The Swiss army knife model of the mind

Cosmides and Tooby are fond of using a Swiss army knife to illustrate their concept of the adapted mind. Just as such a knife has many different blades, each shaped for its specific purpose, so the mind, they claim, is composed of many different modules, each evolved for a different adaptive purpose (Horgan 1995; Barkow et al. 1992). A common reaction on seeing such a knife is to wonder, not just at how many strange blades and attachments it has, but what they could be for: trying to reverse-engineer it, in other words.

To the extent that a Swiss army knife comprises many different blades, it makes a passable analogy with the many different components which we now suspect underlie something like IQ. In part, the Swiss army knife metaphor has been put forward as a corrective to the idea that the mind was a general purpose learning device that could be taught more or less anything because cognitive skills were general, rather than specific.

The problem with using a Swiss army knife as a metaphor for the 'adapted mind' is similar to the one discussed just now that arises when adaptations are defined in terms of how 'well designed' they appear to be to fulfil their function. It suggests that, just as each blade in such a knife is optimally engineered from scratch for just one application, so each 'module' of the mind has been specifically designed by adaptive evolution for its proper purpose. In his account of evolutionary psychology, Wright observes that, faced with having to explain instances of remembering and forgetting, the evolutionary psychologist 'can relax and come up with different explanations for each one' (Wright 1994: 320). Mental modules, it seems, like Swiss army knife blades, can be made to order. The question is: to whose order – evolution's or evolutionary psychologists'?

Darwin saw adaptations more as swords beaten into ploughshares

Although many evolutionary psychologists make much of their self-proclaimed Darwinism, it is important to point out that Darwin's own view of how evolution went about meeting adaptive needs was very different from that suggested by a Swiss army knife:

> If a man were to make a machine for some special purpose but were to use old wheels, springs and pulleys, only slightly altered, the whole

> machine, with all its parts, might be said to be specially contrived for its present purpose. Thus throughout nature almost every part of every living being has probably served, in a slightly modified condition, for diverse purposes, and has acted in the living machinery of many ancient and distinct specific forms. (Darwin 1886: 283)

In this quotation Darwin compares natural selection to someone using pieces of old machinery to make something improvised from existing parts rather than to producing a pristine artefact made from raw materials like the blades of a Swiss army knife. Inevitably, natural selection has to work by modifying an existing, working design, and can only innovate on the basis of what is there already. Taking Darwin's view of the matter, beating a sword into a ploughshare would be a better analogy than the blades of a Swiss army knife.

Although the belief that the brain is a general purpose learning device has been discredited, there is much evidence for plasticity in the brain's internal organization and development. For example, research by V. S. Ramachandran and others on phantom limbs (that is, limbs that have been amputated but still generate sensations such as pain) implies that new pathways that are precisely organized and functionally effective can emerge in the adult human brain in less than three weeks (Ramachandran 1994).

These findings have possible relevance to language, which evolutionary psychologists claim is both a unique human adaptation, and one based on distinct mental modules (Pinker 1994). Gesturing with the hands emerges in young children before the development of language, and is even reported in phantom limbs in the case of a woman born without arms (Ramachandran and Blakeslee 1998)! Linking such movements with speech is found in all parts of the world and in association with all languages. One possible explanation is that these are simply social conventions, learnt by imitation in childhood. However, experiments show that people who have been blind since birth use exactly the same kinds of gestures that sighted people do, and in exactly the same way. Another possibility is that people use gestures to add to what they are saying as a kind of visual aid. But when people speak to listeners who are blind they gesture just as much, even though they know that the person to whom they are speaking can't see what they are doing with their hands (Iverson and Goldin-Meadow 1998). Nevertheless, experiments in which people are asked to describe a story with or without the use of their hands reveal that subjects remember the details better if they are allowed to gesture while they speak (Cohen 1998).

This suggests that the primary function of gesturing might not be to communicate with others so much as to facilitate the speaker's use of language (a possibility also suggested by the common observation that when people are having difficulty with what they are trying to say they tend to gesture much more). Brain-imaging certainly suggests considerable overlap between language, motor control and other centres in the brain. Other recent studies suggest that words may be encoded in different parts of the brain, depending on their meaning and associations: words referring to movement, for example, could be coded in the motor cortex, while hearing-related words may be stored in the auditory parts of the cortex (Motluk 1998). If language evolved fairly recently out of parts of the brain that originally did other things, such findings might be easily explained. Evolution might indeed be using older, more basic cerebral functions for language, just as Darwin believed that it would. To this extent, a language 'module' would certainly be more like a sword beaten into a ploughshare than the purpose-built blade of a Swiss army knife.

Ramachandran concludes from his studies of phantom limbs that

> there must be a great deal of back and forth interaction between vision and touch, so that the strictly modular, hierarchical model of the brain that is currently in vogue needs to be replaced with a more dynamic, interactive model. . . . This result flatly contradicts the view held by the AI [artificial intelligence] community that the brain is composed of a number of autonomous 'modules' that sequentially perform various 'computations' on the sensory input. . . . our results are much more consistent with the dynamic, interactive view of the brain. . . . we must give up a strictly hierarchical, modular view of the brain . . . and replace it with a more dynamic, interactive model. (Ramachandran and Rogers-Ramachandran 1996)

The triune brain

According to a theory put forward by Paul D. MacLean, the three fundamental parts of the brain each reflect a different stage in brain evolution, so that evolutionary constraints may affect its architecture and function, just as they do the features of the human body discussed earlier (MacLean 1990).

1 The brain stem, or reptilian brain You could compare the central nervous system to a tree, and the nerves that run throughout the body to its roots. These come together in the trunk, which would correspond to the spinal chord. The top of the trunk would be the brain stem or what MacLean calls the 'reptilian brain' (figure 1.1). This controls basic functions such as breathing, circulation and digestion. According to MacLean, the largely automatic functions of the brain stem evolved in reptiles some 300 million years ago, and have remained the basis of the brain in all subsequent animals that evolved from them. The responses of the reptilian brain are instinctual, and concerned with typical reptilian behaviours, such as territoriality, self-defence, asserting dominance, aggression and mating.

2 **The limbic system, or palaeo-mammalian brain** The lower limbs of the tree that emerge from the top of the trunk correspond to what MacLean calls the 'palaeo-mammalian brain' by contrast to the reptilian one. This is more often called the *limbic system* (not because it has anything to do with limbs, but because some writers saw it forming the rim or margin – *limbus* in Latin – to the rest of the brain: figure 1.1). The limbic system comprises a number of main parts, each serving different functions. Some are closely associated with the sense of smell and have proved to be involved in oral and genital functions so

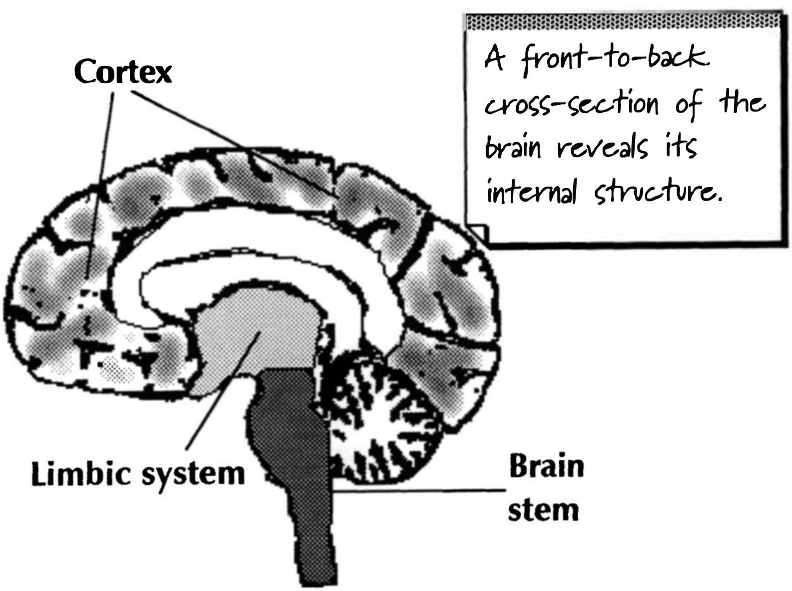

Figure 1.1 The cortex, limbic system and brain stem

that these parts of the brain have also been called the 'visceral brain' or *rhinencephalon* – literally, the 'smell-brain'.

The limbic brain is 'mammalian' to the extent of being concerned with temperature control (mammals, of course, are warm-blooded), parental care (another mammalian speciality), vocal communication, play and long-term memory (all found in mammals more than in reptiles). Numerous findings, such as the clinical study of epilepsy and direct stimulation of the brains of conscious patients during surgery, provide good evidence that the limbic system is involved in the experience and expression of emotion. Many authorities see the limbic system as the main cerebral representative of the internal state of the organism, expressed in the form of emotions and motivation. For these reasons the limbic system is sometimes called the 'emotional brain' (LeDoux 1996).

A critical part of the emotional brain is the *amygdala*. This is an almond-sized component of the limbic system that triggers the fight-or-flight reflex that primes the body for whichever response the higher brain centres decide is appropriate. The amygdala is the link between sensory systems and fear responses. Fear conditioning occurs in all animals, and in all those that have an amygdala, the amygdala appears to be the key. The list includes reptiles, birds and a host of mammals, including humans. Indeed, the amygdala has been called 'the heart and soul of the fear system' (LeDoux 1996). In human beings, direct electrical stimulation of the amygdala produces sensations of anxiety and apprehension (Gloor 1986). Brain-imaging research shows that when people are shown disturbing pictures the amygdala lights up immediately, and the same response is seen to faces registering fear – but not to those showing happiness (Morris et al. 1996). In cases of damage to the amygdala, emotionally loaded memories are impaired or distorted, suggesting that it plays a role in the storage and processing of emotional responses (Allman and Brothers 1994).

3 The neocortex or neo-mammalian brain The crown of a tree, and especially its foliage, might be likened to the final part of the brain, the neocortex, the highly convoluted, sponge-like covering of the brain. This 'new cortex' is so-called to distinguish it from the limbic cortex, which appears to be older in certain respects, at least from the evolutionary point of view, and certainly has not undergone the same dramatic expansion as the neocortex in recent evolution. The deep folds of the neocortex account for the fact that it has a surface area of about 2,500 square centimetres, despite being crammed inside a skull that is only 20 centimetres across. If you opened the cortex and flattened it out, it would correspond to a square 50 centimetres to a side – about the size of an open tabloid newspaper. Overall, it accounts for about two-thirds to three-quarters of all nerve cells in the human brain (figure 1.1).

The neocortex is connected to the senses and appears to be primarily concerned with reacting to the outside world. Much of it is given over to processing sensory inputs, especially from the eyes, ears and the surface of the body. This is the part of the brain that has to decide whether to fight or take flight after arousal by the limbic system. Mammals whose neocortices have been removed continue to live, but will not react very much to outside stimulation and appear to be incapable of initiating anything but the most basic behaviour. In human beings the neocortex is concerned with problem-solving, learning and detailed, conscious memory. Major parts of it are devoted to speech and verbal comprehension, so that on occasions it has been called the 'word brain' by contrast to the limbic system, which has been described as 'illiterate' (MacLean 1949). The neocortex is sometimes portrayed as the 'cognitive' or 'executive' brain because of its prime role in decision-making, intention and reasoning (Keverne et al. 1996a).

Evolutionary psychologists reject MacLean's theory

MacLean's 'triune brain' theory has not been accepted by all authorities, but, whatever reservations they might have about its details, you might have expected evolutionary psychologists to be prepared to consider it – at least as a rough approximation. After all, it is one of the few attempts that have been made to understand the structure of the human brain in terms of its evolution, and has many facts and findings to support it. You would have thought that evolutionary psychologists more than anyone else would be ready to at least consider the possibility that evolutionary constraints may have complicated the brain and produced elements of suboptimal design in the way in which they have so many other features of human anatomy.

But according to one account of evolutionary psychology, MacLean's theory fails to see that the forces of evolution do not just heap layers on an unchanged foundation but modify existing structures to present adaptive needs – a process which includes the older parts of the brain, as well as the new. Looked at from this point of view, the human cortex does not ride piggyback on an ancient limbic system or serve as the terminus for a processing stream beginning there. On the contrary, it works in tandem with it, integrated by many two-way connections.

The amygdala is a case in point, receiving not just simple signals from lower stations of the brain, but abstract, complex information from the brain's highest centres. The amygdala in turn sends signals to virtually every other part of the brain, including the decision-making circuitry of the frontal lobes. MacLean's evolutionary model of the brain is dismissed as a 'Romantic doctrine of the emotions . . . translated into an incorrect theory' (Pinker 1997: 370–2). It is certainly not what the reverse-engineered-Swiss-army-knife approach to the brain would lead you to expect.

Nevertheless, there is nothing necessarily Romantic or incorrect about MacLean's claim that our intellectual functions are carried out in the newest and most highly developed part of the brain, but that our emotional behaviour continues to be dominated by a simpler and more primitive system, which provides a clue to understanding the difference between what we 'feel' and what we 'know' (MacLean 1949).

To return to the amygdala as an example, the neuroscientist Joseph LeDoux has pointed out that neurological projections from the amygdala to the neocortex are much stronger than neocortical projections back to the amygdala. The implication is that the ability of the amygdala to control the cortex is greater than the ability of the cortex to control the amygdala. This may explain why it can be so hard to will away anxiety: emotions, once set into play, can be very difficult to turn off. Hormones and other long-acting substances released in the body during emotions can return to the brain and lock it into a particular state. Once in that state, it can be very difficult for the cortex to find a way of working its way down to the amygdala and shutting it off. Indeed, LeDoux suggests that psychotherapy may be such a long and difficult process because the neocortex is using imperfect channels of communication to try to control the amygdala. The amygdala can control the neocortex very easily, because all it has to do is arouse lots of areas in a very non-specific way. But for the cortex to then turn all of that off is a very difficult job (LeDoux 1997). Summarizing current brain research, LeDoux concludes:

> The remarkable fact is that at the level of behaviour, defense against danger is achieved in many different ways in different species, yet the amygdala's role is constant . . . When it comes to detecting and responding to danger, the brain just hasn't changed much. In some ways we are emotional lizards. I am quite confident in telling you that studies of fear reactions in rats tell us a great deal about how fear mechanisms work in our brains as well. (LeDoux 1996: 174)

In *The Origin of Species* evolutionary psychology got just a single sentence – and that was more of a hope than a statement of fact: 'Psychology', wrote Darwin in 1859, 'will be based on a new foundation, that of the necessary acquirement of each mental power and capacity by gradation.' If LeDoux is right about the amygdala, Darwin's expectation would be wholly justified in the case of basic emotions such as fear. If we are in some ways close to reptiles in our fear reactions, it is because natural selection has indeed beaten the sword of our animal ancestors' amygdalas into the ploughshare of an emotional brain that we still have today. What it has not been able to do is to manufacture a purpose-made Swiss army knife blade specifically for the purposes of having distinctively human fear reactions. On the contrary, a genuinely Darwinian evolutionary psychology would suggest that in our emotions perhaps more than anywhere else we would have retained much of our evolutionary past, with fewer gradations separating us as feeling organisms from our ancestors than some evolutionary psychologists might suppose.

To put it another way, you could say that LeDoux's point is that the amygdala-neocortex connection is a bit like the eye. From the point of view of connectivity to the cortex at least, it is the wrong way round. But, having started out that way long before the human neocortex evolved, we are stuck with something that evolutionary psychology evidently has difficulty accepting: primitive emotional responses built into the brain irrespective of optimal design for cognition.[6]

The benefits of human brain evolution

Seeing something as adaptive has often been criticized as little more than evolutionary story-telling, because it is not difficult to think up adaptive explanations, and often there seems no reason to prefer one adaptive interpretation over another (S. J. Gould and Lewontin 1979). Nevertheless, adaptationist theorizing can be kept within realistic limits if – and only if – questions are asked and satisfactorily answered about both the costs and the benefits of adaptations, and about the evidence on which such answers are based. Nowhere are such issues more critical or important for evolutionary psychology than in relation to the organ on which our evolved psychology relies – the brain.

Human brain expansion has been one of the fastest and most astonishing developments in evolution. Expressed as a ratio of actual brain size to that of an average ape or monkey of similar size, or *encephalization quotient*, chimpanzees have a quotient of 2.0, early humans 3.1, and modern ones 5.8 (Lewin 1993). In two to three million years, the volume of the human brain increased threefold from approximately that found in modern apes (about 450 cc) to its present value (about 1350 cc), while the cortex increased to account for 70 to 80 per cent of the total. According to some authorities, this increase was not continuous, but may have been interrupted by a long static period between about 1.8 million and 150,000 years ago (Ruff et al. 1997). The trend was exponential: in other words, it increased like compound interest, rather than by simple addition (Henneberg 1987). By comparison, average human height increased by only about a quarter, and weight by approximately 70 per cent in four million years (Mathers and Henneberg 1996).

Many attempts have been made to find the cause of brain evolution. Examples are: hunting, tool use, warfare, language, social life, sexual conquest, consciousness, politics and so on. These theories assume that the brain is to human achievement in these respects what the wing of a bird is to its ability to fly: an organ exquisitely adapted to a particular useful function. All of these theories take it for granted that the evolutionary benefits of whatever they propose explain why the brain evolved to facilitate it. They assume that those with just a little more grey matter devoted to tool-making, talking, consciousness or whatever, would have left slightly more descendants who inherited that critical ability than others with less brain in the right place. Their descendants in turn would have had slightly more descendants if they had possessed even more of the little grey cells where it most mattered, and so on. The trouble with such explanations is that they are always ultimately a question of interpreting the results of evolution, and often one interpretation looks as good as another.

You can get round the problems of specific adaptations for brain development by appealing to a general selective trend, for example for increased intelligence. A difficulty here is the finding that humans and other closely related members of the order of primates, such as apes and monkeys, do not grow their brains faster than other mammals, but grow their bodies slower. From an early embryonic stage, primates have smaller bodies than you would expect for their age. The apparent increase in relative brain size in primates is more accurately described as a decrease in relative body size. This poses a serious challenge to the traditional view of primate evolution as characterized by selection for increased intelligence. If primates were selected for increased intelligence, why should this produce a change in body growth but not brain growth (Deacon 1997)?

One of the most plausible and well-argued theories to have been advanced recently is Robin Dunbar's theory linking brain growth, group size and language. According to him, animals cannot maintain the cohesion and integrity of groups larger than a size fixed by the information-processing capacity of their brain. He argues that social networks function as coalitions whose main purpose is to buffer their members against harassment by the other members of the group. The larger the group, the more harassment and stress the individual faces and the more important these coalitions are. A coalition's effectiveness (in the sense of its members' willingness to come to each other's aid) seems to be directly related to the amount of time its members spend grooming each other. Hence, the larger the group, the more time individuals devote to grooming with the members of their coalitional clique (Dunbar 1993).

Dunbar goes on to propose that in human beings grooming has been supplanted by gossip, and that language evolved to allow us to gossip. Plotting the size of the part of the human brain involved with speech and consciousness – the neocortex – against time spent in grooming/gossip, he concludes that the primary human social network numbers about 150, and claims that this is the typical size of effective social units found in armies, business organizations and societies in general. Nevertheless, we are still left with the puzzling question of what drove the increase in group size. Dunbar candidly admits that he doesn't really know, but suggests as possible answers social and environmental factors to do with vulnerability to predators, and the sizes of groups needed to colonize new areas of the world (Dunbar 1996).

Brain expansion has ceased, and we don't have the largest brains

Most of the big-brains-evolved-to-enable-us-to-do-this-that-or-the-other theories are put in doubt by the fact that the now long extinct Neanderthals had larger brains than modern humans – and certainly didn't have significantly smaller ones (R. D. Martin 1983). According to Dunbar's theory, this would indicate group sizes as large or even larger than that of modern humans, and if these are in turn linked to colonization or an ability to resist predators, you wonder why today the world isn't full of Neanderthals.

Again, there is good evidence that brain growth in living humans has not increased in recent times. Indeed, the data suggest that brain size may actually have declined by a factor of about 10 per cent in the last 30,000 years (Henneberg and Steyn 1993). Yet human beings have done much more with their brains since brain growth appears to have stopped and gone into reverse, and many human groups have grown markedly with cultural advances such as agriculture and urbanization. You would think that if selection selected for large brain size in order to allow human beings to apply their brains in larger social groupings, a burst in new brain applications represented by technological, cultural and social advances would have gone with a further increase in brain volume – especially if brain and group size were correlated in the way suggested by Dunbar.

But brain size simply hasn't increased in this way during recent history. On the contrary,

> there may be no very tight relationship between relative brain size and specific behavioral capacities. The latter may be far more dependent on the internal wiring of the brain rather than its overall size. While it is undoubtedly true that large brains are generally superior to small brains, no convincing case has been made for the proposal that any particular feature of behaviour (e.g., feeding ecology, complexity of social organization) has exerted a specific selection pressure for favouring an increase in brain size . . . when the effects of confounding variables such as body size and socio-economic status are excluded, no correlation is found between IQ and brain size among modern humans. Until some behavioral advantage of increased brain size per se has been demonstrated, there is no basis for arguing that specific selection pressures have favoured the development of a very large brain in humans. (R. D. Martin 1996: 155)

As long ago as 1966 George Williams candidly admitted that

> Despite the arguments that have been advanced, I cannot readily accept the idea that advanced mental capabilities have ever been directly favored by selection. There is no reason for believing that a genius has ever been likely to leave more children than a man of somewhat below average intelligence. It has been suggested that a tribe that produces an occasional genius for its leadership is more likely to prevail in competition with tribes that lack this intellectual resource. This may well be true in the sense that a group with highly intelligent leaders is likely to gain political supremacy over less gifted groups, but political domination need not result in genetic domination, as is indicated by the failure of many a ruling class to maintain its members. (Williams 1966: 14–15)

The standard response to such criticisms is to point out that where brain development is concerned size isn't everything, and that it is the relative expansion of areas of the human brain – such as the prefrontal cortex – that really counts. In humans the prefrontal cortex amounts to some 30 per cent of the cerebral hemispheres, and is known to be the site of many distinctively human mental capacities, such as social awareness, conscience and self-restraint.

However, in the case of the *echidna*, or spiny ant-eater *(Tachyglossus aculeatus)*, an allegedly 'primitive', marsupial mammal, the prefrontal region takes up a remarkable 50 per cent of the cerebral cortex as a whole, proportionately more than in any other animal (Augee and Gooden 1993). According to one authority, if human beings had brains with a prefrontal cortex the size of the echidna's, we would have to carry them around in wheelbarrows (Winson 1985)! Writing as long ago as 1902, an authority on brain evolution confessed that the reason the echidna has this large prefrontal neocortex 'is quite incomprehensible. The factors which the study of other mammalian brains has shown to be the determinants of the extent of the cortex fail completely to explain how it is that a small animal of the lowest status in the mammalian series comes to possess this large cortical apparatus' (Griffiths 1968: 101). Today the situation is no different, and the echidna continues to confound adaptationist theories of brain evolution.

However obvious the benefits of human brain evolution may be to most people, scientifically credible explanations are currently unknown, and no single theory has given either a completely convincing answer or one that is universally accepted. An honest answer would be that, although some impressionistic and approximate reasons may be known, no rigorous account of human brain evolution has yet been given, despite a century of unremitting effort. The truth is that, contrary to the assumptions of reverse-engineering evolutionary psychologists, we don't really know why the human brain evolved, what purpose it evolved to serve, precisely who or what benefited from it, how they or it benefited, or why. Given that the brain is the key organ as far as evolutionary psychology is concerned, failure to establish credible and generally accepted answers to these questions leaves the whole undertaking completely without a foundation and makes the reliance of evolutionary psychology on dubious adaptationist argumentation even greater.

The costs of human brain evolution

One of the things that makes adaptationist story-telling most dubious of all is its tendency to concentrate on the presumed benefits of an alleged adaptation without considering the inevitable costs that it will also impose. If we now turn to the question of the costs of the brain as an adaptation, we once again find that the picture is far from simple, and its meaning by no means as clear as the more simple-minded adaptationist explanations would suggest.

In terms of its energy consumption, the brain consumes up to ten times more than the average of the whole human body. Unlike other tissues, the brain can only burn pure glucose, while having little capacity to store significant reserves. Although only 2 per cent of body weight, the brain consumes 20 per cent of the available oxygen and glucose, and even more in childhood. At birth the brain represents 10 per cent of total weight but consumes up to 65 per cent of the body's energy, while only 8 per cent of an infant's total metabolic rate is devoted to muscle tissue (Holliday 1978). In the first year and a half of life a human infant needs almost 10 per cent more energy per day to run its brain than a chimpanzee of the same size. At six years of age the brain's consumption of total oxygen intake peaks at about 50 per cent. If you replaced the brain with a light bulb, it would be rated at just under 15 watts (the wattage of a refrigerator light). The ever-beating heart, by comparison, would radiate at 10 watts, and the skin would barely glow at one-and-a-half. Energy consumption always produces heat as a by-product, and the human head has been engineered by evolution to radiate away as much of it as possible through a complex system of veins and an ability to sweat profusely (Falk 1992).

So significant is the energy cost of the brain that some believe that economies have had to be made elsewhere in the human body to accommodate it. The digestive tract also uses a lot of energy, but its total mass is only 60 per cent of what you would expect to find in an ape or monkey of similar size to a human being. The increase in mass of the human brain appears to have been balanced by an almost identical reduction in the length of the intestines. This in its turn suggests that, whatever may have driven human brain size enlargement, it was accompanied by an increasing reliance on a high quality, meaty diet that could be digested efficiently by a shorter gut, in its turn aided by food-processing and cooking skills made possible by the expanded brain (Aiello and Wheeler 1995).

Finally, the large size of the human brain imposes significant costs in the form of obstetric complications. The longest axis of the foetal head only just fits the widest axis of the human mother's birth canal. In order to allow the minimum cross-section to pass through the maximum diameter of the outlet, the foetal head must rotate from facing sideways to facing towards the back of the mother as the baby squirms through the narrow opening. Because the human foetus emerges from the birth canal facing in the opposite direction from its mother, it is difficult for the mother, whatever her position, to reach down as ape and monkey mothers often do to clear a breathing passage for the infant or remove the umbilical cord from around its neck. If a human mother tries to assist in the delivery by guiding the infant from the birth canal, she risks damaging the baby. However, expansion of the diameter of the mother's birth canal also imposes costs in terms of the efficiency of walking, so that evolution has had to strike a balance between the obstetric constraints imposed by human brain enlargement and those dictated by the adoption of an upright posture. The result is that the fit between the human pelvic opening and the typical newborn baby's head is a tight one. Largely thanks to this, human birth is painful, difficult and dangerous – and yet another example of distinctly suboptimal adaptive design.

Thanks to the constraints of having to give birth to a large-brained baby through a narrow pelvic canal, three-quarters of human brain growth has to take place after birth, rather than before it. This in its turn results in human newborns being notably retarded in their development by comparison with other primates. Whereas most monkeys are sufficiently developed to actually assist their own birth once their hands are free, human newborns are totally passive, not just during birth, but for some considerable time afterwards. This long period of helplessness in turn imposes huge costs on the mother, who must compensate by nurturing the baby much more intensively and for much longer than any other primate (Rosenberg and Trevathan 1996).

The costs of human brain development fall on the mother

The importance of considering cost as well as benefit in evolutionary explanation is illustrated by the *maternal energy hypothesis*. Once again, this raises complications glossed over by most adaptationist accounts, and highlights the very different way that the costs of brain development fall on individuals. While adaptationist accounts usually assume that everyone benefits from a large brain, they notably fail to point out that some individuals pay much more of the cost than others, and completely fail to advance any credible adaptive explanation of why this should be so.

Because most of the growth in size of the brain has taken place by the time of weaning in mammals, recent research has found that the size attained by the brain is dependent on the input made by the mother during gestation and lactation. This suggests that it is the mother's energy turnover that primarily constrains the final brain size achieved by her offspring. According to this way of looking at it, all mammals have the largest brains that are compatible with the resources available to their mothers during gestation and lactation (Martin 1996). Indeed, it has even been suggested that the recently discovered 3–5 per cent shrinkage in the size of the mother's brain at the end of pregnancy may be because human mothers not only contribute the greatest amount of free resources they can to building their babies' brains, but even raid their own brains in doing so (Horrobin 1998). (See box 6.3, 'Why breast is best', pp. 215–16 below.)

In the case of human brain development, one of the critical questions is: why should mothers pay the exorbitant costs of human brain development, rather than anyone else? Any rigorous theory of human brain evolution ought to be able to answer this question, but it is seldom asked and even more rarely answered – least of all by reverse-engineering evolutionary psychology.[7]

~~The evolutionary psychology of evolutionary psychology~~

~~Whatever the truth about its evolution, it would be naive to think that the human brain was in any way specifically adapted to understand evolution in general, or evolutionary psychology in particular. On the contrary, the likelihood is that natural selection would have built into the human mind attitudes and capabilities primarily concerned with individual survival and reproductive success in primal hunter-gatherer societies. One of the most important of these would probably be a feeling of your own significance and of the necessity of your own survival. The problem here is that, looked at objectively, any individual human being in the past would only be in the order of a millionth part of the human race, and so, as far as evolution is concerned, probably next to totally insignificant. (And of course, today, with billions of people on the planet, the problem is a thousand times worse!)~~

~~The result is that individual human beings suffer from a psychological myopia where their own existence and importance in the grand evolutionary scheme of things is concerned. They see themselves and their immediate environment clearly, but their minds cannot grasp the vast expanses of other humans and evolutionary time that surround them. But this is exactly what you have to grasp in some fashion if evolutionary insights are to be credible. Again, the mindless cruelty of~~