3 Grandmama's Teeth

Is there biological evidence for innate language capacity?

> 'O grandmama, what big teeth you have!' said Little Red Riding Hood.
> 'All the better to eat you with, my dear,' replied the wolf.

If an animal is innately programmed for some type of behaviour, then there are likely to be biological clues. It is no accident that fish have bodies which are streamlined and smooth, with fins and a powerful tail. Their bodies are structurally adapted for moving fast through the water. The same is true of whales and dolphins, even though they evolved quite separately from fish. Similarly, if you found a dead bird or mosquito, you could guess by looking at its wings that flying was its normal mode of transport.

However, we must not be over-optimistic. Biological clues are not essential. The extent to which they are found varies from animal to animal and from activity to activity. For example, it is impossible to guess from their bodies that birds make nests, and, sometimes, animals behave in a way quite contrary to what might be expected from their physical form: ghost spiders have tremendously long legs, yet they weave webs out of very short strands. To a human observer, their legs seem a great hindrance as they spin and move about the web. On the other hand, the orb spider, which has short legs, makes its web out of very long cables, and seems to put a disproportionate amount of effort into walking from one side of the web to another (Duncan 1949, quoted in Lenneberg 1967: 75). In addition, there are often inexplicable divergences between species which do not correlate with any obvious differences in behaviour. The visible sections of the ear differ in chimps, baboons and men – but there is no discernible reason behind this. However, such unpredictability is not universal, and need not discourage us from looking for biological clues connected with speech – though we must realize that we are unlikely to find the equivalent of a large box labelled 'language'.

Changes in the form of the body or *structural* changes are the most direct indications of innate programming. But we must also take into consideration *physiological* adaptations – changes in the bodily functions, such as rate of heartbeat and breathing. The first part of this chapter looks at parts of the human body where adaptations related to language are likely to be found. The organs used to produce and plan it are examined – the mouth, vocal cords, lungs and the brain.

The second part of the chapter is slightly different. It considers aspects of language where complex neuromuscular sequencing is involved. It becomes clear that the co-ordination required is perhaps impossible without biological adaptations.

Mouth, lungs and grey matter

If we look at the organs used in speech, humans seem to be somewhere in the middle between the obvious structural adaptation of birds to flying, and the apparent lack of correlation between birds and nest-building. That is, the human brain and vocal tract have a number of slightly unusual features. By themselves, these features are not sufficient to indicate that people can talk. But if we first assume that all humans speak a language, then a number of puzzling biological facts fall into place. They can be viewed as *partial* adaptations of the body to the production of language.

For example, human teeth are unusual compared with those of other animals. They are even in height, and form an unbroken barrier. They are upright, not slanting outwards, and the top and bottom set meet. Such regularity is surprising – it is certainly not needed for *eating*. Yet evenly spaced, equal-sized teeth which touch one another are valuable for the articulation of a number of sounds, S, F, and V, for example, as well as SH (as in *shut*), TH (as in *thin*) and several others. Human lips have muscles which are considerably more developed and show more intricate interlacing than those in the lips of other primates. The mouth is relatively small, and can be opened and shut rapidly. This makes it simple to pronounce sounds such as P and B, which require a total stoppage of the airstream with the lips, followed by a sudden release of pressure as the mouth is opened. The human tongue is thick, muscular and mobile, as opposed to the long, thin tongues of monkeys. The advantage of a thick tongue is that the size of the mouth cavity can be varied allowing a range of vowels to be pronounced.

It seems, then, that humans are naturally geared to produce a number of different sounds rapidly and in a controlled manner. Their mouths possess features which either differ from or appear to be missing in the great apes. In all, one cannot help agreeing with the comment of a nineteenth-century writer:

> What a curious thing speech is! The tongue is so serviceable a member (taking all sorts of shapes just as it is wanted) – the teeth, the lips, the roof of the mouth, all ready to help; and so heap up the sound of the voice into the solid bits which we call consonants, and make room for the curiously shaped breathings which we call vowels!
>
> (Oliver Wendell Holmes)

Another important difference between humans and monkeys concerns the larynx, which contains the 'voice box' or 'vocal cords'. Strangely, it is simpler in structure than that of other primates. But this is an advantage. Air can move freely past and then out through the nose and mouth without being hindered by other appendages. Biologically, streamlining and simplification are often indications of specialization for a given purpose. For example, hooved animals have a reduced number of toes, and fish do not have limbs. So the streamlining of the human larynx may be a sign of adaptation to speech. But we pay a price for our specialized larynx. A monkey can seal its mouth off from its windpipe and breath while it is eating. Humans cannot do this, so food can get lodged in the windpipe, sometimes causing them to choke to death.

We now come to the lungs. Although there is no apparent peculiarity in the structure of our lungs, our breathing seems to be remarkably adapted to speech. In most animals the respiratory system is a very finely balanced mechanism. A human submerged under water for more than two minutes will possibly drown. Anyone who pants rapidly and continuously for any length of time faints and sometimes dies. Yet during speech the breathing rhythm is altered quite noticeably without apparent discomfort to the speaker. The number of breaths per minute is reduced. Breathing-in is considerably accelerated, breathing-out is slowed down. Yet people frequently talk for an hour or more with no ill-effects. A child learning to play the flute or trumpet has to be carefully instructed in breathing techniques – but no one has to instruct a 2-year-old in the breathing adaptations required for talking. It is impossible to tell which came first – speech or breathing adaptations. As the biologist Eric Lenneberg inquired (1967: 81), do donkeys say *hee-haw* on inspired and expired air so efficiently because of the way their breathing mechanisms were organized, or did the *hee-haw* come first? The answer is irrelevant. All that matters to us is that any child born in the twentieth century has a breathing mechanism apparently biologically organized for speech.

It seems, then, that there are clear indications in the mouth, larynx and lungs that we speak 'naturally'. However, let us now consider the human brain. To what extent is this programmed for speech? The answer is unclear. Our brain is very different in appearance from that of other animals. It is heavier, with more surface folding of the *cortex*, the outer layer of 'grey matter' which surrounds the inner core of nerve fibres – though grey matter is actually pink in live humans, it goes grey after death. Of course, size alone is not particularly important. Elephants and whales have bigger brains than humans, but they do not talk. But elephants and whales also have bigger bodies, so some people have suggested that it is the brain–body ratio which matters. At first sight, this seems a promising approach. It appears quite reasonable to suggest that a high brain–body ratio means high intelligence, which in turn might be a prerequisite for language, especially when we find that the brain of an adult human is more than 2 per cent of his or her total weight, while that of an adult chimp is less than 1 per cent. But such ratios can be very misleading. Some animals are designed to carry around large reserves of energy which makes their bodies enormously heavy. Camels, for example, are not necessarily more stupid than horses just because they have huge humps.

But even apart from problems such as this, brain–body ratio cannot be a decisive factor as far as language is concerned, since it is possible to find young chimpanzees and human children who have similar brain–body ratios – yet the child can talk and the chimp cannot. Even more convincing is a comparison between a 3-year-old chimp and a 12-year-old nanocephalic dwarf – a human who because of a genetic defect grows to a height of around 760 mm (or 2 feet 6 inches).

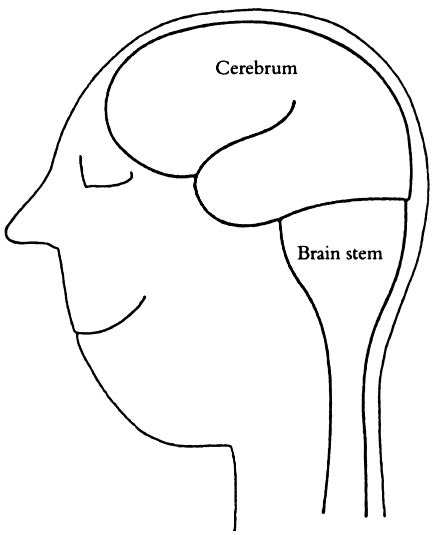
	Brain (kg)	*Body (kg)*	*Ratio*
Human, age 13½	1.35	45	1 : 34
Human dwarf, age 12	0.4	13.5	1 : 34
Chimp, age 3	0.4	13.5	1 : 34

Source: Lenneberg 1967: 70

Although the chimp and the dwarf have exactly the same brain and body weights (and so, of course, the same brain–body ratio), the dwarfs speak, in a somewhat limited fashion, but the chimps do not.

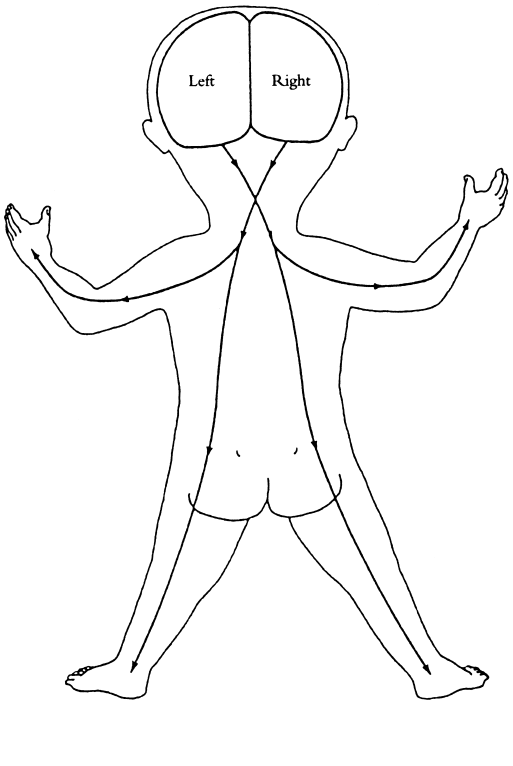
These figures show conclusively that the difference between human and chimp brains is a *qualitative*, not a *quantitative* one.

Superficially, the brains of a chimp and a human have certain similarities. As in a number of animals, the human brain is divided into a lower section, the *brain stem*, and a higher section, the *cerebrum*. The brain stem keeps the body alive by controlling breathing, heartbeats and so on. A cat with the upper section of its brain removed but with the brain stem intact could still swallow milk, purr, and pull its paw away from a thorn when pricked. The higher section, the cerebrum, is not essential for life. Its purpose seems to be to integrate an animal with its environment. This is the part of the brain where language is likely to be organized.

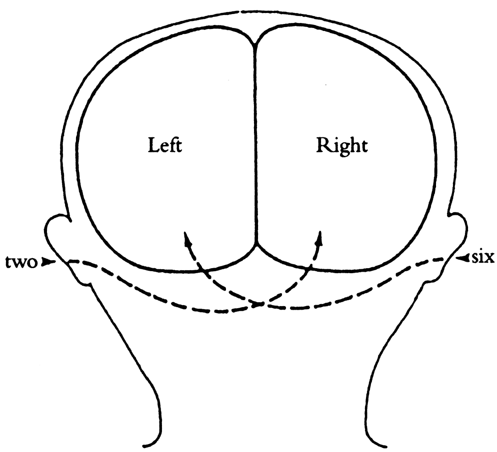


The cerebrum is divided into two halves, the *cerebral hemispheres*, which are linked to one another by a series of bridges. The left hemisphere controls the right side of the body, and the right hemisphere the left side.

But the two hemispheres do not function identically. This was first discovered over a hundred years ago. A Frenchman, Marc Dax, read a paper at Montpellier in 1836, pointing out that paralysis of the right side of the body was often associated with loss of speech, while patients whose left side was paralysed could usually talk normally. This suggested that the left hemisphere controlled not only the right side of the body, but *speech* also. Dax's hypothesis turned out to be correct. Speech in the majority of humans is the concern of the *left*, not the right hemisphere. But it was a long time before this was reliably confirmed. Until relatively recently, statistics could only be drawn up by chance observations, when researchers managed to note cases of people in whom loss of speech was associated with right-side paralysis. But in the twentieth century more sophisticated methods were adopted. One is the sodium amytal test developed by Wada in the 1940s. In this test the patient was asked to count out loud while a barbiturate (sodium amytal) was injected into an artery carrying blood to one side of the brain. If this was the hemisphere used in speech, the patient lost all track of his counting and experienced severe language difficulties for several minutes. If it was not, the patient could resume normal counting almost immediately after the injection. Although this test was effective, it also carried an element of risk. So it was only used when brain surgery was advisable (as in severe epilepsy) and the surgeon wished to know whether he was likely to disturb vital speech areas. If so, he was unlikely to operate.



Simpler and less invasive methods for discovering which hemisphere controls language are now the norm. The first was the use of dichotic listening tests (Kimura 1967; Obler and Gjerlow 1999). The subject wears headphones, and is played two different words simultaneously, one into each ear. For example, he or she might hear *six* in one ear, and *two* in the other. Most people can report the word played to the right ear (which is directly linked to the left hemisphere) more accurately than the word played to the left ear (linked to the right hemisphere). It is clear that this is not simply due to an overall preference for sounds heard in the right ear, because for non-linguistic sounds the left ear is better. If different tunes are played simultaneously into each ear, subjects will identify the tune played into the left ear better than the one directed into the right ear. We conclude that the left hemisphere is better at processing linguistic signals – and so is normally the dominant one for speech.



A further technique is tachistoscopic (fast-view) presentation. An image is presented very fast to either the left or right visual field (the area that can be seen to left or right without moving the head or eyes). A linguistic stimulus will normally be processed faster if it is presented to the right visual field, which is then transferred to the left (usually language dominant) hemisphere.

In another twentieth-century technique, electrodes are attached to the skull in order to measure the amount of electrical activity in the area beneath (as will be discussed later). Spoken words produce a greater response in the left hemisphere, whereas noises such as mechanical clicks arouse a greater response in the right (Rosenfield 1978).

The results of the observations and tests described above are surprisingly consistent. The majority of normal human beings – perhaps as many as 90 per cent – have speech located primarily in the left hemisphere. This cannot be due to chance.

A further related discovery is that the location of speech centres in the left hemisphere seems to be linked to right-handedness. That is, most humans are right-handed, and most people's speech is controlled by the left hemisphere. In the nineteenth century it was commonly assumed that left-handers must have speech located in the right hemisphere, and this seemed to be confirmed by a report in 1868 by the influential neurologist John Hughlings Jackson that he had discovered loss of speech in a left-hander who had sustained injury to the right side of the brain. But this viewpoint turns out to be false. Surprisingly, most left-handers also have language controlled predominantly by the left hemisphere, though the picture is not completely straightforward. Of the relatively few people who do not have their speech centres located in the right hemisphere, more are left-handed than right-handed.

Location of speech centres	*Right-handers*	*Left-handers*
Left hemisphere	90% or more	70–90%
Right hemisphere	10% or less	10–30%

(Figures averaged from Penfield and Roberts 1959; Zangwill 1973; Milner, *et al.* 1964.)

These figures indicate two things: first, it is normal for speech and handedness to be controlled by the same hemisphere, and it has been suggested that speech and writing problems are found more frequently in children where the two are not linked. Second, there is a strong tendency for speech to be located in the left hemisphere even when this appears to disrupt the standard linking of speech and handedness.

Some work has been directed at finding out if *all* speech processing must be located in one hemisphere or whether subsidiary linguistic abilities remain in the non-dominant hemisphere. One group of researchers at Montreal, Canada, found ten patients who had speech abilities in both halves of the brain. The sodium amytal test disturbed speech whichever side of the brain it was injected. Interestingly enough, all these patients were either left-handed or ambidextrous (Milner, *et al.* 1964).

Other studies suggest that the right hemisphere contains a limited potential for language which is normally latent, but which can be activated if needed. Patients who have had the whole of the left hemisphere removed are at first without speech. But after a while, they are likely to acquire a limited vocabulary, and be able to comprehend a certain amount, though they always have difficulty in producing speech (Kinsbourne 1975). The right hemisphere is not useless, however. Patients with right hemisphere damage have difficulty with intonation, and in understanding jokes and metaphors (Caplan 1987).

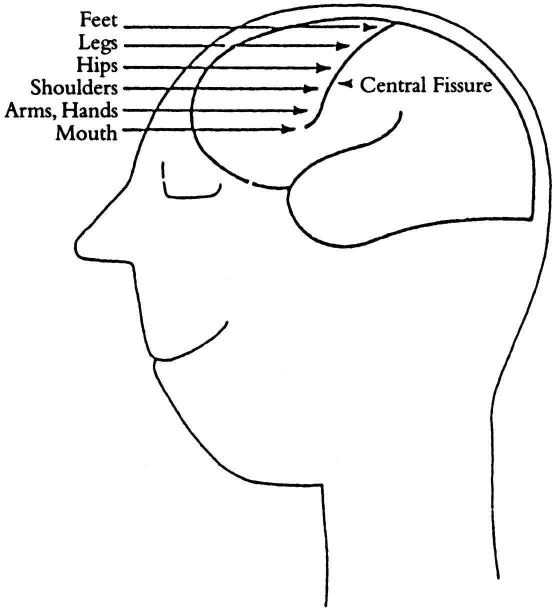
Perhaps the most widely reported experiments on this topic are those involving 'split brain' patients (Gazzaniga 1970, 1983). In cases of severe epilepsy it is sometimes necessary to sever the major links between the two hemispheres. This means that a patient has virtually two separate brains, each coping with one half of the body independently. A patient's language can be tested by dealing with each hemisphere separately. An object shown to the *left* visual field is relayed only to the *right* (non-language hemisphere). Yet sometimes the patient is able to name such an object. This indicates that the right hemisphere may be able to cope with simple naming problems – but it seems unable to cope with syntax. However, the results of these experiments are disputed. Some people have suggested that the information is being transferred from one hemisphere to the other by a 'back route' after the major links have been severed.

This lateralization or localization of language in one half of the brain, then, is a definite, biological characteristic of the human race. At one time, it was thought to develop gradually. But later research indicated that it may be present at birth (Kinsbourne and Hiscock 1987). Even foetuses have been claimed to show traces of it, with some areas of the left hemisphere being bigger than the right (Buffery 1978). The issue is an important one for psycholinguists, since it has sometimes been argued that the period of lateralization coincides with a 'critical period' for language acquisition (to be discussed in Chapter 4).

Although most neurologists agree that language is mainly restricted to one hemisphere, further localization of speech is still controversial. A basic difficulty is that until recently all the evidence available was derived from brain-damaged patients. And injured brains may not be representative of normal ones. After a stroke or other injury the damage is rarely localized. A wound usually creates a blockage, causing a shortage of blood in the area beyond it, and a build-up of pressure behind it. So detailed correlations of wounds with speech defects cannot often be made, especially as a wound in one place may trigger off severe speech problems in one person, but only marginally affect the speech of another. This suggests to some neurologists that speech can be 're-located' away from the damaged area – it has (controversially) been suggested that there are 'reserve' speech areas which are kept for use in emergencies. This creates an extremely complex picture. Like a ghost, speech drifts away to another area just as you think you have located it. But these problems have not deterred neurologists – and some progress has been made.

Until fairly recently, observation and experiment were the two main methods of investigation. Observation depended on unfortunate accidents and post-mortems. A man called Phineas Gage had an accident in 1847 in which a four-foot (over a metre long) iron bar struck and entered the front left-hand section of his head, then exited through the top. Gage kept the bar as a souvenir, until his death, twenty years later. The bar and skull are now preserved in a museum at the Harvard Medical School. Although Gage's personality changed for the worse – he became unreliable and unpredictable – his language was unaffected. This suggests that the front part of the brain is not crucially involved in language. Conversely, a French surgeon named Broca noted at a post-mortem in 1861 that two patients who had had severe speech defects (one could only say *tan* and *sacré nom de Dieu*) had significant damage to an area just in front of, and slightly above, the left ear – which suggested that this area, now named 'Broca's area', is important for speech.

The experimental method was pioneered in the 1950s by two Canadian surgeons, Penfield and Roberts (1959). They were primarily concerned with removing abnormally functioning cells from the brains of epileptics. But before doing this they had to check that they were not destroying cells involved in speech. So, with the patients fully conscious, they carefully opened the skull, and applied a minute electric current to different parts of the exposed brain. Electrical stimulation of this type normally causes temporary interference. So if the area which controls leg movement is stimulated, the patient is unable to move his or her leg. If the area controlling speech production is involved, the patient is briefly unable to speak.

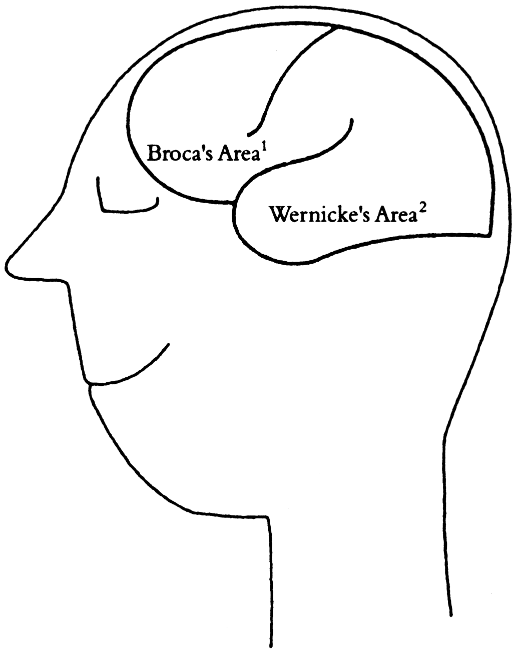


There are obvious disadvantages in this method. Only the surface of the brain was examined, and no attempt was made to probe what was happening at a deeper level. The brain is not normally exposed to air or electric shocks, so the results may be quite unrepresentative. But in spite of the problems involved, certain outline facts became clear long ago.

First of all, it was possible to distinguish the area of the brain which is involved in the actual articulation of speech. The so-called 'primary somatic motor area' controls all voluntary bodily movements and is situated just in front of a deep crack or 'fissure' running down from the top of the brain. The control for different parts of the body works upside down: control of the feet and legs is near the top of the head, and control of the face and mouth is further down.

The bodily control system in animals works in much the same way – but there is one major difference. In humans, a disproportionate amount of space is allotted to the area controlling the hands and mouth.

But the sections of the brain involved in the actual articulation of speech seem to be partly distinct from those involved in its planning and comprehension. Where are these planning and comprehension areas? Experts disagree. Nevertheless, perhaps the majority of neurologists agree that some areas of the brain are statistically likely to be involved in speech planning and comprehension. Two areas seem to be particularly relevant: the neighbourhood of *Broca's area* (in front of and just above the left ear); and the region around and under the left ear, which is sometimes called *Wernicke's area* after the neurologist who first suggested this area was important for speech (in 1874). Damage to Wernicke's area often destroys speech comprehension, and damage to Broca's frequently hinders speech production – though this is something of an over-simplification, since serious damage to either area usually harms all aspects of speech (Mackay *et al.* 1987).



[1] Broca's Area covers approximately the space under the *s* of Broca's and the *A* of *Area*

[2] Wernicke's Area is roughly the space directly above the word *Wernicke's*.

Particularly puzzling are cases of damage to Broca's or Wernicke's area where the patient suffers no language disorder. Conversely, someone's speech may be badly affected by a brain injury, even though this does not apparently involve the 'language areas'. There may simply be more variation in the location of brain areas than in the position of the heart or liver. A particular function may be:

> narrowly localized in an individual in a particular area . . . localized equally narrowly in another area in another individual, and carried out in a much larger area . . . in the third. The only constraint seems to be that core language processes are accomplished in this area of neocortex.
>
> (Caplan 1988: 248)

A further problem is that neurologists do not necessarily agree on the exact location of Broca's and Wernicke's areas, though the boundaries are more contentious than the central regions (Stowe *et al.* 2005). In addition there are deeper brain interconnections about which little is known.

Comparisons with the brains of other primates, incidentally, show that humans have a disproportionately large area at the front of the brain, sometimes referred to as the 'prefrontal cortex', though it is unclear how much of this involves language, and how much more general interconnections.

Luckily, brain scans can now supplement our information. From the 1970s onward, these have moved forward in leaps and bounds. First, and prior to 'proper' scans was the EEG (electroencephalograph) which showed the numerous electrical impulses in the brain, and the general state of alertness of a patient, but was unable to provide precise mappings. Then came so-called CT or CAT scans, short for 'X-ray computed tomography'. The tissues within the brain (and the body) differ in density, so a tumour (for example) might appear as an extra dense portion, and these differing densities showed up on the X-rays.

Next PET scans were developed, short for 'positron emission tomography'. These recorded blood flow. Blood surges in the brain when someone uses language, just as extra blood is pumped into the arms and hands when someone plays the piano. Radioactive water was injected into a vein in the arm. In just over a minute, the water accumulated in the brain, and could show an image of the blood flow in progressively more difficult tasks. In one experiment, subjects were first asked to look at something simple, such as a small cross on a screen, and the blood flow was measured. Then, some English nouns were shown or spoken. As a next stage, the subjects were asked to speak the word they saw or heard. Finally, they were asked to say out loud a verb suitable to the noun: for example, if they had heard the word HAMMER, then HIT might be appropriate (Posner and Raichle 1994).

The results showed strong differences between the various tasks. Simply repeating involved only the areas of the brain which dealt with physical movement. But both Broca's and Wernicke's areas became active when subjects consciously accessed word meaning and chose a response. In short, comprehension and production cannot be split apart in the way it was once assumed. In production, selecting a verb was the most complex task, and involved several areas – though with practice, the activity grew less, and became more like that of nouns. So practice not only makes it all easier, but actually changes the way the brain organizes itself. In another experiment, subjects were presented with lists of verbs, and asked to provide the past tense. Regular past tenses such as CLIMBED, WISHED showed different blood flow patterns from irregular ones such as CAUGHT, HID (Jaeger *et al.* 1996).

The brain, it appears, relies on tactics similar to those used by a sprinter's muscles, with an increase in oxygen in any area where neurons show extra activity – though a basic problem is the tremendous amount happening at any one moment. Pinpointing only the activity relevant to speech is difficult, especially as deeper connections are turning out to be as important as those near the surface. However, techniques are improving all the time. These enable the ebb and flow in blood vessels to be monitored continuously.

More recently, attention has been directed particularly towards ERPs 'event related potentials', and MRI 'magnetic resonance imaging'. These techniques are non-invasive, in that nothing needs to be injected into the body, which can simply be scanned. They are therefore potentially safer, and can be used with a wider range of people.

ERPs monitor electrical activity in the brain, following some stimulus (an 'event') such as reading a sentence. Electrodes are placed on the scalp, and the reaction, the ERP ('event related potential') is measured. The brain responds differently to syntactic and semantic ill-formedness, for example, showing that a division between the two has some type of 'reality' for speakers of English (Kutas and van Petten 1994).

MRI ('magnetic resonance imaging') exploits the finding that human heads and bodies contain hydrogen atoms which can be (temporarily and safely) re-aligned by means of the MRI machine's magnetic field. Images of the brain are produced by taking photos of cross-sectional 'slices'. These are far clearer and more precise than any previous attempts at picturing the brain. They confirm that a huge amount of activity takes place continuously.

The brain is therefore like an ever-bubbling cauldron, seething non-stop. Neurons are organized into complex networks: 'The language areas may be understood as zones in which neurons participating in language-related cell assemblies cluster to a much higher degree than in other areas' (Müller 1996: 629). But connections matter quite as much as locations, with far more buzzing between areas than was previously realized. So *connectionism* is the general name for this type of theory about how the mind works, largely inspired by all this work on the brain. Multiple parallel links are turning out to be the norm in any mental activity, and especially in language. 'Mental operations appear to be localized, but performance of a complex task requires an integrated ensemble of brain regions' (Fiez *et al.* 1992: 169).

Patting one's head and rubbing the stomach

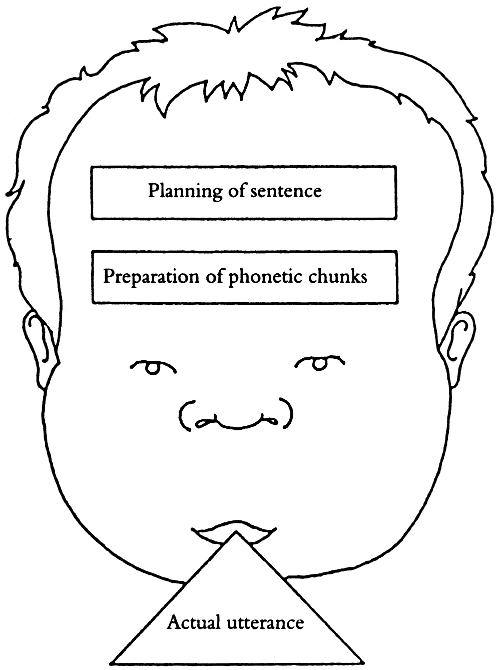
As all this new work confirms, a type of biological adaptation which is not so immediately obvious – but which is on second sight quite amazing – is the 'multiplicity of integrative processes' (Lashley 1951) which take place in speech production and comprehension.

In some areas of activity it is extremely difficult to do more than one thing at once. As schoolchildren discover, it is extraordinarily hard to pat one's head and rub one's stomach at the same time. If you also try to swing your tongue from side to side, and cross and uncross your legs, as well as patting your head and rubbing your stomach, the whole exercise becomes impossible. The occasional juggler might be able to balance a beer bottle on his nose, twizzle a hoop on his ankle and keep seven plates aloft with his hands – but he is likely to have spent a lifetime practising such antics. And the exceptional nature of these activities is shown by the fact that he can earn vast sums of money displaying his skills.

Yet speech depends on the simultaneous integration of a remarkable number of processes, and in many respects what is going on is considerably more complex than the juggler's manoeuvres with his beer bottle, plates and hoop.

In speech, three processes, at the very least, are taking place simultaneously: first, sounds are actually being uttered; second, phrases are being activated in their phonetic form ready for use; third, the rest of the sentence is being planned. And each of these processes is possibly more complicated than appears at first sight. The complexities involved in actually pronouncing words are not immediately apparent. One might assume that in uttering a word such as GEESE one first utters a G-sound, then an EE-sound, then an S–sound in that order. But the process is much more involved.

First, the G-sound in GEESE differs quite considerably from the G in GOOSE. This is because of the difference in the following vowel. The speaker appears to anticipate (subconsciously) the EE or OO and



alter the G accordingly. Second, the vowel in GEESE is shorter than in a word such as GEEZER. The speaker is anticipating the voiceless hissing sound of S in GOOSE rather than the voiced, buzzing sound of Z in GEEZER, since in English (and some other languages) vowels are shortened before voiceless sounds (sounds which do not involve vibration of the vocal cords).

Therefore a speaker does not just utter a sequence of separate elements:

1	2	3
G.	EE.	SE.

Instead he executes a series of overlapping actions in which the preceding sound is significantly influenced by the sound which follows it:

G . . .
    EE . . .
        SE . . .

Such overlapping requires considerable neuromuscular co-ordination, particularly as the rate of speech is often quite fast. A normal person often utters over 200 syllables a minute. Meanwhile, simultaneously with actually uttering the sounds, a speaker is activating phrases of two or three words in advance in their phonetic form. This is shown by slips of the tongue, in which a sound several words away is sometimes accidentally activated before it is needed. The linguist who once said PISS AND STRETCH in a lecture for 'pitch and stress' was already thinking of the final -SS of 'stress' when he started to say the first word. And the person who said ON THE NERVE OF A VERGEOUS BREAKDOWN had also activated the syllable 'nerve' before she needed it.

PITCH AND STRE$\boxed{\text{SS}}$

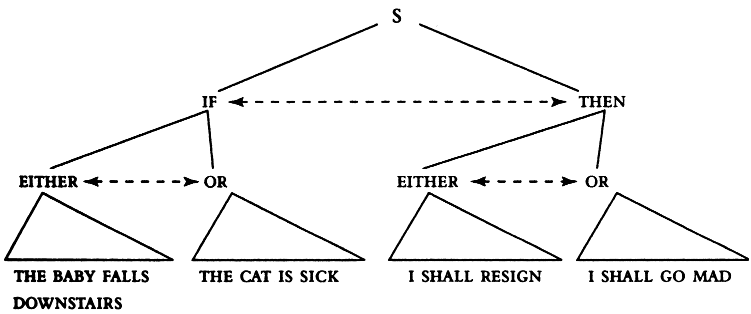
VERGE OF A $\boxed{\text{NERV}}$OUS BREAKDOWN

If humans only spoke in three or four word bursts, perhaps the prior activation of phrases would not be very surprising. What *is* surprising is that this activation is going on at the same time as the planning of much longer utterances. Lenneberg (1967: 107) likens the planning of an utterance to laying down a mosaic:

> The sequence of speech sounds that constitute a string of words is a sound pattern somewhat analogous to a mosaic; the latter is put together stone after stone, yet the picture as a whole must have come into being in the artist's mind before he began to lay down the pieces.

Sometimes, sentences are structurally quite easy to process as in THE BABY FELL DOWNSTAIRS, THE CAT WAS SICK, AND I'VE RESIGNED. At other times they are considerably more complex, requiring the speaker and the hearer to remember quite intricate interdependencies between clauses. Take the sentence IF EITHER THE BABY FALLS DOWNSTAIRS OR THE CAT IS SICK, THEN I SHALL EITHER RESIGN OR GO MAD. Here, IF requires a dependent THEN, EITHER requires a partner OR. In addition, FALLS must have the right ending to go with BABY, and IS must 'agree' with CAT – otherwise we would get *IF EITHER THE BABY

FALL DOWNSTAIRS OR THE CAT ARE SICK . . . This whole sentence with its 'mirror-image' properties must have been planned considerably in advance.



These examples show that in most human utterances, the amount of simultaneous planning and activity is so great that it seems likely that humans are specially constructed to deal with this type of co-ordination. But what type of mechanism is involved? In particular, how do humans manage to keep utterances in the right order, and not utter them in an incoherent jumble, as they think of them? How do most people manage to say RABBIT quite coherently, instead of BARIT or TIRAB – examples of misordering found in the speech of brain-damaged patients?

Lenneberg (1967) suggests that correct sequencing is based on an underlying rhythmic principle. Everybody knows that poetry is much easier to remember than prose because of the underlying 'pulse' which keeps going like the ticking of a clock:

> I WANDERED LONELY AS A CLOUD
> (ti-tum-ti-tum-ti-tum-ti-tum)
>
> THAT FLOATS ON HIGH O'ER VALES AND HILLS
> (ti-tum-ti-tum-ti-tum-ti-tum)
>
> Wordsworth

There may be some underlying biological 'beat' which enables humans to organize language into a temporal sequence. Breakdown of this beat might also account for the uncontrollable acceleration of speech found in some illnesses such as Parkinson's disease. Lenneberg suggests that one-sixth of a second may be a basic time unit in speech production. He bases his proposals on a number of highly technical experiments, and partly on the fact that around six syllables per second seems to be the normal rate of uttering syllables. However, some people have queried the notion of a fixed 'pace-maker', and suggested that the internal beat can be re-set at different speeds (Keele 1987). This may be correct, since with practice speech can be speeded up, though the relative length of the various words remains the same (Mackay 1987).

Intelligence, sex and heredity

Can studies of the brain clarify how language relates to intelligence? A bit, but not very much. Intelligence is a complex fabric of interwoven skills. Exactly where (if anywhere) each is located is highly controversial. The most we can say is that certain aspects of intelligence, such as judgements of space and time, are largely independent of language. Sufferers of a strange disorder known as Williams Syndrome lack spatial awareness, and find it hard to draw a picture of an elephant or a bicycle. Instead, they draw bits and pieces which they cannot assemble. In contrast, their speech is fluent: 'What would you do if you were a bird?' one sufferer was asked. 'I would fly where my parents could never find me. Birds want to be independent' was the answer (Bellugi, *et al.* 1991: 387).

Sex differences in the brain are also important for language. Women, on average, have greater verbal fluency, and can more easily find words that begin with a particular letter. Men are better at spatial tasks and mathematical reasoning. These variations probably reflect different hormonal influences on developing brains (Kimura 1992).

Heredity is another topical issue (Gopnik 1997; Stromswolo 2001; Fisher 2006). Can language defects be handed down from generation to generation? Dyslexia, or 'word blindness', often runs in families. So does another puzzling language problem. Several families have been found of whom a proportion of their members cannot put endings on words, the most famous of whom are known as the 'KE family' (Gopnik 1994; Gopnik *et al.* 1997). ZACKO was given as the plural of the nonsense word ZAT by one sufferer, and ZOOPES as the plural of the nonsense word ZOOP. Those affected have to learn each plural separately, and they find it impossible to learn a general rule such as 'Add-S'. They also find it hard to use pronouns, and tend to repeat full nouns, as: 'The neighbours phone the ambulance because the man fall off the tree. The ambulance come along and put the man into the ambulance' (Gopnik and Crago 1991). At first, optimistic researchers hoped that they had found a gene for language, and even provisionally labelled it the SPCH1 gene. Later, it was realized that the affected members in the KE family (and some other families) had a cluster of language problems, as well as some non-linguistic ones. The defective gene, eventually labelled FOXP2, is still being investigated by researchers, and the details are proving complex (Lal *et al.* 2001). As well as difficulties with inflections, the affected family members are unable to break down words into their constituent sounds, and they also have problems with the sequencing of mouth movements.

Mind-reading and mirror neurons

As researchers puzzle over exactly why humans are such competent language users, new findings have emerged, which may turn out to be of vital importance. Humans have an ability to 'mind-read', to put themselves into another person's shoes, as it were, and envisage their mental state (p. 35). Mind-reading is an awareness that develops with age: 3-year-olds are typically unable to achieve it, but 4-year-olds can normally do so without difficulty. This trait is lacking in those who suffer from the mental disorder of autism, a condition sometimes known as 'mindblindness' (Baron-Cohen 1999; Ramachandran and Oberman 2006). There seem to be layers of mind-blindness. Chimps have some inkling of mind-reading (Chapter 2), though not the same level of awareness as normal humans. This has led researchers to probe into the neurological background behind this ability

An intriguing discovery is that of so-called 'mirror neurons', which according to some researchers, may underlie the ability to understand another person's intentions, and also the ability to imitate. Mirror neurons have been found both in humans and monkeys. An Italian neuroscientist, Giacomo Rizzolatti, is credited with their discovery (Rizzolatti and Arbib 1998). He noticed that a section of the frontal lobe of a monkey's brain fired when it performed certain actions, such as reaching for an object or putting food in its mouth. But bizarrely, the same neurons would fire when it watched another monkey performing the same actions. Rizzolatti labelled these 'mirror neurons' and speculated that he may have identified the neurological basis of mind-reading. Later work has emphasized the importance of mirror neurons in imitation, a skill at which humans seem to be better than apes, and may be crucial in language learning. (Rizzolatti *et al.* 2006), and also their possible role in the evolution of language (Stamenov 2002).

We do not yet know all the details, but the overall picture is clear. Humans are physically adapted to language in a way that snails, sheep and even apes are not. Their vocal organs, lungs and brains are 'pre-set' to cope with the intricacies of speech in much the same way that monkeys are pre-set to climb trees, or bats to squeak. Chapter 4 gives further evidence of this biological programming by showing that language follows an inner 'time-clock' as it emerges and develops.