

The Evolution of Human Cleverness

RICHARD HALLAM



'Prof. Hallam has written a unique and most interesting book on evolution. What is unique about this book is the psychological perspective applied to help us understand modern human evolution. In addition to traditional genetic and anatomical topics Hallam helps us understand how human evolution has been shaped by social and psychological processes from early hominins to the present. His introduction to the human characteristic of *cleverness* and its development in the context of multiple evolutionary processes is both unique and brilliant. The text consists of 81 relatively brief and interesting sections on topics that can be read in nearly any order to form a meaningful Gestalt or mosaic without overtaxing the reader's ability to attend, comprehend, or focus. The book is most informative and is a pleasure to read without requiring any special knowledge or background.'

Glenn Shean, *PhD, Professor of Psychology Emeritus, College of William and Mary, Williamsburg, VA, USA*

'The book is a panoramic and comprehensive survey of contemporary knowledge and debate on the subject of the evolution of human cleverness. Its content is structured in encyclopaedic fashion, with entries covering the topic from multiple perspectives. The style is lucid and concise, guiding the reader in masterly fashion through a complex maze of theory, fact, and speculation. The book offers the reader a rich, worthwhile, and illuminating voyage.'

Ariel Stravynski, *Professeur Honoraire, Département de Psychologie, Université de Montréal, Canada*

'Ever wonder what makes humans so clever? Read this book and you'll find out. It tells the evolutionary story of how our abilities emerge, what they enable us to do and how our cleverness is now impacting the whole planet. The question is: Can we use our cleverness to solve the problems we have created for ourselves in time to preserve our fragile world? Richard Hallam's book details the tools we have at our disposal, we just need to use them. A marvellous book, highly recommended.'

Freddy Jackson Brown, *Consultant Clinical Psychologist, North Bristol NHS Trust Associate Fellow, Centre for Educational Development, Appraisal, and Research, University of Warwick*

'As in his other books, Hallam's talent is in making clear how things are complex. This is not to say that we are missing the juice of the matter, or that the picture is confused: On the contrary, in this book one can find clearly set out strong proposals concerning all we can reasonably know about human cleverness but, fortunately, one can also find all we don't know about it, and all we can't probably know.'

Adriano Bugliani, *PhD, Assistant Professor, History of Philosophy, University of Firenze, Italy*



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The Evolution of Human Cleverness

The Evolution of Human Cleverness presents a unique introduction to the way human cognitive abilities have evolved. The book comprises a series of mini-essays on distinct topics in which technical terms are simplified, considering how humans made the long journey from our ape-like ancestors to become capable of higher-level reasoning and problem-solving.

All the topics are cross-linked, allowing the reader to dip in and out, but certain key concepts run through the underlying reasoning. Chiefly, these are adaptation and selection, the distinction between ultimate and proximate causes of behaviour, gene-culture co-evolution, and *domain-general* versus *domain-specific* cognitive processes. The book should help the reader draw lessons for the human species as a whole, especially in view of the environmental threats to its own existence.

Entries have been carefully crafted to cut through scientific jargon, providing bite-sized and digestible chunks of knowledge, making the topic accessible for students and lay readers alike. The author draws on research from diverse fields including Psychology, Anthropology, Archaeology, Biology, and Neuroscience to provide an unbiased account of the field, making it an ideal text for students of all levels.

Richard Hallam worked as a clinical psychologist, researcher, and lecturer until 2006, mainly in the National Health Service and at University College London and the University of East London. Since then, he has worked independently as a writer, researcher, and therapist.



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Part 1

Introduction



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1 Aims

The evolution of hominin cleverness covers a vast area of knowledge in numerous academic disciplines. The task I have set myself for this book is to summarise a mosaic of somewhat disconnected islands of expertise that deal with different aspects of the subject. The concept of cleverness ties them together, and this concept is broader than intelligence. I have aimed to provide bite-sized chunks of knowledge in which technical terms are simplified. I do not focus too much on the historical origins of competing schools of thought. It is not possible to cover everything that is relevant. The work of integration is left largely up to the reader who can dip at will into any entry and follow the links to associated material. Despite the mosaic structure, the entries do link up and they all cast light on the subject.

It is a challenge to get to grips with this material, but the subject is of interest to almost everyone. Speculation about the way our earliest ancestors thought and behaved deals with a past so remote that agreement can hardly be expected. Scientists who prefer to deal with ‘the facts’ tend to study fossils and archaeological traces. One 850-page encyclopaedia of human evolution devotes only around 200 words to ‘cognition’, and there are no entries for consciousness or intelligence [591]. In a survey of expert opinion on evolutionary origins, all seven ‘unique human traits’ selected for the survey were of an anatomical nature [551].

My background is that of a behavioural psychologist and psychotherapist, not a biologist, and this is bound to influence the way I present some topics. I have given little consideration to neuroscience, and with regard to the cleverness of animals, I consider only humans’ nearest primate relatives, the two species of chimpanzee. I have tried to compensate for scant coverage by liberally referencing books and articles, each of which is numbered in the text, and listed at the end of the book. Each entry is fairly short, usually between 500 and 2,500 words, hopefully sufficient to whet the appetite but not too heavy on stomach or brain.

All entries have a bearing on the evolution of hominin cleverness. It is generally accepted that humans evolved from an animal that resembles the living great apes. The main thread tying the topics together is the evolutionary thinking first presented clearly by Charles Darwin. I will assume that our earliest ancestors evolved to become cleverer in order to deal with any problem thrown at them, and that this in some way furthered their survival and reproductive success. Of course, living humans do not always produce ‘clever’ solutions to problems, and the problems they pose are not always well chosen. For perhaps the first time in the evolution of the species, humans have become aware of the possibility of their own extinction, brought about by numerous unthinking actions. Human cleverness did not evolve to solve this kind of problem. In the vast expanse of

hominin evolution, our ancestors lived in relatively small groups and their cleverness seemed to be adapted to community living. Consequently, contemporary humans, living in huge populations, with access to technology and forms of communication that are still only decades old, are liable to all kinds of stupidity.

Cleverness nevertheless differentiates *Homo sapiens* most clearly from other primates, given that our emotions and sexual appetites are not that dissimilar. In terms of survival and reproduction, the human species has been outstandingly successful, but the verdict must be out for a longer timescale. Evolution is not driven by foresight, although humans are now technically in the position, through gene editing and selective breeding, to contemplate different paths for their own future. It is already 'saving' other species from extinction in order to save itself. There is a sense that humans are becoming aware that they have to apply their problem-solving skills for the collective interest of the species. It is questionable whether humans actually have a capacity to imagine and deal with problems on a larger scale. Our ancestors evolved in the way that they did because they learned to solve small-scale problems together. Unlike our closest relatives, who seem to be primarily self-oriented, hominins began to solve problems for mutual benefit.

If our hominin ancestors resembled competitive apes, it seems remarkable that they evolved into a cooperative species with pro-social motives. In some way, they recognised that shared cleverness would benefit everyone. In the contemporary world, these ancestral traits reassert themselves most strongly when disaster threatens. This return to mutual support is not a product of philosophical reflection or a resurgent sense of morality. The impulse must be as hardwired as sex because, at some stage of our evolution, it proved unbeatable.

Evolution works without a purpose on the material available, and so in this sense, human cooperation is an 'accident'. It seems to have been an accident of both nature *and* culture. Hominins were clever enough, once a capacity to formulate a problem symbolically had evolved, to appreciate its nature and seek a solution. Non-human primates face choices, moment to moment, between eating, mating, grooming, sleeping, playing, defending a territory, etc., but when hominins evolved the capacity to recall past experiences and imagine future possibilities, a whole new world of problems loomed into view. Rules evolved to regulate what would otherwise be an anarchic state of affairs. The resulting 'cultures' were probably Heath Robinson affairs from which the wheels could easily spin off. Contemporary cultures are also extremely variable and undergo constant change, often in ways that social scientists are unable to predict. Nevertheless, the ancestral condition of communal problem-solving has probably been retained as a feature of 'human nature'.

For day-to-day problems, humans turn to family, friends, counsellors, and voluntary organisations. This form of problem-solving is in marked contrast to the rule-governed procedures of policymakers, planners, and scientists. Society-wide problems are rarely addressed by communal decision-making as it might have been conducted by our hunting and gathering forebears. 'Social policy' for the common good is presently the domain of politicians, specialists, and technologists. These experts do of course provide solutions to threats to survival: medicine, non-polluting forms of energy, industrial farming, welfare benefits, etc. Experts are largely motivated by career progression, a badge of honour, or commercial success. The links with communal problem-solving are tenuous.

The belief that science and technology are capable of producing a solution to almost any problem is strong. Scientists see themselves as working towards a unified body of knowledge, towards 'consilience', the title of a book by the biologist E. O. Wilson [588].

The aim is to get closer to objective truth, which, it is assumed, will assist the human race to understand and solve the predicaments it confronts. It is as if the destiny of human evolution is cleverness itself. Scientists are sometimes happy to take on the mantle of a priesthood, sharing the myth that the solution to any new challenge is just a matter of extra effort and diligence. They stand for ‘progress’, even though each application of science tends to bring additional problems in its wake. An alternative destiny, more consistent with our earlier evolution, would be to get by as best we can, designing stable and serviceable social arrangements. With this aim in mind, an ambition to travel to Mars, let alone live there, would be a superfluous luxury.

Perhaps, our human ancestors always thought that the grass was greener on the other side of the hill and that this was a stimulus for the evolution of their problem-solving powers. Eventually, humans found themselves endowed with an unfettered imagination going beyond anything available to their mere senses. Problem-solving for its own sake became sufficiently interesting to fill up the whole day. This book explores how we might have arrived with a capacity for abstract thinking and its intelligent application. Humans are both blessed and burdened with an enquiring nature. In the face of what seem to be enormous problems of our own making, directing our attention onto the evolution of human cleverness might assist us in meeting them. Cleverness is the only resource we have, apart from a desire to do better.

Simplification of technical terms

Certain technical terms that are shared across disciplines are retained. The term *hominin* refers to humans and their forebears, plus any other bipedal primate that split off from an ancestral lineage around 6–9 million years ago (mya). Apart from an erect posture, hominins have a larger brain than other primates and they behave in more complex ways. *Hominins* were formerly called *hominids*, but the primate family *Hominidae* is a classification that now includes primates known as the great apes.

I have tried to limit the number of technical terms and also devise simplifications of my own. For practitioners of the ‘palaeosciences’, the correct technical terms trip off the tongue but with respect to geological eras and phases in evolution, it is easier to refer to ‘numbers of years ago’, that is, thousand years ago (kya), or million years ago (mya). Human history is very recent, but the bigger picture is the *Miocene* (23.03–5.3 mya), *Pliocene* (5.3–2.6 mya), *Pleistocene* (2.6 mya–11.7 kya), and *Holocene* (the current epoch since the end of the last major ice age). Climate variability has been an extremely significant influence on human evolution, possibly accounting for the fact that agricultural revolutions occurred independently in different parts of the world approximately 12 kya [566:41]. This marks the end of the last major ice age.

There is a bewildering number of Latin names for hominin genera and species. Where appropriate, I mention them in detail. Otherwise, I refer to *Ancestral hominins*, our early ape-like ancestors living approximately between 7 mya and 2 mya, such as *Australopithecus*. *Early Homo* (2.5 mya to around 1 mya), refers to different species of *Homo*, the most notable of which is *H. erectus*. *Late Homo*, from around 800 kya, includes *H. heidelbergensis* from which *H. neanderthalensis* and *H. sapiens* are assumed to have evolved.

The hominin past has also been classified into eras of stone tool production. *Oldowan* tools were made with one or a few flakes that were chipped off with another stone (2.6–1.7 mya). *Acheulean* tools were oval and pear-shaped ‘hand-axes’ made from various rocks, requiring much more skill to produce (from around 1.8 mya). Later tools, with

various refinements for different purposes, belong to what is called the *Mousterian* period (160–40 kya). The *Middle Stone Age* refers to African prehistory (280–25 kya). The New Stone Age (*Neolithic*) began around 12 kya and ended with the arrival of civilisations approximately 3.5 kya.

Speculation about hominin evolution has greatly benefitted through comparisons with other great apes, principally, the common chimpanzee (*Pan troglodytes*) and the bonobo (*Pan paniscus*). Humans were not descended from a species of great ape but from an ancestor common to all of them. It is widely assumed that the two species just mentioned resembled the common ancestor. Their separation into distinct species is thought to have occurred around 1.5–2 mya. I will refer to both as ‘chimpanzees’, distinguishing them only where necessary. Humans are primates, but I will occasionally use the word primate to refer only to its non-human representatives.

2 Overview

The title of this book refers to *cleverness* rather than *intelligence*, two words that carry an important difference in meaning. The English language is rich with words, many of them slang, that slide between these concepts. For ‘intelligence’ we have brainy/brainless, bright/dull, gifted/dense. For cleverness, we have profound/shallow, thoughtful/ill-considered, level-headed/muddle-headed. The intelligence quotient or IQ is derived from answers to questions and puzzles that have little to do with cleverness because they do not refer to any real-world problem. They sample the size of a person’s vocabulary but not any practical use of it. In another typical item, the subject is required to rearrange coloured blocks to match a pattern. While intelligence is highly valued, people give equal weight to being wise, balanced, or shrewd. Practical problem-solving is a matter of getting what you want, given the constraints and resources. Intelligence and cleverness are closely related but nevertheless somewhat different traits (see 75. *The evolution of reasoning*).

For our human ancestors, the key requirement was to survive and reproduce. Cleverness was needed for techniques of foraging and for working together on everything from child-care to managing relationships within their own community. Unfortunately, they left few clues of their cleverness in the latter respect. Even the fossils of their skeletons and their stone tools do not give a lot away. Perhaps, our early ancestors gazed at the night sky, seeing it as a giant crossword puzzle, but the next morning they would have had to find food and water, look out for predators, and keep an eye on infants liable to wander off.

The concept of *cleverness* in the sense of finding adaptive solutions to problems of survival can be applied to all species and obviously takes a variety of forms. For humans, intelligence in the somewhat narrow sense of reasoning about abstract relationships is probably the most convincing explanation for recent human success and world dominance. The need to combine it with cleverness has, however, never gone away. This book surveys its early foundations, the first 7 million years rather than the last 10,000.

Virtually every aspect of hominin evolution has a bearing on cleverness, and there is no neat story to be told. Each species is clever in its own way, whether they are crows, dolphins, or octopuses. Unrelated species can hit upon similarly clever ways of solving a problem, a phenomenon called *convergent evolution*. For instance, bats and birds have evolved to fly although the mechanism has been arrived at by different routes. The cleverness of our closest primate relatives is most relevant to humans, partly because our earliest ancestors resembled them and faced similar problems. It is still not known what led hominins into becoming extra-clever primates. A few captive apes have been taught a form of sign language and some have been happy to be raised alongside human children (see 44. *Signing chimpanzees*, 45. *Home-reared chimpanzees*). We can identify closely with them, but

the evolutionary path of their social behaviour and life history are distinctly different (see 20. *Family structure, pair bonding, and communal breeding*).

Many academic disciplines have devoted themselves to the puzzle of hominin cleverness. With the exception of comparative and evolutionary psychology, the science of psychology has not been especially concerned with evolutionary questions [208]. The currently popular paradigm, cognitive science, theorises about humans who already display sophisticated abilities in the area of memory, reasoning, and decision-making. This book aims to link up very different disciplines, and so it is necessary to examine the conceptual, methodological, and philosophical positions that differentiate them. These have to be addressed in order to connect the findings of one discipline with those of another.

Some of the entries give a brief summary of essential concepts while others are an in-depth discussion of aspects of cleverness. *Evolutionary psychology* is distinctive in the sense of wholeheartedly endorsing neo-Darwinian principles. It traces present-day psychological traits to their likely origins during the longest sustained period of a *H. sapiens* lifestyle, namely hunting and gathering during the past 300,000 years. It is only in the last 50–100,000 years that humans have exerted such an influence on their environment that the main pressures that shaped their evolution were ones they created for themselves – their culture. Even so, recent human evolution is still extremely short compared with its total span. A hunting and gathering mode of life does of course remain in isolated pockets. The survivors of the old ways have been subjected to genocide, colonisation, and almost all of them been strongly influenced by more technically advanced cultures. Anthropological research into hunter-gatherer societies has been an important source of speculation about earlier periods of hominin evolution.

A number of key concepts underpin the reasoning in entries throughout the book. These are *adaptation* and *selection*, the distinction between *ultimate* and *proximate* causes of behaviour, *gene-culture co-evolution*, and *domain-general* versus *domain-specific* cognitive processes.

An animal has a portfolio of *adaptations*, in other words, ways of making sure that it eats, defends itself, mates, reproduces, etc. There is usually a trade-off between one adaptation and another. When the earliest ancestral primates began foraging on the ground rather than in trees, there was a trade-off between freed-up hands and feet that were less adapted for climbing. All organisms (a population) that belong to a species are said to have a range of inherited or *phylogenetic traits* that evolved as adaptations. Individuals vary in the extent to which they express each trait. Evolution takes place when there is a change in the distribution of inherited traits within a population across successive generations. Organisms that survive and reproduce most successfully will be the ones that are selected to pass on their genes to the next generation. A ‘new’ trait is a modification of what has existed before, a change that can take hundreds or thousands of generations to evolve.

Many explanations have been given for why traits associated with cleverness were selected. Some experts stress the *technical* challenges of survival while others point to the *social* demands of cooperating and living in a group. Obviously enough, different selection pressures can work in combination and their influence will have varied at different times.

The distinction between *ultimate* and *proximate* causes of behaviour is fundamental (see 3. *Proximate and ultimate causes*). Proximate causes are those mechanisms built into the design of the brain and the body that serve the *adaptations* promoting survival and reproductive success. It is thought that some of the proximate mechanisms of living humans are not particularly adaptive in modern circumstances. A liking for fat and sugary tastes, useful in the past, can induce obesity when surrounded by plenty. An example of a useful

proximate mechanism would be the disgust produced by the smell of putrefaction, leading us to avoid the source of the smell. The *proximate* causes are therefore all the perceptual, motivational, and physiological mechanisms that bring about disgust and lead to its avoidance. The *ultimate cause* of disgust was probably the fact that if a hominin wanted to survive, it was best to avoid eating putrefying meat. Individuals who were genetically predisposed to experience disgust would have been preferentially selected. Thus, the *ultimate* causes of disgust were the ways in which it enhanced survival and reproductive success.

Cleverness cannot be regarded as a single trait. It probably consists of interacting components or mechanisms which are motivational and social as well as intellectual. This makes it difficult to identify ultimate causes. It is certain that all the various mechanisms were not acquired in a sudden leap of brilliance when ‘modern’ *H. sapiens* first appeared on the scene.

Hominins have always surrounded themselves with an environment that was partly of their own making. In fact, some living humans are hardly aware of ‘nature’. Hominins are not unique in this respect as the example of beavers building dams illustrates. The difference between beavers and humans is that dam-building is an inherited trait that does not have to be learned from scratch. Hominins evolved with *general* learning mechanisms which meant that an ability like fashioning a stone tool or controlling the use of fire could be learned by trial and error and be taught by others. Over time, the need to learn cultural skills grew incrementally. Few modern humans live so ‘close to nature’ that they could survive alone in a natural environment. One possible exception was a Japanese soldier who refused to surrender after World War Two and survived for 29 years in the jungle. However, he had already learned his survival skills earlier in life. The inherited traits most closely associated with survival and reproductive success are now ones that allow rapid social learning and mastery of modern cultural skills, such as reading. The implication is that genes and culture co-evolve. The building blocks for acquiring culture surround each new generation – educational resources, concerned parents, and a society that needs the skills. As far as cognitive skills are concerned, it is as if software is ready to be installed into a child’s brain. This co-evolving process has shaped the structure of the brain itself and how it acquires its neural connections during development (see 5. *Nature, nurture, and culture*, 26. *Gene–culture co-evolution*).

Although inherited dispositions and learning are equally required for cleverness, judging the weight to attach to each of these causes is difficult because whatever is observed in behaviour is the product of an interaction between both of them. There are enduring controversies over language. Almost every child with their senses intact learns to speak the local language. It seems to be a ‘natural’ accomplishment, as if little learning is involved. In reality, the child must be learning all the time. Furthermore, the concepts passed on through language are the product of a long history, providing a child with many ready-made and fundamental distinctions. Concepts of number and logic were worked out by human ancestors, but they are assimilated with little awareness of their origins. A rich cultural inheritance must account for the speed of technological change in the last 10,000 years. The genetic contribution is almost impossible to separate from the cultural.

The inherited traits that predispose a person to acquire cultural knowledge have been classified as *domain-general* and *domain-specific*. *Domain-general* traits are involved in all (or almost all) learning and problem-solving tasks whereas the latter are specialised for particular sensory channels and response systems. Examples of general processes are attending to something, perceiving it, holding information in short-term memory, detecting covariation between events, and acquiring responses that lead to the satisfaction of a person’s

goals. Knowledge and habits learned in this way then become available as resources for various problem-solving tasks. By contrast, *domain-specific* capacities (otherwise called *modular*) are specialised for responding to certain *kinds* of information related to *specific* functions (see 34. *Modularity*). For instance, a capacity to learn a language probably requires modular mechanisms as well as *domain-general* learning processes. The brain seems to be built in such a way that it is ready to process the system of phonemes that make up words. To some degree, *modular* mechanisms must be able to process information independently of each other but, in practice, they could function only if linked together and coordinated by *domain-general* processes. Arguments about *domain-general* versus *domain-specific* processes have been quite heated in some areas of evolutionary thinking, especially with regard to ‘perspective-taking’ and ‘imitation learning’.

One way to view the evolution of cleverness is to see it as a mosaic, leapfrogging affair in which an evolved trait (whether anatomical, behavioural, or cognitive) opened the way for some new application to problem-solving. In other words, a trait evolved for one purpose was a *pre-adaptation* for the evolution of another. For instance, an ape’s pincer grip for plucking fruit would have served a later function in making and using a stone tool. It has been argued that the sequence of chained actions in making a stone tool, involving a repetition of earlier steps (gripping and striking the stone in the same way), could have been a pre-adaptation for producing the sequenced motor movements that underly speech.

An innovation, such as the wheel, was clearly not the result of a genetic mutation for wheel-making behaviour. Its invention must have recruited abilities that, together, were sufficient to permit some early hominins to gain an insight into the movement potential of a wheel-like structure. Its antecedents are unknown, but the wheel would not have been the inspiration of a lone genius. The problem-solving conducted by an individual both takes from and contributes to a group process. It is for this reason that theorists have placed so great an emphasis on social learning (see 48. *Social learning: imitation*).

One thing seems certain – cleverness was important to hominins. This can be inferred from the fact that, when compared with chimpanzees (who themselves take around eight years to mature), an increasing amount of time was spent by the young in an immature state, not simply dependent on their mother but also on older siblings, grandmothers, and carers (see 20. *Family structure, pair bonding, and communal breeding*). A longer gestation period and an extended childhood and adolescence are assumed to have evolved because cleverness was so important for survival. They were necessary to allow the brain a long enough time to structure its neural pathways and absorb the cultural skills that learning to be clever required.

This book is not meant to be read cover to cover. There are links between related topics and the reader can move back and forwards between them. Nevertheless, there is a general direction in the book towards more complex aspects of cleverness. The final section tries to draw lessons for the human species as a whole, especially in view of the environmental threats to its own existence.

Part 2

Essential themes



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3 Proximate and ultimate causes

The distinction between ultimate and proximate causes is central to evolutionary theory [473]. This becomes clear when it is realised that evolutionary change is driven by *ultimate* endpoints, that is, traits that adapt a species to the environment it happens to exploit – success being measured in terms of survival and number of offspring (see 4. *Adaptation and selection*). Natural selection must have favoured mothers who took care of their babies and babies who made sure they were firmly attached and looked after. The *proximate* causes are those hormonal, motivational, and behavioural mechanisms that consolidate the mother–child relationship. Genes associated with a mother’s lack of interest in babies or babies that were too clingy or not clingy enough would have decreased in frequency. Chimpanzee mothers are very protective of their babies, while chimpanzee fathers, who are unaware of their status, are not. Consequently, the involvement of fathers was a new adaptation in hominin evolution whose *ultimate cause* was presumably related to the fitness of a small kinship group (see 20. *Family structure, pair bonding, and communal breeding*).

Humans do not necessarily think about ultimate causes at all. Instead, the *proximate causes*, such as sexual attraction and wanting to bond, are present in awareness and ensure that traits are expressed. Evolutionary psychologists have taken a considerable interest in how sexual attraction works between human males and females [512]. Living humans express many competing proximate mechanisms, moderated to a large degree by an understanding of their influence and outcome. An individual might decide *not* to reproduce because the proximate causes are rewarding in themselves, and she or he is not concerned with evolution’s ultimate (reproductive) causes.

A proximate mechanism such as jealousy might have evolved to ensure that mates could be relied upon to provide essential resources (provisioning, childcare, etc.). In the contemporary world, the strength of this emotion can be maladaptive in a proximate sense, causing distress and disrupting otherwise satisfactory bonds.

4 Adaptation and selection

Hominins evolved to be what they were and now are because certain traits that they expressed promoted their survival and reproductive success (known collectively as their ‘fitness’). Insofar as these traits expressing their *phenotype* were heritable, they were ‘naturally selected’ [383]. Put differently, some individuals bore genes that helped to cause these traits to develop (a property of their *genotype*), and it was these individuals who made a greater contribution to the gene pool of the breeding population of which they were members. Thus, it is not selfish genes that want to reproduce themselves but selfish and non-selfish individuals who are more or less winners in the process of selection. For instance, an adaptation, such as pale skin, will have evolved in Northern latitudes where the sun’s strength is weaker. Too much sun (or at least its ultraviolet component) destroys the vitamin, folate, whereas enough sun is needed to produce vitamin D. Darker skin, found nearer the equator, protects against the damaging effect of ultraviolet radiation. Rather than thinking of a single trait, such as skin colour, it is more accurate to conceive of many traits functioning together to promote fitness. An ability to fly is an *adaptive strategy* that has worked for different animals. It evolved in birds and bats by the gradual modification of pre-existing traits, and it happened through different routes.

Selection can take place only when there are individuals who vary, however slightly, in the traits they express. A trait will be ‘fixed’ in a population when all of its members express it to the same degree. In some populations, a trait may fail to vary because the founders of that population showed no genetic variation in the trait concerned (a so-called *founder effect*) (see 25. *Non-selectionist processes*). For a similar reason, a population might possess members with hereditary peculiarities (e.g., causing a disease) not found in other populations.

The ultimate cause of an adaptation is greater fitness. However, it is not always possible to deduce why a trait would have produced this outcome. Hominins gradually became more fully bipedal, but there is disagreement over why this trait was selected. Some traits, such as stereoscopic colour vision, are shared with distant primate ancestors while others are new adaptations (so-called *derived* traits) such as sweat glands to cool a hominin’s relatively hairless body. Some traits that were adaptive in past environments may no longer be so in a modern environment. Natural selection is a process occurring over hundreds of generations and so this result would not be too surprising. Over time, maladaptive variations which reduce fitness will be selected out.

Under normal circumstances, adaptive traits develop in all members of the species and reliably perform their biological functions. However, there are always costs (in terms of effort and energy consumption) as well as benefits to fitness when exercising a biological function. Therefore, the sum total of evolving traits is a balance between them, a kind

of optimal solution for fitness. A fear of snakes should not be so strong as to prevent a primate from foraging where snakes lurk. Given these compromises, adaptations are not always ideal from a body-design point of view. A larger body might be an advantage in fighting off predators or competitors, but it consumes more resources to build, and in a tree-dwelling animal, it reduces manoeuvrability [70].

Precisely why and in what ways cleverness increased hominin fitness is not known. We may assume it involved a gradual modification of the cognitive capacities of a chimpanzee-like ancestor. One hypothesis is an increase in the capacity of *working memory*, a construct developed by cognitive scientists to explain how ‘the mind’ controls behaviour (see 70. *Working memory*). This speculation rests on shakier evidence than the kind of inferences that can be drawn from the size, shape, and function of fossilised bones (see 56. *Brain evolution: structure and function*).