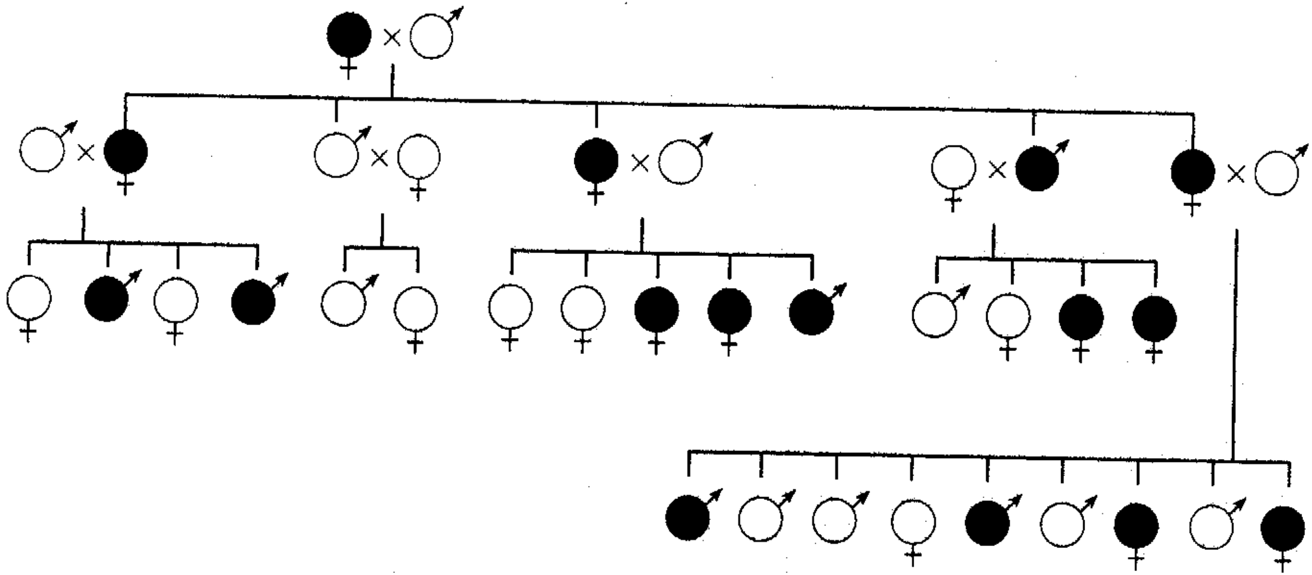

Figure 13.3 Pedigree of a family with a specific language impairment, after Myrna Gopnik. Affected individuals are shown by filled circles; ♂ indicates a male, and ♀ a female.

reveal best how the normal system works. We expect similar progress towards a science of linguistic genetics. The job is much harder, however, because language is unique to humans, so that, instead of being able to cross individuals at will, or elicit mutations in them, we are restricted to the analysis of existing family pedigrees.

From alarm calls to the Tower of Babel: evolution of the language capacity

The evolutionary gap to be bridged is between 'protolanguage' and Chomskyan universal grammar. Examples of protolanguage include pidgin, the language of children under two, the learnt language of apes, and the language of people brought up in linguistic deprivation. Some examples are given in Table 13.1. Its characteristics include the following:

1. The use of words as Saussurean signs (Fig. 13.4); that is, a word must stand for a concept, both for the speaker and for the hearer.
2. The lack of purely grammatical items, such as *if, that, the, when, in, not* that do not refer to anything.
3. The absence of hierarchical syntax—for example, the use of phrases discussed above.

Although lacking these essential features of language, such protolanguage has already a lot. In particular, most linguists would argue that there is no convincing example of proper words used by animals *in the wild*. Consider, for example, the signals that vervet monkeys have for martial eagles, leopards, and pythons. It is accepted that adult monkeys give different calls when they see these different predators. Juvenile monkeys know without learning that the eagle call, for example, should be given in response to flying objects, but must learn its precise application; at first, they may give the call to other, harmless birds, and even to a falling leaf. Monkeys hearing such a call respond appropriately; it is a good

Table 13.1 Examples of protrolanguage: A, utterances of 2-year-old children; B, signed statements of a chimpanzee raised by humans; C, utterances of Genie, a girl deprived of linguistic input until the age of 13 years

A	B	C
big train	drink red	want milk
red book	comb black	Mike pain
Mommy lunch	tickle Washoe	At school wash face
go store	open blanket	I want Curtis play piano

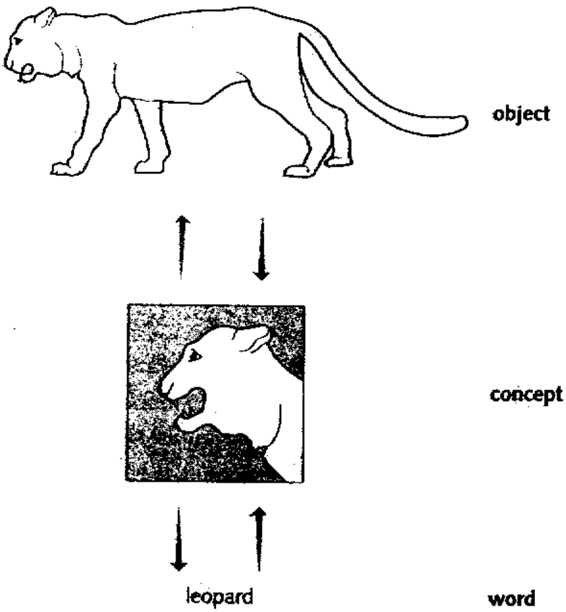

Figure 13.4 The structure of a Saussurean sign. Arrows indicate a direct connection. Note that there is no direct connection between an object 'out there' and the corresponding word: concepts stand in between. If one either hears or sees a leopard, that elicits in the mind the concept of a leopard, which in turn elicits the word 'leopard': in reverse, if one hears the word 'leopard', this elicits in the mind the concept of a leopard, and one can then imagine the sight or the sound of a leopard. To qualify as a word, a signal must be such a sign: all the arrows must be present. Whereas concept formation is, to varying degrees, quite common in animals, it is unclear how often words are used. For example, if a vervet monkey hears the alarm call for a snake, does it first form the concept of a snake in its head, or does it just respond? We don't know. After all, it would be easy to design a machine that responded in a specific way to a specific sound, without forming anything corresponding to a concept.

idea to climb to the tip of a branch if there is a leopard about, but not if there is an eagle. But, and this is the crucial point, there is no evidence that when a vervet hears the alarm call for python, it actually forms the concept of a snake in its brain; it may respond without knowing why it does so. Thus one arrow may be missing from the diagram in Fig. 13.4.

Other animals seem to be able to use real Saussurean signs, maybe even in the wild. One of the suspects is the dolphin. Remarkably, the size of the brain relative to body size is second only to humans: the great apes have only half the score of dolphins. This by itself may be of limited significance; after all, Neanderthals had a bigger skull than we have. Dolphins, however, have a very rich vocal repertoire that seems to be open-ended: a dolphin can learn new signals until the end of its life. Dolphins can listen to the signals of conspecifics and react appropriately by extracting the relevant information. Some of the signals seem to be 'signatures' identifying the emitter. It is very likely, although not yet proven, that dolphins can use Sausserean signs—or words for short. For example, when a dolphin 'says' something in reaction to a shown object, another dolphin is able to pick another piece of the same object without knowing what the first individual saw.

They also seem to have an understanding of the importance of word order, and hence have been credited with 'sentence comprehension'. For example, they can be taught to distinguish properly between *pipe fetch hoop* and *hoop fetch pipe*. They are able to react to several hundred 'sentences' of two to five 'words' in length and perform appropriate actions. Once they get accustomed to a syntax such as Direct object + Action + Indirect object, they can use this template with novel words at the first instance. For example, having learnt that the sentence *hoop fetch pipe* means 'fetch the hoop to the pipe', and also the meanings of the words *net* and *basket*, it seems that a dolphin will correctly interpret the sentence *net fetch basket* the first time it is experienced as meaning 'fetch the net to the basket'.

This performance is remarkable, but there are three limitations:

1. Comprehension in general is easier than production: as we all know; it is easier to understand than to explain.
2. The dolphins did not produce sentences in the experiment.
3. We do not have the faintest idea whether they use words, let alone syntax, in the wild, whatever they may do in captivity.

Mária Újhelyi called attention to the fact that the songs used in territorial defence by some monkeys that live as monogamous pairs, and by gibbons, which have a similar social system, qualify as a pre-linguistic systems, in the following sense. They combine discrete elements in different sequences, and these sequential differences have a meaning, such as the signing of sex, identity, territory, and so on. The songs are particularly fascinating in gibbons, where a phenomenon called duetting also occurs between members of a 'married couple'. It seems that chimpanzees and bonobos (pigmy chimpanzees) retained this pre-linguistic faculty, as exemplified by their long calls, although they are not monogamous. An outstanding question is, of course, the referential nature of such vocalizations: what do they actually mean?

As must be clear by now, we think that there must have been intermediate stages of grammar. It is not hard to think of intermediates. For example, David Premack has suggested that there could have been a stage when it was be possible to say *the dog bit John*, but not that *John was bitten by the dog*. That is, the subject of the sentence had to appear first, and had to refer to the active 'agent'.

In fact, one can suggest a number of steps by which language could have been extended:

- Items for negation, such as *no*.
- '*Wh*-' questions, such as *what*, *who* and *where*.
- Pronouns (instead of repeating proper names).
- Verbal auxiliaries such as *can* and *must*.
- Expression for temporal order (e.g. *before* and *after*).
- Quantifiers such as *many* and *few*.

Of course, without any one of these additions, there would have been things one could not say. But so what? As we have seen, an imperfect eye can be a lot better than no eye at all.

Yet some linguists, including Derek Bickerton, argue that much of syntax must have originated abruptly in evolutionary terms. Novelties in evolution can appear rather suddenly if they are modifications of a structure that evolved to perform some other function. For example, we suggested in Chapter 4 that the genetic code may have evolved from a system in which amino acids functioned as coenzymes of RNA enzymes. Similarly, the feathers of birds first evolved for thermoregulation rather than flight. But when this happens, the old structure will at first be rather inefficient in its new role, and will require fine-tuning by selection.

Bickerton has suggested that syntax may have evolved by the connection of two pre-existing faculties, one being a social 'cheater detector', and the other a protolinguistic ability. This would be a kind of symbiosis, but between two genetic systems in the same organism, not between previously independent organisms. We have already argued that symbiosis can be the source of sudden novelty. If this idea, or something like it, turns out to be correct, it would help to explain both the suddenness and the complexity of human language. A crucial part of the idea is that the 'Machiavellian' thinking of which non-human primates seem to be capable must have had a syntax with some equivalent of phrase structure. This sounds credible: it is difficult to imagine a good Machiavellian who could not think about who did/does/will do what to whom and why, and who could not do this recursively; for example, if I tell Joe, then Joe will tell Mary.

Even if this explanation is correct, there would still have been a need for substantial evolutionary fine-tuning. Think again of the example of organelle evolution: without the protracted phase of evolution leading to specific transport systems, metabolic utilization of photosynthates and ATP would have been impossible, even if a lot was given free by symbiosis.

This idea of a connection between the protolinguistic and the social modules in the brain is similar to the ideas of Steven Mithen described in Chapter 12. According to him, the early human mind, around 100 000 years ago, consisted of modules of domain-specific mentality: social intelligence, intelligence for natural history (hunting, food gathering, etc.), technical intelligence, and language (the latter linked to social intelligence). Archaeological data show that, some 50 000 years ago, there was a great spurt in technical inventiveness and artistic creativity. Mithen suggests in his book *The prehistory of the mind* that the cause of this spurt was an increase in communication between the previously rather isolated modules: for example, the striking increase in the range of tools made at that time required that people think simultaneously about hunting and toolmaking. Language would have helped such communication; there is a sense in which thinking is talking to oneself.

The charm of these ideas is that they are in principle testable by looking at the function, development, and breakdown of specific parts of the brain. It would be particularly persuasive if some neurological disorders turn out to arise from the decoupling of these modules.

One puzzle remains: how could grammatical novelties spread in a population? There is no point in one individual using a new phrase or construction if others do not understand. Would not the novelty be selected against as a 'Hopeful Monster': hopeful in words but hopeless in reality? The first thing to note here is that when we meet a linguistic novelty, we do not give up too easily: we try to guess the meaning by watching others, as well as by trying it out ourselves. Second, grammatical novelties must be built on pre-existing neuronal structures, and so are likely to be compatible with what is already present, just as the latest (and usually more elaborate) forms of computer software tend to be compatible with previous editions.

So a new mutant extending linguistic competence would survive, because others would learn and adopt the novelty. But if the mutation is to spread by natural selection, it must confer an advantage. Why should the new mutant actually be fitter, if others can do by learning what the mutant is hard-wired to do? Two linguists, Steven Pinker and Paul Bloom, have suggested that a possible way out of this trap is by 'genetic assimilation learning'. This is an evolutionary process that can convert a behaviour that is learnt into one that is genetically programmed, without supposing that acquired characters are inherited. It can best be explained by describing a fascinating computer simulation by G. E. Hinton and S. J. Nowlan. They suppose that, in order to perform some action, neuronal switches must be correctly set. The switches can be set by genetics or by learning. But if we depend on genetics alone, a population will never evolve the capacity to perform the action, because the chance that a genotype specifying all the correct settings will arise by random mutation is vanishingly small. Even if such a genotype does arise, it will be broken up by genetic recombination in the next generation. With pure genetics, having 99 per cent of the switches set correctly is no better than having only 10 per cent in the correct mode.

The situation changes dramatically if we assume that learning can occur during the lifetime of an individual; that is, only some of the switches are set by genetics, and many random trials can be done on the switches that are not so set. The earlier in its lifetime an individual hits on the right combination, the more offspring it will send into the next generation. Thus, if a higher proportion of switches are genetically correct, the expected time until the rest of the correct settings are found decreases, so that the expected number of offspring increases. When learning is combined with genetics, having 90 per cent of the switches genetically set in the correct mode is a lot better than having 70 per cent of them set correctly. Thus, a trait that is adaptive, and that *must be learnt* in the first place, can evolve to be hard-wired into the brain, because learning can guide natural selection.

The suggestion, then, is that genetic assimilation can help to explain the evolution of our hard-wired competence to acquire grammar. New components of grammar would first be tried out by individuals, just as new turns of phrase are tried out today, and learnt by other members of the population. If skill in communication increases fitness, then those who learnt new grammatical tricks fastest would leave most descendants, and the initially learnt grammatical novelties would be genetically assimilated.

Are there any other human faculties whose evolution may have positively influenced that of language? A serious suggestion is that the skill to manipulate objects and combine them so that the outcome 'makes sense', so characteristic of humans, may have coevolved with the language faculty. The point is that in purposeful object manipulation an 'action grammar' is apparent. For example, take the sentence *(I) want more grape juice.* The grammar follows what can be called a subassembly strategy: *more* combines with *grape juice* to form a noun phrase, and then the latter is combined with the verb. A similar strategy is apparent, for example, in eating with a spoon: one has to combine the food with the spoon, and the combination has to be put into the mouth.

The analogy goes deeper than this. The neuropsychologist Susan Greenfield has observed children playing the familiar game in which a set of cups of graded size must be fitted one inside another. She finds that action grammar develops in stages that resemble the acquisition of language grammar. Children adopt three strategies for the former: the pairing, the pot, and the subassembly method (Fig. 13.5). These strategies are arranged in an order of increasing complexity that agrees with the temporal order of their emergence in development. The analogous linguistic phases of sentence construction come later in child development. Greenfield points out, however, that analogous stages

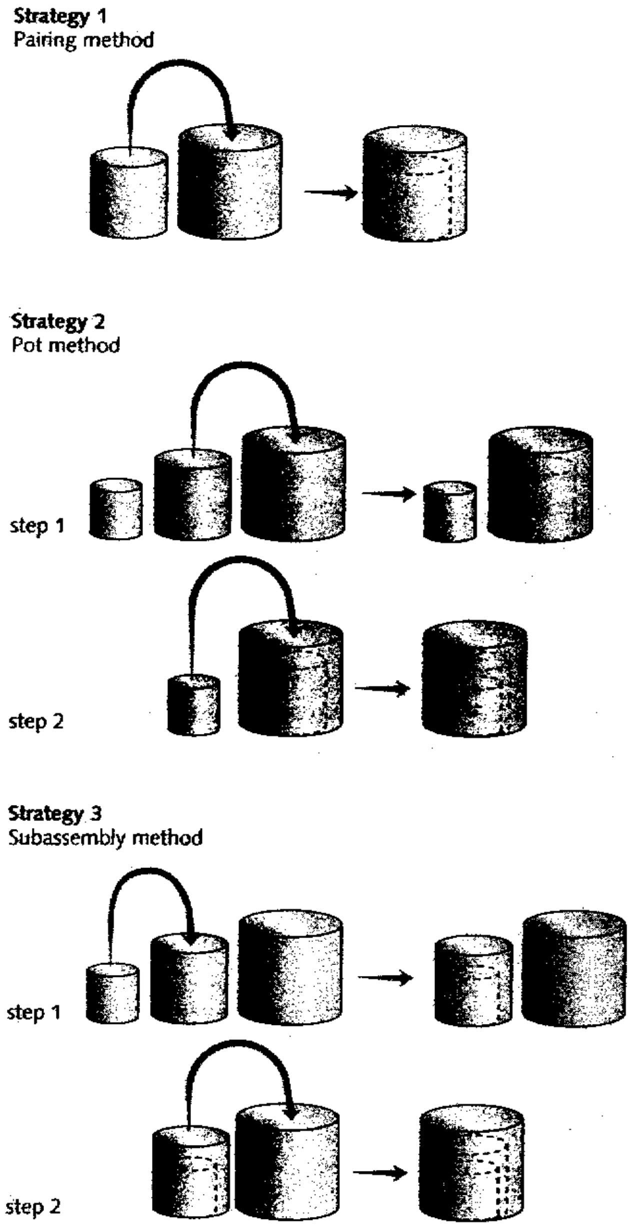

Figure 13.5 Action grammar. Three ways in which a child can arrange a set of cups, with small ones inside larger ones. These have formal similarities to ways of constructing sentences. The pairing method is similar to a simple sentence such as *Mary ate the fish.* In the pot method, two sentences are joined, as in *John caught the fish and Mary ate the fish.* Finally, in the subassembly method, a phrase is first formed, and then used as part of a sentence, as in *Mary ate the fish which John had caught.*

occur as a child acquires the ability to form words by combining phonemes, and suggests that the real synchrony is between action grammar and word construction.

It is remarkable that apes do not use the subassembly strategy for object manipulation in the wild, although some of them seem to have mastered it in captivity. It is of significance that two chimpanzees that discovered the subassembly strategy in the nesting-cup experiments had been exposed to intensive linguistic training. It is perhaps even more important that the only demonstrated example of teaching (not to be confused with learning) in the wild happens in chimpanzees when the mother teaches her offspring how to crack a nut with a hammer and an anvil. Thus Greenfield imagines a coevolutionary process between teaching, using more and more words and grammar; and using tools to perform more and more complicated tasks. This is plausible. One should not forget, however, that one important aspect of language is that we can talk about things that we could never do. To perform complex meaningful actions we must go through many impractical ones in our head: to do good solid science we need well-developed fantasy and imagination.

Language and the future

As we approach the end of our story, we want to reflect on what happened in evolution, and on what may happen next. In several of the major evolutionary transitions one can see either that a novel type of inheritance system arises, or that a system with limited heredity, able to encode only a small number of alternative messages, evolves into one with potentially unlimited heredity. Different inheritance systems include:

- Autocatalytic cycles and networks, as described in Chapter 1 and illustrated in Fig. 1.2.
- Small oligonucleotides; that is, strings of only a small number of nucleotides.
- RNA-like and DNA-like molecules, consisting of some hundreds of nucleotides.
- Chromosomes, like those of bacteria, with only a single origin of replication.
- Chromosomes with many origins of replication, as found in eukaryotes.
- Primitive states of gene regulation, such as the *lac* operon described in Chapter 10, in which the regulated state—on or off—is copied when the cell divides.
- Advanced gene-regulation systems, found in multicellular organisms (for example, it has been suggested that a gene expressed in one tissue type may have regulators for stage of development, tissue specificity, cell-lineage

identification, cell-cycle tuning, amplitude control, and reception of signals from adjacent cells).

- Protolanguage.
- Language.

The analogy between the genetic code and human language is remarkable. Spoken utterances are composed of a sequence of a rather small number of unit sounds, or phonemes (represented, at least roughly, by the letters of the alphabet). The sequence of these phonemes first specifies different words, and then, through syntax, the meanings of sentences. By this system, the sequence of a small number of kinds of unit can convey an indefinitely large number of meanings. The genetic message is composed of a linear sequence of only four kinds of unit. This sequence is first translated, via the code, into a sequence of 20 kinds of amino acid. These strings of amino acids fold to form three-dimensional functional proteins. Through gene regulation, the right proteins are made at the right times and places, and an indefinite number of morphologies can be specified.

Thus in both systems a linear sequence of a small number of kinds of unit can specify an indefinitely large number of outcomes. But there is one respect in which the two systems cannot usefully be compared. In language, the meanings of sentences depend on the rules of syntax. These rules are formal and logical. In contrast, the 'meaning' of the genetic message cannot be derived by logical reasoning. Thus, although the amino acid sequence of the proteins can be simply derived from the genetic message, the way they fold up to form three-dimensional structures, and the chemical reactions that they catalyse, depend on complex dynamic processes determined by the laws of physics and chemistry. It does not seem possible to draw a useful comparison between the way in which meaning emerges from syntax, and that in which chemical properties emerge from the genetic code.

Are there ways in which a system of unlimited heredity could work, other than by a linear sequence of a small number of kinds of discrete units? There seems to be no necessary reason why the message should be one-dimensional, except that a linear sequence is easy to arrange, and it is sufficient. But the discrete, digital nature of the units is probably necessary. If meaning was conveyed by signs that could vary continuously, instead of belonging to one of a small number of classes, meaning would be gradually lost, as in the game of Chinese whispers. However, it seems that human language does not depend on phonemes, or their equivalent. Thus the sign languages invented by the deaf do not involve a one-to-one correspondence between signs and phonemes, although 'words' do exist. It would be interesting to know how far these languages are digital.

We have treated the origin of language as the last of the major transitions. This shows that we are biologists, not historians. Language was indeed the last transition that required biological evolution, in the sense of a change in the genetic message. But there have been two major changes in the way in which information is transmitted since the origin of language. The first was the invention of writing. Without writing, or some equivalent way of storing information, large-scale civilization was impossible, if only because one cannot tax people without some form of permanent record. The latest transition, through which we are living today, is the use of electronic means for storing and transmitting information. We think that the effects of this will be as profound as were those after the origin of the genetic code, or of language, but we are not rash enough to predict what they will be. Will our descendants live most of their lives in a virtual reality? Will some form of symbiosis between genetic and electronic storage evolve? Will electronic devices acquire means of self-replication, and evolve to replace the primitive life forms that gave them birth? We do not know.